The Chief Digital Officer Position and Its Firm-Level Impact

A Literature Review on CDO Research and an Analysis of CDO Presence and Performance Implications

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With rapidly advancing technologies and digital innovations, companies face the need to adapt to the new digital world and to digitally transform their business models. For executing the digital transformation process, more and more companies decide to entrust a new C-level manager with all challenges and complexity arising from digital transformation, the Chief Digital Officer (CDO). As the CDO position is still fairly new, research in this field is limited and requires further attention by scholars. Therefore, this study aims to address three fundamental research questions concerning the nature of the CDO position and corresponding implications not only to inform practitioners but also to enrich the scholarly discussion on CDOs. By understanding existing literature on CDOs based on a systematic literature review, this thesis answers the first research question regarding what characterizes the CDO position. Building on these insights and drawing from a comprehensive theoretical framework consisting of upper echelons theory, contingency theory, human capital theory and the resource-based view, hypotheses are developed for answering research questions two and three. While the second research question focuses on factors, which influence CDO presence within a company, the third research question addresses the impact of a CDO on company performance. Based on a large-scale sample of panel data comprised of S&P 500 companies, generalized estimating equations models, propensity score matching and fixed effects regression models are exploited in order to derive answers for both research questions two and three. As influencing factors for CDO presence, the results show that especially early tenure CEOs and CEOs of larger companies are more likely to employ a CDO. Although no evidence can be observed for positive performance implications of CDOs, also given different company contingencies, the insights of this study's analyses show that certain CDO characteristics as well as in combination with CIO presence and varying CEO characteristics are more favorable over others in terms of company performance measured by return on assets and Tobin's Q.

HHL LEIPZIG GRADUATE SCHOOL OF MANAGEMENT

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Foreword

I would like to take the opportunity and sincerely thank everyone, who supported me throughout my time at HHL Leipzig Graduate School of Management.

First of all, I would like to acknowledge Prof. Dr. Tobias Dauth as my supervisor, advisor and sparring partner, who provided valuable comments and challenging impulses on this study. Next to his deep subject expertise and consistent guidance, I am also thankful for his prompt feedback and the time for clarifying urgent matters on short notice.

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I would also like to thank my family, my partner and my friends for their unconditional support throughout my doctoral program.

Finally, I would also like to note that some parts and results of this study have been used for the preparation of a separate article. This article will be presented at the EURAM Conference 2021 and is currently in the review process of the Strategic Management Journal. Affected paragraphs, which contain relevant parts for this article, are marked with an asterisk (*) at the end. Selected results of this thesis (including their discussion and visualization) were included in the article as well. As formulations of affected paragraphs substantially differ from the article, dedicated markings with an asterisk were not included (see corresponding footnotes).

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List of Abbreviations

AIC – Akaike's information criterion

ATT – Average treatment effect on treated

CDIO – Chief Digital Information Officer

CDO – Chief Digital Officer

CEO – Chief Executive Officer

CFO – Chief Financial Officer

CIO – Chief Information Officer

CMO – Chief Marketing Officer

COO – Chief Operating Officer

CSCO – Chief Supply Chain Officer

CSO – Chief Strategy Officer

CSuO – Chief Sustainability Office

GEE – General estimating equations

GICS – Global industry classification standard

GLM – Generalized linear models

HR – Human resources

IT – Information technology

MTT – Median treatment effect on treated

OLS – Ordinary least squares

PSM – Propensity score matching

QIC – Quasi-likelihood under the independence model criterion

R&D – Research and development

RACI – Reponsible, accountable, consulted and informed

ROA – Return on assets

ROE – Return on equity

TMT – Top management team

US – United States

VIF – Variance inflation factors

1. Introduction

1.1 An Introduction to the Chief Digital Officer Position and the Underlying Research Questions of the Study

In recent years, remarkable advancements in communication, connectivity and information technologies have led to a new digital era (Bharadwaj et al., 2013). These new digital technologies are heavily reshaping or even disrupting traditional business models (Bharadwaj et al., 2013; Fitzgerald et al., 2013). In order to adapt to the new digital world and to exploit innovative digital technologies, companies from all industries have put digital transformation on top of their strategic agendas (Hess et al., 2016). With increasing interest in the topic of digital transformation, the amount of research conducted in this field is continuously growing, both from practitioners' (Fitzgerald et al., 2013; Westerman, Bonnet, & Mcafee, 2014) and scholars' side (Bharadwaj et al., 2013; Matt et al., 2015). Yet, it not is surprising that there are several variations in defining digital transformation (Vial, 2019). Based on 23 unique definitions for digital transformation, Vial (2019) defined digital transformation as "…a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies" (p. 121). Affected company properties typically include major business operations and processes, products and services, and organizational structures (Matt et al., 2015). While it is not only technology, which adds complexity to digital transformation (Vial, 2019), the transformational process of a company's strategy, processes, structures and even culture itself contributes a significant proportion to complexity as well (Bharadwaj et al., 2013; Kane et al., 2017; Kohli & Melville, 2019; Matt et al., 2015; Vial, 2019). In order to address all facets of digital transformation properly, companies are required to define clear responsibilities for both defining a digital transformation strategy as well as for the actual implementation of digital transformation (Matt et al., 2015). Formulating the strategic aspects for digitally transforming the company ideally relies within the authority of the Chief Executive Officer (CEO) (Hess et al., 2016). The actual execution of digital transformation is

typically delegated to another senior executive ranging from either a manager of the most affected business unit, of the digital business unit or also the Chief Information Officer (CIO) (Hess et al., 2016). Alternatively, more and more companies decide to create the Chief Digital Officer (CDO) position within their company as responsible C-level manager for driving digital transformation and as coping mechanism for the corresponding complexity (Grossman & Rich, 2012; Hess et al., 2016; Singh & Hess, 2017; Tumbas et al., 2017).

The first known company, which decided to hire a CDO, was MTV Networks already back in 2005 (Singh et al., 2019). Since then, the CDO position became increasingly popular as companies more frequently decided to follow the lead of MTV networks and created a CDO position within their top management team (Singh & Hess, 2017). According to Friedrich and Péladeau (2015), this trend became especially visible within recent years, as in 2015, about six percent of the largest 1,500 international companies, or 86 in absolute figures, opted for creating a CDO. Since then, the number of new yearly CDO appointments remained on a high level (Péladeau & Acker, 2019). As it can be seen in Figure 1, a survey of the largest 2,500 international companies unveiled that in 2018 almost 17% of companies, or 242 in absolute numbers, were entrusting a CDO with driving digital transformation (Péladeau & Acker, 2019).[1] Since the CDO position is still relatively new, especially as the adoption rates within companies just started to rise within recent years, the availability of research conducted by scholars in the field of CDO research is also fairly limited (W. Becker et al., 2018). Based on an initial literature screening, results around CDO research seem to be fragmented and a common understanding of the CDO position based on a comprehensive overview of existing literature is yet to be derived.

As mentioned before, the range of options for companies to address digital transformation is not limited to one alternative only, namely appointing a CDO. A high share of international companies is not deciding in favor of creating a CDO position

[1] While the figures on CDO appointments for 2016, 2017 and 2018 are based on the largest 2,500 international companies, the figures for 2015 are based on the largest 1,500 international companies. Thus, a direct comparison is only reasonable to the extent of highlighting the continuous absolute growth rates. Scaling the figures for 2015 would be possible, but not changing the interpretation.

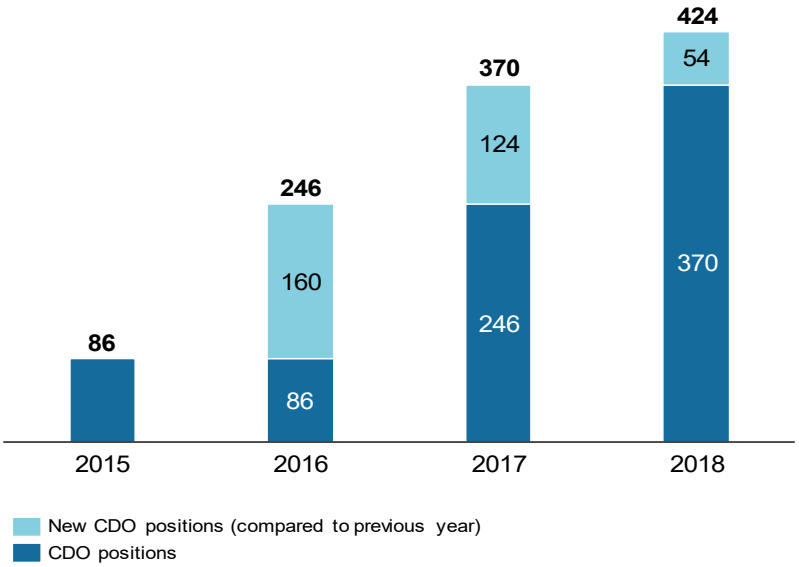

Figure 1: Development of CDO Appointments, 2015-2018
Source: Own illustration, based on Friedrich and Péladeau (2015), and Péladeau and Acker (2019).

(Friedrich & Péladeau, 2015; Péladeau & Acker, 2019), which implies that their digital transformation activities are conducted by someone else than the CDO. Reasons for the phenomenon of appointing a CDO could be very varied. For example, a high workload of the IT function with activities unrelated to digital transformation, might fill up the schedule of a company's CIO, and therefore, limiting their capacity for driving digital transformation leading to appointing a CDO (Tumbas et al., 2017). Other reasons might include company internal and external factors such as the level of complexity due to company size, or the company's customer and competitor landscape (Haffke et al., 2016). Yet, a dedicated assessment of which factors influence CDO presence within a company requires further research attention.

Although the underlying idea of creating a CDO within the company is to have digital transformation addressed appropriately in order to ensure its success and to improve the company (Vial, 2019), appointing new C-level managers might also imply potential drawbacks. Not only is the company growing by additional organizational layers, but the subsequently increasing complexity is also extending the company's cost structure (Hambrick & Cannella, 2004). In addition, the appointment of an additional C-level manager not only extends organizational complexity, but also implies another high payed executive on the company's monthly payroll leading to further costs for the

company (Drechsler et al., 2019; Friedrich & Péladeau, 2015). Opposing to causing additional costs, by successfully implementing digital transformation a CDO should realize corresponding benefits. For example, improvements of productivity, increases in sales and innovations in value creation should ultimately offset all incurred costs for the company of creating a CDO position (Matt et al., 2015). Still, it remains unclear whether the latter actually holds true. Therefore, it seems reasonable to investigate whether a CDO can live up to the expectations, offset all their additional costs and ultimately derive financial benefits for the company. In other words, an assessment of the implications of a CDO on company performance remains open to additional research.

Summing up all previous thoughts, the main purpose of and motivation for this thesis are to investigate the CDO position and provide new academical results in this area of research. Specifically, the overarching research questions for this thesis can be summarized as follows:

(1) What characterizes the CDO position?

(2) Which factors influence CDO presence within a company?

(3) What is the impact of a CDO on company performance?

Before exploring proposed research questions around the CDO position, it is worthwhile to examine and understand digital transformation itself. As digital transformation is the actual trigger leading to appointing CDOs, it is also the environment in which they operate on a daily basis, are exposed to challenges and are required to manage all implied risks. Thus, and especially for analyzing the first research question, i.e., characteristics of the CDO position itself, understanding digital transformation is important to fully grasp what defines the CDO position and corresponding attributes.

1.2 Digital Transformation and its Implications for Top Management Teams

Research around the concept of digital transformation and its components is manifold and addresses several different aspects ranging from digital technology itself and strategy to organizational change of structures, processes and culture (Bharadwaj et

al., 2013; Kane et al., 2017; Kohli & Melville, 2019; Matt et al., 2015; Vial, 2019). In order to combine existing knowledge on digital transformation, Vial (2019) collected and analyzed more than 280 different documents in order to derive a conceptual definition of digital transformation on the one hand, and a framework summarizing all building blocks of digital transformation on the other hand.

Based on 23 unique definitions for digital transformation and following rules and guidelines for conceptual definitions and clarity (Suddaby, 2010; Wacker, 2004), digital transformation can be conceptualized as "…a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies" (Vial, 2019, p. 121). From this definition, four main elements can be identified which comprise and describe the digital transformation process. First, the underlying entity of digital transformation is not bound to companies only, but also other forms of entities such as entire industries and societies (Agarwal et al., 2010; Hanelt et al., 2015; Pagani, 2013; Vial, 2019). Second, the scope of digital transformation is to change an entity and its underlying properties (Hess et al., 2016; Vial, 2019). Third, digital technologies act as means in order to for achieving an entity's change (Bharadwaj et al., 2013; Vial, 2019). And fourth, the expected outcome of digital transformation is improvement, yet its realization cannot be guaranteed (Singh & Hess, 2017; Vial, 2019) and instead might even fail (Davenport & Westerman, 2018). Still, each of the four aspects is depending on the individual situation, meaning that which properties are changed and towards what direction might be different by entity or industry. Similarly, what type of digital technologies is exploited to achieve such change might vary significantly. Finally, the expected outcome might differ completely by entity as, for example, not all companies optimize for the same set of key performance indicators.

Figure 2 represents the inductive framework, which summarizes existing research results on digital transformation, based on eight major building blocks (Vial, 2019). Further, the framework displays relationships between each building block, which have been discovered during the literature analysis of Vial (2019), resulting in a processual representation of digital transformation. It is not surprising that the framework's core consists of digital technologies and their exploitation, which on the one hand cause

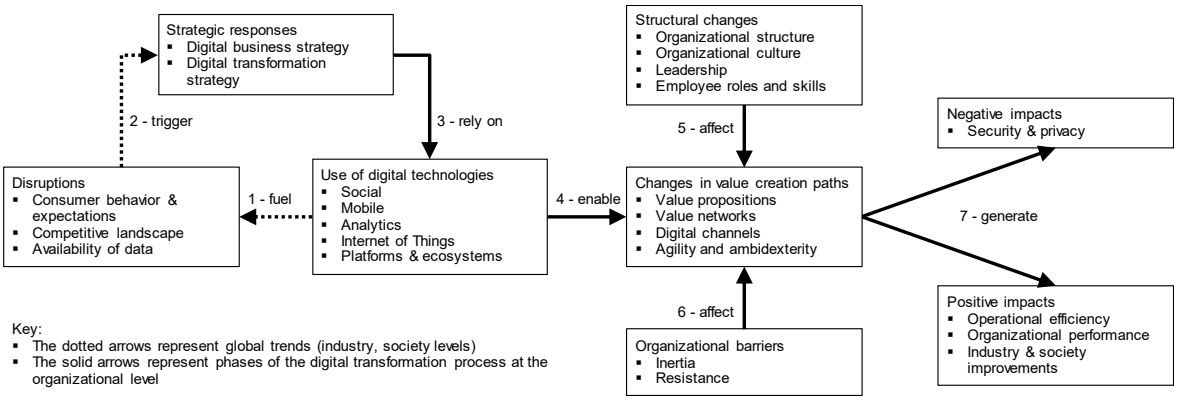

Figure 2: Building Blocks of the Digital Transformation Process
Source: Vial (2019), p. 122.
Note: "The arrows do not represent a statistical relationship or a causality found in variance models. Rather, they detail an overarching sequence of relationships described by the literature on [digital transformation]" (Vial, 2019, p. 122).

and reinforce disruptions, and on the other hand enable innovations in value creation paths (Bharadwaj et al., 2013; Vial, 2019). The areas and types of digital technology commonly described in digital transformation literature include social (L. Li et al., 2018), mobile (Pousttchi et al., 2015), analytics (Günther et al., 2017), cloud (Du et al., 2016), and the internet of things (Petrikina et al., 2017). These technologies are also known as SMACIT technologies (Sebastian et al., 2017). Further technologies include platforms, ecosystems and combinations of technologies (Tiwana et al., 2010; Vial, 2019).

The disruptive nature of described digital technologies leads to three different types of disruption, which have been identified across digital transformation literature (Karimi & Walter, 2015; Vial, 2019). With increasing access to information and communicative power, consumers interact more actively with companies and its shareholders (Yeow et al., 2018). This also changes the way customers see themselves in comparison to companies, meaning that customers are rising to an equal level compared to a company and thus also have increasing expectations towards provided products and services (Lucas et al., 2013; Vial, 2019). Further, digital technologies allow for new competitors to more easily enter new markets and redefine products and services generating new types of combined digital offerings (Woodard et al., 2013; Yoo et al., 2010). Finally, the increasing amount of available data allows companies to exploit data analytics in order to derive products, which are more aligned with their customers,

and to conduct processes with higher efficiency (Günther et al., 2017; Vial, 2019). Since digital technologies might not only create groundbreaking opportunities, but also considerable existential risks, companies are required to maintain their competitiveness (Sebastian et al., 2017). To establish their competitive position in times of digital disruption, strategic adjustments either in form of a digital business strategy (Bharadwaj et al., 2013) or a digital transformation strategy (Matt et al., 2015) are required. While the first strategic response focuses on applying digital technologies' differential value creation, a digital transformation strategy aims to transform products, processes and the organization due to new digital technologies (Bharadwaj et al., 2013; Matt et al., 2015).

With the alignment of digital technologies and a company's strategic direction in order to withstand the disruptive power of such technologies, companies might become able to identify new paths in value creation processes by redefining their business models (Vial, 2019). As it can be seen in Figure 2, four main themes can be identified regarding transformations in the value creation process. By incorporating digital technologies, companies are able to extend physical product portfolios by also offering corresponding digital services and innovations, and thus adapt their value propositions (Barrett et al., 2015; Porter & Heppelmann, 2014). Further, digital technologies create the opportunity to reinvent value networks, meaning that all participants and their relationship in the network of value creation can be redefined and lead to, for example, bypassing intermediaries (Delmond et al., 2017; R. Hansen & Sia, 2015). Implementing digital technologies can also bring change to sales and distribution channels of a company (Vial, 2019). Digital channels include new ways to directly accessing customers, for example, via social media (R. Hansen & Sia, 2015), and decision-making for coordination of organization-wide activities based on algorithmic decision-making (Günther et al., 2017; Vial, 2019). Finally, companies are better equipped to quickly adapt to changing conditions in the environment leading towards more agility and ambidexterity (Günther et al., 2017; Haffke et al., 2017).[2]

[2] In the organizational literature, ambidexterity is commonly defined as "…an organization's ability to pursue two disparate things at the same time…" (Gibson & Birkinshaw, 2004, p. 210). Established as dynamic capability (O'Reilly & Tushman, 2008), ambidexterity, for example, in IT is the capability to

Alongside adaptions in the business model and value creation processes, digital transformation also implies several structural changes (Vial, 2019). In order to successfully conduct digital transformation, the organizational structure of a company should be open towards cross-functional collaboration across business units and free from functional silos (Earley, 2014; Maedche, 2016). Similarly, digital transformation requires the adaption of a company's culture towards more openness regarding innovation and less inertia preventing change (Hartl & Hess, 2017; Karimi & Walter, 2015). Next to changes within the organizational structure and culture, digital transformation also requires corresponding efforts from a company's leadership (Vial, 2019). It is the leadership's responsibility to develop the organization towards a digital mindset while handling disruptions caused by digital technologies (Benlian & Haffke, 2016; Vial, 2019). Several companies also extend the top management team by an additional C-level executive, the CDO, in order to signal the strategic importance of digital transformation as well as to properly exploit digital technologies in line with the digital transformation strategy (Horlacher, 2016; Singh & Hess, 2017).[3] Finally, digital transformation also affects all employees' roles and skills, as employees outside of the IT function are required to take the lead on more technology-oriented projects whereas employees from the IT function should increase their affinity with business related aspects of such projects (Dremel et al., 2017; Yeow et al., 2018). As already indicated, all highlighted and necessary changes within the company might encounter barriers from within the organization. On the one hand, inertia in terms of existing capabilities of an organization might hinder the innovation process (Srivastava & Shainesh, 2015; Svahn et al., 2017). On the other hand, employees might demonstrate resistance following the introduction of disruptive digital technologies (Singh & Hess, 2017).

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manage contradictory objectives by exploiting existing IT resources for creating value and to explore new chances for innovatively applying IT (Gregory et al., 2015; Haffke et al., 2016).

[3] In the management literature, by a company's top management team it is typically referred to a group of individuals, who are responsible for steering a company and setting its direction (Cyert & March, 1963; Macharzina & Wolf, 2018; Wiersema & Bantel, 1992). Which person actually counts as top manager (or C-level manager) of a company is interpreted differently across literature (F. G. Becker, 2007; Carpenter et al., 2004). For this study, a clear delimitation of the individual positions of the top management team is not necessary as the focus lies on an individual C-level manager. See Carpenter et al. (2004) for a more fine-grained discussion on who constitutes a company's top management team.

Although digital transformation might result in impacts on society and industry level like the improvement of an individual's life quality (Agarwal et al., 2010), most literature on digital transformation argues about implications on an organizational level (Vial, 2019). Benefiting from automation (Hess et al., 2016), improving business processes (Gust et al., 2017) and cost reductions (Pagani, 2013), digital transformation has the potential to improve a company's operational efficiency (Vial, 2019). With increasing efficiency, companies might also be able to realize benefits regarding organizational performance. These benefits might be related to a company's financial performance (Karimi & Walter, 2015) and growth (Tumbas et al., 2015), but also its innovativeness (Svahn et al., 2017), reputation (Yang et al., 2012) and competitive advantage (Neumeier et al., 2017). Still, digital transformation and the application of digital technologies also bears some risks and undesirable outcomes (Vial, 2019). One major threat, which is highlighted throughout the digital transformation literature, is related to security and privacy related risk regarding data and individuals (Newell & Marabelli, 2015).

Summing up, top management teams face an extensive amount of challenges from digital transformation. A company's leadership needs to identify and pace with new digital technologies in order to recognize potential threats from disruption, or even drive disruption themselves in order to keep an advantage compared to competitors. Further, the top management team should formulate an appropriate strategic response to the disruptive power and ensure an adequate use of digital technologies. In order to benefit from resulting changes in value creation paths, leadership teams must assure that structural changes within the company are driven consequently and potential barriers are removed. As highlighted before, companies react more and more to this comprehensive number of tasks by creating the CDO position as new C-level manager, dedicated to digitally transforming the company. Yet, the CDO position is still a relatively new phenomenon and up to further research. For ensuring that this thesis and its results about the CDO position are contributing to existing literature in the field of top management team research, the following section aims to recap the current status-quo in top management team research.

1.3 Status-quo of Top Management Team Research

Beginning with the publication of Hambrick and Mason's (1984) article on the upper echelons perspective in 1984, research on top management teams has developed into one of the most important research areas in the management field (Menz, 2012). Research in this area has strongly focused on top management team composition and the CEO (Carpenter et al., 2004). Since recent years and with increasing interest, scholars have also studied other individual top management team members than the CEO (Menz, 2012). Such individual members of the top management team include the Chief Operation Officer (COO) (Hambrick & Cannella, 2004; Marcel, 2009), the Chief Financial Officer (CFO) (Geiger & North, 2006; D. M. Zorn, 2004), the Chief Information Officer (CIO) (Banker et al., 2011; Enns et al., 2003), the Chief Strategy Officer (CSO) (Breene et al., 2007; Menz & Scheef, 2014), the Chief Marketing Officer (CMO) (Nath & Mahajan, 2008), the Chief Supply Chain Officer (CSCO) (Roh et al., 2016), Chief Sustainability Office (CSuO) (Kanashiro & Rivera, 2019) and as most recent addition, the CDO (Firk et al., 2019). Although research about individual top management team members is still relatively new, derived results are already disconnected (Menz, 2012). Based on a review of 39 articles in the field of research on individual top management members, Menz (2012) derived an organizing framework of existing literature, which can be seen in Figure 3. With this framework, Menz derived both an overview of existing results, and highlighted the potential of this research field for contributing to

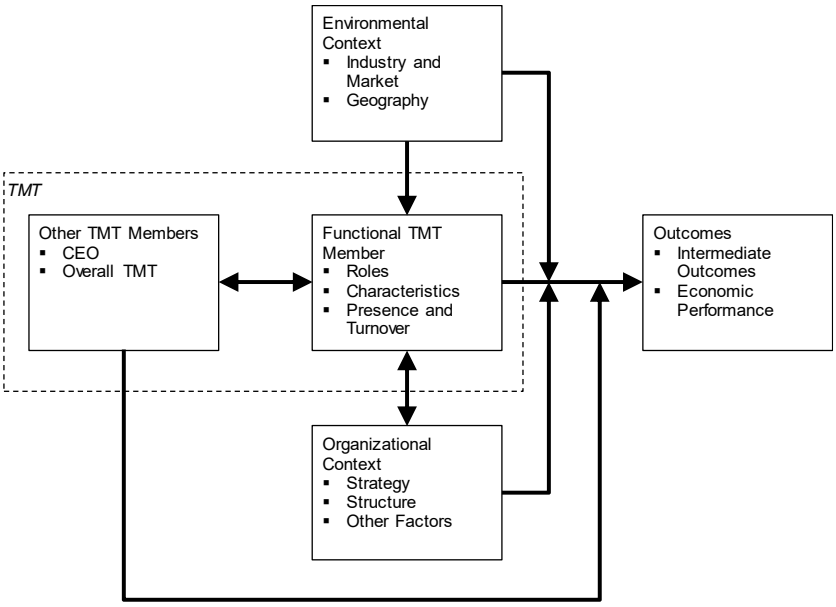

Figure 3: Organizing Framework for Research on Individual Top Management Team Members
Source: Menz (2012), p. 50.

the overall top management team literature by displaying current gaps, which should be addressed by future scholars in this area.

In the center of the framework, Figure 3 displays the functional or individual top management team member, as these positions were the core of the review. Many researchers informed about the individual positions themselves, meaning the actual role of the top management team member, their daily agenda including tasks and activities as well as how these positions may have changed over time (Menz, 2012). Such studies have been conducted, for example, regarding CFOs (Gerstner & Anderson, 1976), COOs (N. Bennett & Miles, 2006) or CIOs (Chun & Mooney, 2009). A large proportion of literature also addressed the implications of such individual top management team members' characteristics on organizational outcome (B. Cannella et al., 2008). Frequently studied characteristics include age, gender, company-specific or functional experience (Adler & Ferdows, 1990; Chatterjee et al., 2001; Kanashiro & Rivera, 2019; Mian, 2001). Although most individual top management team members should possess similar communicational and social skills, technical competences vary in type and scope (Menz, 2012). Further, presence and turnover of individual top management team members, with focus on antecedents and performance

implications, was strongly discussed in literature as well (Menz, 2012). Authors like Hambrick and Cannella (2004), Nath and Mahajan (2008) or Marcel (2009) analyzed factors most often from a contingency perspective, like structural, environmental or strategic factors, regarding the decision to appoint the respective top management team member or not.

Further, the framework also describes the relationship of individual top management team members within the overall top management team, i.e., with other members of the top management team (Menz, 2012). Despite the importance of these relationships and interactions (B. Cannella et al., 2008), available literature regarding these aspects is limited (Menz, 2012). Since individual top management team members oftentimes have a direct reporting line to the CEO, this specific relationship has been subject to investigation by several scholars (Menz, 2012). One common underlying theme of studies in this area builds up on the idea that a CEO's lacking knowledge, experience and skill set regarding a certain topic is compensated by the corresponding individual top management team member (Angwin et al., 2009; Hambrick & Cannella, 2004; Nath & Mahajan, 2008). Only few authors addressed the relationship between individual top management team members other than the CEO (Menz, 2012). Most literature focusses on the relationship of individual top management team members with the overall top management team, for example, regarding the fit or process-related factors between them (Menz, 2012).

Apart from the top management team, scholars also focused on environmental and organizational factors when studying individual top management team members (Menz, 2012). Organization related factors were most often investigated in relation to antecedents and performance implications of individual top management team member presence (Menz, 2012). This factors include strategic factors, oftentimes measured by diversification (Hambrick & Cannella, 2004; Nath & Mahajan, 2008), factors about organizational design and structure, like centralization (Aaker, 2008), company specific factors like size (Hambrick & Cannella, 2004) or other factors, which are related to the studied individual top management team member. An example for the latter case is IT orientation and IT infrastructure (Sobol & Klein, 2009), and climate and support for IT (Preston et al., 2008) in research conducted around the CIO position.

Research on environmental factors like industry and geographical aspects related to an individual top management team member's role and presence found growing attention in literature as well (Angwin et al., 2009; Hambrick & Cannella, 2004; Nath & Mahajan, 2008). Still, the influence of geographical factors remains mostly untouched by scholars when assessing an individual top management team member's presence, attributes and position (Menz, 2012).

The last part of existing literature on individual top management team members covers aspects on implications regarding outcome (Menz, 2012). Some authors investigated effects on the organization in general (Medcof, 2008), amount and quality of investors (Higgins & Gulati, 2006) and strategic change (Zhang, 2006). Other research results cover the impact on other top management team members or on qualitative aspects of the relationship with either CEO or other top management team members (Earl & Feeny, 1994; Enns et al., 2003; Zhang, 2006). Finally, implications from individual top management team members on company performance measured by different approaches emerged across literature (Menz, 2012). Such measures include on the one hand market-based measures like market-to-book ratio and Tobin's Q, as well as on the other hand accounting-based measures such as sales growth and return on assets (Hambrick & Cannella, 2004; Marcel, 2009; Nath & Mahajan, 2008). Although authors approached analyses similarly, results vary when comparing different literature on the same or on several individual top management team members (Menz, 2012). Still, the variation oftentimes arises with differing data bases and depends on several industry, company and top management team specific factors (Menz, 2012), implying the importance of controlling for such attributes.

Besides an overview on existing literature organized by the framework displayed in Figure 3, Menz (2012) also pointed out opportunities for future research and highlighted several aspects, which scholars should consider, in order to further increase quality of research on individual top management team members. He especially pointed out that due to different levels of conducted research, derived knowledge and applied methods, the research focus and approach for each individual top management team member differs and thus, should be chosen appropriately by future scholars. For rather unexplored positions, like the CDO, it is important to identify

uncovered research areas and to contribute to the initial understanding of the position (Menz, 2012). Overall, five research opportunities were identified by the author for guiding future scholars. First, future research in the field of individual top management team members should address fundamental questions regarding tasks, activities and features of the role, not only for previously analyzed positions, but also for unexplored positions (Menz, 2012). In order to fully understand individual top management team members and the overall top management team's nature, a considerable amount of research around their roles and activities is required, especially considering varying settings (B. Cannella et al., 2008; Menz, 2012). The second proposed research opportunity considers the fit between the individual top management team members and the CEO or even the overall top management team (Menz, 2012). Due to the limited amount of results, more research is needed regarding the top management team composition, their characteristics and role structures including processes within top management team relationships in order to fully acknowledge the potential benefits (Hambrick, 2007; Menz, 2012). Thirdly, Menz (2012) presented the interaction of individual top management team members with roles beyond the top management team, such as boards of directors, beyond company boundaries to external partners, or middle managers, as further research opportunity. As fourth opportunity, scholars should further investigate an individual top management members' impact (Menz, 2012). As impact can be broad, future research might consider implications regarding organizations and its strategy, strategic decision-making as well as company performance, measured either by classical performance measures or specific measures aligned with the respective position (Menz, 2012). Finally, the fifth future research opportunity addresses time as crucial factor for the development of an individual top management team member position, i.e., the implications of changing top management team composition and structure over time (Menz, 2012). Relationships, interactions and role interdependencies change within the overall top management team with varying individual top management team member presence, and are crucial to understand as these factors also impact the overall top management team's effectiveness (Menz, 2012).

In section 2.4, these opportunities are compared to the current status-quo of CDO research in order to guide future research as well as this thesis. In the next chapter, research question two as presented before will be addressed.

1.4 Structure of the Study

Before addressing all proposed research questions as outlined in section 1.1, the overall structure of this study will be briefly introduced in the following. After recalling research question one and discussing the underlying research objective, chapter 2 explains the methodology of systematic literature reviews followed by its application in the field of CDO literature. Results of the systematic literature review will be presented and put into the context of existing top management team research regarding other relevant C-level managers. In chapter 3, research questions two and three will be detailed based on insights from chapter 2. Following that, hypotheses for answering both research questions will be developed alongside a comprehensive specification of the theoretical framework combining upper echelons theory, contingency theory, human capital theory and the resource-based view. In chapter 4, research question two and the corresponding objective will be outlined. Following a description of the data set and its collection procedure for all quantitative assessments of derived hypotheses, an explanation of the chosen methodology will be provided. After applying outlined methodological approach to the collected data set, derived results will be presented. Chapter 5 follows a similar structure as chapter 4 for addressing research question three. In chapter 6, a concluding discussion of overarching insights from previous chapters will be provided. Derived results and implications as well as limitations of this study will be considered. Finally, future research opportunities will be suggested.

2. Research Question One: Understanding Existing Research on the Chief Digital Officer Position

2.1 Objective

As highlighted before, an initial literature screening on CDO research revealed that a common understanding of the CDO position was not yet derived. In addition, existing literature appears to be rather fragmented and a summary of existing results should be derived in order to clarify what is currently known about the CDO position and all its aspects, and what is not known. Pointed out by Menz (2012) by his first research opportunity, fundamental questions regarding activities, task and other relevant features of the role help not only shaping the understanding of the investigated individual top management team member, but also help clarifying the overall picture of top management teams. Thus, this research opportunity can be addressed by summarizing existing knowledge about the CDO.

In order to answer the first proposed research question, i.e., what characterizes the CDO position, and to help clarifying the current status of research on the CDO position, a methodological approach common across many fields like social policy, health care, medicine, management or organization studies was chosen (Briner & Denyer, 2012). By conducting a systematic literature review on available CDO literature, the objective of this section is to:

(1) Derive a systematic review of existing literature on the CDO position

(2) Provide a categorization of identified CDO literature

(3) Identify research gaps in the field of CDO research for guiding future research

(4) Refine initially proposed research questions

The desired characterization of the CDO position should not only result in a general role description like key tasks and activities, it is also expected to provide an overview of relevant capabilities and corresponding responsibilities. Furthermore, the systematic review should help clarifying how current literature discusses the relationship of the CDO position with the overall top management team and other individual top management team members. As listed by the fourth objective, the systematic literature

review also aims to identify current knowledge on what potentially affects the decision to appoint a CDO as well as on the impact of the CDO on company performance. As the purpose of this thesis is also to answer both research questions two and three, understanding existing knowledge on the CDO position ensures that answering these questions can be conducted without overlaps to existing results and be based on existing knowledge. Next to the importance of developing a comprehensive summary of knowledge in this field, conducting a literature review also allows for identification of general research gaps and guidance for future research efforts (Kunisch et al., 2018)

In the following, the methodology of systematic literature reviews will be presented and applied afterwards in order to identify relevant results of CDO research for answering the first research question.

2.2 An Introduction to the Methodology of Systematic Literature Reviews

The origin of systematic literature review as a key tool for developing an appropriate evidence base for any scientific activity has been emerging from medical science since the 1980s (Tranfield et al., 2003). In applications of medical science it became increasingly difficult to understand and process the mass of newly produced knowledge with often contradictory information (Ohlsson, 1994). Especially in practice, this amount of new knowledge combined with poorly conducted reviews could result in inappropriate recommendations for patients (Cook, Greengold, et al., 1997). As medical science strengthened the general approach to base scientific work on best available evidence, this approach has also become more relevant and applicable in other disciplines (Tranfield et al., 2003).[4] For example, the approach was applied to

[4] As the British National Health Service, which supports clinical research, provides expertise in research and functions as a source of new developments, was in need for systematic reviews, they developed the Research and Development strategy (Peckham, 1991). One aspect of the Research and Development strategy included that systematic reviews of existing research should not only be based on the most appropriate available literature, but should also be summarized and presented suitably for relevant decision-makers and scholars (Peckham, 1991). Following the Research and Development strategy, the review process was constantly subject to development and quality improvements. The target of the review process became to collect and summarize information by reproduceable and transparent methods for reporting information about health and social care delivery to decision-makers and governments (Cook, Greengold, et al., 1997; Cook, Mulrow, et al., 1997; Wolf et al., 2001).

certain extends in nursing (Evans & Pearson, 2001), public sector (H. T. O. Davies & Nutley, 1999), housing policy (Maclennan et al., 1999), social care (Macdonald, 1999) and criminal justice (T. Bennett et al., 2006; Laycock, 2000). In the 1990s, when the field of management research was still relatively new (Tranfield et al., 2003) and subject to more fundamental discussions concerning the nature of management research, knowledge production as well as theoretical and methodological correctness (Hodgkinson, 2001; Starkey & Madan, 2001; Tranfield & Starkey, 1998), the ability to apply evidence-based research to management science was still unclear. Tranfield et al. (2003) suggested to apply a more systematic literature review process in management science in order to satisfy the partially different nature of management science compared to medical science.

Briner and Denyer (2012) described the systematic literature review as precondition and basis for evidence-based management aiming to incorporate available knowledge and evidence for informing about research and practice. A systematic review addresses a specific question, helps to perform a thorough literature search and a critical assessment of individual studies by exploiting transparent and explicit methods, and concludes about what is currently known and what is not known about a certain topic, problem or question (Briner & Denyer, 2012). For a systematic literature review it is of importance, as for primary research, to apply the same level of accuracy and consistency, to maintain transparency regarding conducted methods and to deliver a sufficient level of reporting detail and clearness such that replicability can be assured (Briner & Denyer, 2012; Randolph, 2009). As the overall target of management research is both to extend existing knowledge as well as to provide insights into practice, it is crucial to consider the beforementioned factors in order to base the research activity on solid grounds of previous research such that achieving the target can be assured (Briner & Denyer, 2012).

There are several purposes for conducting a systematic literature review, but overall it should serve to demonstrate the authoring scholar's knowledge about their field of study, corresponding vocabulary, theories, main variables and phenomena, as well as methods and history (Randolph, 2009). Beyond this argumentation, systematic literature reviews can be conducted, for example, for definition of a research problem,

avoidance of unpromising approaches, determination of further research recommendations, identification of theoretical foundations and achievement of methodological knowledge (Gall et al., 1996, as cited in Randolph, 2009). Further, systematic literature reviews may serve as framework for connecting previous results as discovered during the systematic literature review with new results, findings or insights, which were derived beyond the systematic literature review (Randolph, 2009). Many examples for applied systematic literature reviews can be found in the field of management (-relevant) research. As listed by Briner et al. (2009), there are some examples of published management-relevant systematic literature reviews, which were commissioned by government agencies or organizations, such as the reviews of Phelps et al. (2007), Buchanan et al. (2005) or Pittaway et al. (2004).[5]

For avoidance of mistakes, conduction of the systematic literature review follows a clearly defined approach from planning to finalization of the results report (Tranfield et al., 2003).[6] Before conducting the systematic literature review, the researcher should begin by planning the review (Randolph, 2009). One approach to planning the review is by considering Cooper's taxonomy of literature reviews (Cooper, 1988). Cooper's taxonomy of literature reviews comprises six characteristics, each with several attributes: "Focus, goal, perspective, coverage, organization and audience" (Cooper, 1988, p. 109). By categorizing the intended systematic literature review according to these six characteristics, the researcher can tailor the approach of their systematic literature review accordingly.

Despite differences in wording and intermediate steps as described in various scholar's research (Briner & Denyer, 2012; Kunisch et al., 2018; Randolph, 2009; Rousseau et al., 2008; Tranfield et al., 2003), the approach for conducting a systematic literature review can be summarized by five main steps:

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[5] Further examples for systematic literature reviews in the field of management research and practice, as displayed by Briner and Denyer (2012), include the articles of Walker (2010), Keupp and Gassmann (2009) or Adams et al. (2006).

[6] Commonly made mistakes include, for example, that the search procedure used during the systematic literature review is not reported, contradicting results and alternative synthesizing approaches for quantitative literature are not considered or not all best-available sources for reviewing literature are identified and exploited (Gall et al., 1996, as cited in Randolph, 2009).

(1) Identification of the research problem and question

(2) Location and collection of literature

(3) Assessment of literature quality and relevance

(4) Analysis and synthesis of relevant literature

(5) Dissemination of review findings

First, basis for the systematic literature review is to identify and define a precise, substantial and answerable research question (Briner & Denyer, 2012) by deriving it from a conceptional debate of the research problem and arguing for the significance of the problem (Tranfield et al., 2003). Based on the research question, the researcher is able to define a formal process description called the review protocol (Tranfield et al., 2003). The review protocol documents the specific research question, the relevant literature population, the approach to literature identification, and inclusion and exclusion criteria for assessment of the literature's relevance for the systematic literature review (H. T. Davies & Crombie, 1998, as cited in Tranfield et al., 2003). Tranfield et al. (2003) further recommended to keep the review protocol flexible throughout the course of conducting the systematic literature review as management research often follows an explorative developing process. In case the researcher modifies the review protocol, the researcher needs to clearly specify and document the applied changes (Tranfield et al., 2003).

Second, for location and collection of literature it is necessary to define a set of search terms, which allow the scholar for searching within databases for literature (Briner & Denyer, 2012; Randolph, 2009; Tranfield et al., 2003). The selection of relevant databases for applying the search terms typically depends on the field of research (Randolph, 2009). After searching for literature with defined search terms, the researcher should accurately document the date of the searching period, the used databases, the amount of database results as well as the corresponding search terms including potential combinations of these, which allows for future replication and transparency (Randolph, 2009; Tranfield et al., 2003). In addition to database searches, the researcher might want to investigate the reference list of relevant literature or apply citation searches (Briner & Denyer, 2012; Randolph, 2009). The

result of the applied searching methods should be a list of all potential literature records (Tranfield et al., 2003).

Third, based on the defined set of inclusion and exclusion criteria from the first step, the researcher narrows down the full list of potential literature records (Briner & Denyer, 2012; Randolph, 2009). Oftentimes it might be suitable to apply a two-step approach for identification of literature records, which should be excluded from the further review process. By examination of title, abstract and listed keywords per literature record, the researcher might be able to remove obviously irrelevant literature records (Briner & Denyer, 2012; Randolph, 2009). After eliminating obviously irrelevant literature records, remaining literature records are subject to closer and more detailed examination regarding relevance and quality based on inclusion and exclusion criteria, which will results in the final, relevant literature base for the systematic literature review (Randolph, 2009; Tranfield et al., 2003).

Fourth, the researcher analyses relevant literature by extracting therein contained information (Randolph, 2009). Depending on the focus and goal of the systematic literature review, for example, focus on applied methodology or on exploited theoretical frameworks, only relevant information is extracted from the literature (Randolph, 2009) next to some general information such as title, authors and publication year (Tranfield et al., 2003). The documentation of extracted relevant information is a crucial step as it acts as basis for the synthesis, is a historical record of the extraction process and gives a holistic summary of the topic (Briner & Denyer, 2012; Tranfield et al., 2003). A commonly used approach for documentation is the application of a coding book in electronic format, such as a computer-based spreadsheet (Randolph, 2009; Tranfield et al., 2003). Based on the review question and nature of relevant literature, the researcher then applies an adequate method for literature synthesis (Briner & Denyer, 2012). Commonly used methods for synthesis can be grouped by four categories: "aggregation, integration, interpretation and explanation" (Rousseau et al., 2008, p. 491). As described by Rousseau et al. (2008) each of the four forms of literature syntheses implies certain strengths and weaknesses, follows a certain methodological approach, incorporates different types of data and aims to fulfill a certain goal.

Fifth, as last step, synthesized information from comprehensive primary research, should be reported for both practitioners and scholars in an easy and understandable format (Tranfield et al., 2003). Depending on the nature of the systematic literature review and the researcher's gained knowledge, the researcher determines which information is more relevant and therefore reported as well as which information should be left out (Randolph, 2009). In management research, one option to frame and report information is to use a two-stage report (Tranfield et al., 2003). In the first stage, the researcher might describe descriptive analysis of investigated literature based on the coding book, such as geographic focus, publication periods, categorization of information, etc. (Tranfield et al., 2003). The second stage should then provide a thematic analysis of the literature by identifying key emerging topics, drawing conclusions from common and contradicting opinions and highlighting linking themes (Tranfield et al., 2003). From here, the researcher might want to derive and formulate further research questions (Randolph, 2009).

By examining the five-step approach for conducting systematic literature reviews, it becomes clear that each step is targeted to maintain transparency regarding the applied procedure of the researcher and therefore to assure reproducibility for any researcher in the future. Especially in comparison to traditional non-systematic literature reviews, where, for example, the inclusion and exclusion of literature might not be following a clear approach, the systematic literature review minimizes the risk of researcher bias and ensures comprehensiveness of results (Briner & Denyer, 2012; Tranfield et al., 2003).

2.3 Application of Systematic Literature Review Methodology

For understanding current CDO literature, systematic literature review was selected as the most appropriate and best suitable approach and methodology. Not only was this approach selected to maintain systematics, reproducibility and transparency, but also to derive research gaps, possible future research opportunities, a solid basis for the empirical analysis and to link results from empirical analysis to existing research results.

As described in the previous section, the systematic literature review is based on a five-step approach for conducting the review. The identification of the research problem and research question can be found in the beginning of this chapter, which guided the definition of the review protocol. To recall, the research question can be summarized by the goal to identify, understand and synthesize available CDO research and literature. Based on the research question, the following review protocol was derived. As the CDO position and its corresponding research field are relatively new and still under-researched, the population of potential literature was expected to be naturally bounded (W. Becker et al., 2018). Therefore, there was no limitation defined regarding size, focus or scope of the relevant population in this specific field of research.

Online available databases and search engines for scholarly and scientific purposes were exploited for the identification of potential literature. In regards of this particular research question, the databases in scope for conducting the literature search were set to EBSCO Business Source Premier,[7] WISO[8] and JSTOR.[9] In addition, the search engine Google Scholar[10] was used for literature search as well, as it was expected to discover a broader range of literature, which was not published in journals, but instead, for example, presented on conferences. These databases and search engines are commonly used in (management-related) systematic literature reviews (Dauth et al., 2015; Stefania, 2016; Wrona & Sinzig, 2018). No further literature was identified from

[7] "The industry's most widely used business research database, Business Source Premier features full text and searchable cited references for top journals covering a variety of business disciplines." For further details, see https://www.ebsco.com/.
[8] "wiso ist das Hochschulangebot von GBI-Genios mit einem breiten Spektrum wissenschaftlicher und studienrelevanter Inhalte. Dazu gehören hochkarätige Referenzdatenbanken sowie die Volltexte ausgewählter Fachzeitschriften und eBooks. Professionelle Recherche-Tools, integrierte Thesauri sowie unterstützende Filter- und Monitoring-Funktionen ermöglichen das schnelle und zuverlässige Finden der gesuchten Informationen." For further details, see https://www.wiso-net.de/.
[9] "JSTOR provides access to more than 12 million academic journal articles, books, and primary sources in 75 disciplines. We help you explore a wide range of scholarly content through a powerful research and teaching platform." For further details, see https://www.jstor.org/.
[10] "Google Scholar provides a simple way to broadly search for scholarly literature. From one place, you can search across many disciplines and sources: articles, theses, books, abstracts and court opinions, from academic publishers, professional societies, online repositories, universities and other web sites." For further details, see https://scholar.google.com/.

reference lists of literature, which was derived from databases and search engine results.

Further, a set of inclusion and exclusion criteria was defined. Published (peer-reviewed) journal articles, book sections as well as conference proceedings were considered for the review, whereas work-in-progress/research-in-progress documents, full books, (bachelor, master or doctoral) theses, editorials, interviews, non-scientific magazines or news articles as well as practitioner reports such as consultancy reports were excluded from further reviewing. Conference proceedings, which served as basis or pre-version of published journal articles or book sections were also excluded from the review as it was assumed that, besides improvements due to conference feedback, the content was not changed substantially, and the journal article or book section reflects the most mature version of the document and content. In addition, literature was excluded if there was no link to the CDO position or another dedicated top management team position, which is responsible for digital transformation, and instead the document focused on a generalized discussion about digital transformation such as importance of a digital transformation strategy, success factors and challenges of digital transformation or phases of digital transformation.[11] Literature was also excluded if none of the search terms were included in title, abstract or key words of each document.[12] Finally, only literature in German and English language was considered for further assessment. These exclusion criteria were refined throughout the course of analyzing an initial pilot set of literature.

In order to apply the inclusion and exclusion criteria to potential literature resulting from searching within database and search engines, a set of search terms was defined: *Chief Digital Officer(s)*, *Chief Digitalization Officer(s)*, *Chief Digitalisation Officer(s)*, *CDO(s)*, *Chief Digital Information Officer(s)* and *CDIO(s)*.[13] In addition, the combination of *digital transformation* with either *top management team*, *executive team* or *Chief*

[11] For further insights regarding digital transformation in general, see section 1.2.
[12] The criterion regarding title, abstract and keywords was assessed by exploiting database and search engine features meaning that only literature records were suggested as search results, which had one of the search terms included in title, abstract or keywords.
[13] The "s" in brackets can be interpreted as using, for example, both the search terms CDO and CDOs.

Digital Officer resulting in three different combinations were added to the set of search terms. An overview of the set of search terms can be found in Table 1.

#	Search term	Description	Reference
1	Chief Digital Officer(s)	"CDOs are often appointed to pursue and implement digital transformation activities and to drive change across an organization."	Singh et al. (2019, p. 2)
2	Chief Digitalization Officer(s)	*Similar to Chief Digital Officer(s)*	Ohain (2019, p. 2)
3	Chief Digitalisation Officer(s)	*Similar to Chief Digital Officer(s)*	*See above*
4	CDO(s)	*CDO(s) is the abbreviation of Chief Digital Officer(s)*	*See above*
5	Chief Digital Information Officer(s)	*Similar to Chief Digital Officer(s)*	Sibanda and Ramrathan (2017, p. 199)
6	CDIO(s)	*CDIO(s) is the abbreviation of Chief Digital Information Officer(s)*	*See above*
7	Digital transformation	"Digital transformation is concerned with the changes digital technologies can bring about in a company's business model, which result in changed products or organizational structures or in the automation of processes."	Hess et al. (2016, p. 124)
7a	Top management team	"Top management teams make strategic decisions, and the products of their decision-making influence organizational performance."	Amason (1996, p. 123)
7b	Executive team	"Executive teams are particularly important determinants of organizational outcomes in that they are at the boundary between an organization and its environment."	Keck and Tushman (1993, p. 1315)
7c	Chief Digital Officer	*See above*	*See above*

Table 1: Overview Set of Search Terms
Source: Own illustration.

Defined by the research object itself, it becomes obvious to include the search team *Chief Digital Officer* (and its plural or abbreviation).[14] The set of search terms also covered the terms *Chief Digitalization Officer* and *Chief Digitalisation Officer* (and its plurals) due to the interchangeable use in literature (Pabst von Ohain, 2019) as well as the use of both spellings of the terms "digitalization" and "digitalisation". Especially

[14] As other terms for the CDO position like "Chief Digital Executive" have not been observed and used in literature, such variations have not been added to the set of search terms.

the terms "digital" and "digitalization" are commonly used with the same meaning. Further, *Chief Digital Information Officer* (and its plural or abbreviation) was included as it is used as another alternative for the term *Chief Digital Officer* as well (Sibanda & Ramrathan, 2017). Also as described by the research object before, the search term *digital transformation (*and its German translation) combined with either *top management team* or *executive team* was used in order to identify results from literature, which discussed a dedicated top management team position, which is responsible for digital transformation, but not necessarily the CDO. Both *top management team* and *executive team* can be interpreted similarly (Amason, 1996; Keck & Tushman, 1993). Due to the operational differences of the sources for literature search (as described below), the third term *Chief Digital Officer* for combination with *digital transformation* (and its German translation) was selected. The overall set of search terms as well as inclusion and exclusion criteria were also defined and aligned with the supervisor of this thesis during an initial literature screening before conducting the systematic literature review.[15]

As all four sources for literature search (i.e., EBSCO Business Source Premier, WISO, JSTOR and Google Scholar) imply operational differences, applying the search term logic and exclusion criteria was conducted with slight differences for each.

For EBSCO Business Source Premier, the single search terms were explicitly searched for in either title, abstract or keywords. Due to the limiting character of using a combination of two search terms, combined search terms were not restricted to either title, abstract or keywords, and instead, both search terms of the combination had to be at least somewhere in the text of the document. The results from this search have then been narrowed down by filtering out, for example, non-scientific magazine articles or news articles.

[15] German equivalents of each search term were considered. Yet, from all defined search terms, only *digital transformation* appeared to be suitable to be also included in German, as the other search terms are oftentimes used in English within German literature. Further, by applying the German equivalent of *digital transformation*, only two additional documents were identified (after applying exclusion criteria), which were not covered by the set of English search terms. For the sake of completeness, these documents were included.

For WISO, both the single search terms and the combined search terms were not limited to title, abstract and keywords only, but instead searched for without limitation as the results were already quantitatively limited. Similar to the search logic for EBSCO Business Source Premier, results from this search have been reduced by filtering out, for example, non-scientific magazine articles or news articles.

For JSTOR, the single search terms were explicitly searched for in either title or abstract, while searching within keywords was not provided by JSTOR. Again, similar to EBSCO Business Source Premier, combined search terms were not restricted to either title or abstract. Instead, both search terms of the combination had to be used anywhere in the text of the document. In addition, the same filter application as for EBSCO Business Source Premier and WISO has been exploited.

For Google Scholar, the single search terms were explicitly searched for in title only and for the combined search terms, *digital transformation* was explicitly searched for in title only and the additional search term was allowed to appear anywhere in the text of the document. The last adjustment was made mainly due to the fact that by searching for *digital transformation* and another search term without limitation on Google Scholar, the search engine yielded several thousand (mostly irrelevant) literature records.

By applying the above described search procedure, a total number of 1,239 literature records were identified. The majority of literature records were in English (1,049), several literature records in German (167) and remaining literature records in other languages (23). As four different sources for literature review were exploited as well as the same search terms might yield the same search results, some duplicates were listed. The amount of unique literature records sums up to 1,068. Further, the described search procedure was applied between January 08th and January 15th, 2020. Literature published after January 15th, 2020 was not considered for the systematic review. An overview of literature records, which resulted from the database and search engine searches per search term can be found in Table 2.

Search term	EBSCO Business Source Premier	WISO	JSTOR	Google Scholar	Total per one search term	Unique per one search term	Unique across all search terms
Chief Digital Officer(s)	7	26	0	20	53	49	49
Chief Digitalization Officer(s)	0	0	0	0	0	0	0
Chief Digitalisation Officer(s)	0	0	0	0	0	0	0
CDOs	357	490	57	11	915	811	795
Chief Digital Information Officer(s)	4	0	0	0	4	4	3
CDIO(s)	10	27	3	19	59	58	58
Digital Transformation[16]	5	9	1	193	208	182	163
Total	**383**	**552**	**61**	**243**	**1,239**	**1,104**	**1,068**

Table 2: Overview Database and Search Engine Results
Source: Own illustration.

Despite the fact that the search terms *Chief Digitalization Officer* and *Chief Digitalisation Officer* (and its plurals) have an interchangeable use with *Chief Digital Officer* in literature, there was no literature identified for these search terms following the before outlined review protocol. One possible reason for this result might be that scholars, which conduct research around the field of the Chief Digital Officer position, use the more frequently used and established term *Chief Digital Officer* for describing their work.

Based on the 1,068 potential literature records, the two-step approach for identification of relevant literature was applied as described before. Literature, which is obviously not relevant for further reviewing due to matches with the exclusion criteria, was removed from further examination. In order to identify these obviously irrelevant literature records within the search results, an assessment of title, abstract and keywords was conducted. For example, many results from the search terms *CDO(s)* were linked to "Collateralized Debt Obligations", which is in the context of the research

[16] Representing all search term combinations: *Digital transformation* and *top management team*, *digital transformation* and *executive team*, *digital transformation* and *Chief Digital Officer*.

question not relevant. Further for the same search terms, some literature has been identified discussing other C-level executives (e.g., "Chief Data Officer", "Chief Diversity Officer", "Chief Development Officer", "Chief Design Officer", "Career Development Officer"), but not in the required context of digital transformation. The literature records, which were not in English or German language were excluded from further reviewing as well.

After investigation of title, abstract and keywords, the number of relevant literature records was reduced to 44 documents, which were then subject to further examination. Five documents were not available for a detailed assessment. Further, five documents were excluded from the review as these were identified as consultancy reports (four) or as full book (one).

The remaining 34 documents were subject to an evaluation of the exclusion criteria based on a full reading of the document. Six documents had to be further removed due to classification as work-in-progress/research-in-progress documents (two), as conference proceedings, which served as pre-version of later on published documents (three) as well as due to too generic discussion of digital transformation (one). Finally, step four and five of the systematic literature review were based on the remaining 28 documents.

As suggested by Randolph (2009) and Tranfield et al. (2003), relevant information was extracted from the remaining literature and collected in a coding book based on an electronic spreadsheet. Based on the research objective and research question, namely, to understand existing literature on the CDO position, the coding book was designed for grasping comprehensive information. In detail, the coding book includes the following information: title, authors, year of publication, language, published journal or book publisher or conference, key words defined as in the document, study focus and topics, research questions, (theoretical) framework, applied methodology, research population and data, variables, geographic coverage, industry coverage, results and suggested future research. A similar approach was selected, for example, by Dauth et al. (2015). Further, the coding book was extended by a categorization and a summary as well as if needed, further comments.

Based on the nature of the research question, meaning an exploratory research question for understanding current literature approaches and results on the topic of the Chief Digital Officer position or another executive dedicated to driving digital transformation, the synthesis follows an integrative methodological approach. As single studies most often try to answer one specific question, integrative synthesis overcomes this issues and allows to address the kind of multi-faceted research questions within the context of this review (Rousseau et al., 2008). Further, integration allows to combine and to analyze literature, which is based on more than one type of data collection method (Rousseau et al., 2008).

2.4 Results from Systematic Literature Review about the Chief Digital Officer Position

In the following section, the two-stage reporting approach is applied as suggested by Tranfield et al. (2003). An overview of investigated literature will be presented including categorization and descriptive analysis followed by detailed description and comparison of results.

2.4.1 Overview of Results

As it was expected from the fact that the CDO position is still relatively new and from a scholarly perspective still relatively under-researched (W. Becker et al., 2018), first literature, which satisfies the before laid out inclusion criteria, was only published in 2015. Figure 4 shows that since 2015, the number of published and relevant journal articles, book chapters or conference proceedings increased continuously until 2019. Overall, the systematic literature review was based on fifteen articles (54%), eight conference proceedings (28%) and five book chapters (18%) satisfying the inclusion criteria.

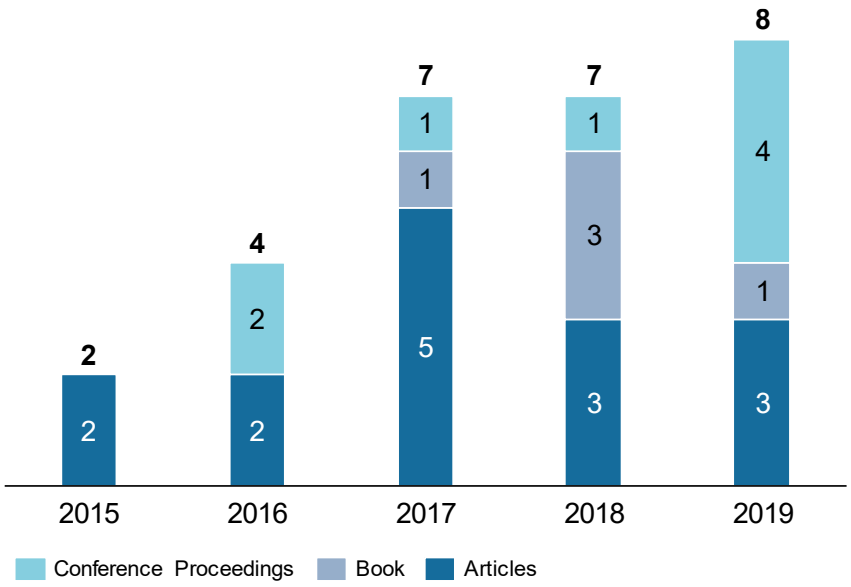

Figure 4: Distribution of Relevant Literature by Type and Year
Source: Own illustration.

Eighteen (64%) of investigated documents were in English, whereas the other ten (36%) documents were in German. From Table 3 it becomes clear that besides some journals with two publications, no journal specifically focuses on the research field around CDOs so far. Further, the research area is relevant both for business and information system related journals and conferences.

Type	Number of documents
Journal	
Business & Information Systems Engineering	1
Business Horizons	1
Controlling & Management Review	2
Economic and Business Review	1
HMD Praxis der Wirtschaftsinformatik	1
ISACA Journal	1
Journal of Economic Development, Environment & People	1
Journal of Information Technology	1
Long Range Planning	1
MIS Quarterly Executive	2
Wirtschaftsinformatik & Management	2
Zeitschrift Führung + Organisation : ZfO	1
Book	
CIOs and the Digital Transformation: A New Leadership Role (Springer)	1
Digitale Transformation (Springer)	1
Digitalisierung in Unternehmen (Springer)	1
Geschäftsmodelle in der digitalen Welt: Strategien, Prozesse und Praxiserfahrungen (Springer)	1
Grundzüge der Wirtschaftsinformatik (Springer)	1
Conference	
11th International Conference on Education and New Learning Technologies, Palma, Spain, 2019	1
13th International Conference on Service Systems and Service Management, Kunming, China 2016	1
14th Italian Conference on Information Systems, Milano, Italy, 2017	1
24th Americas Conference on Information Systems, New Orleans, USA 2018	1
37th International Conference on Information Systems, Dublin, Ireland 2016	1
40th International Conference on Information Systems, Munich, Germany 2019	2
79th Academy of Management Proceedings, Boston, USA 2019	1

Table 3: Alphabetic Order of Relevant Literature by Journal, Book and Conference
Source: Own illustration.

An analysis of the geographic origins for each document reveals that more than 65% of investigated literature was published in Germany (eleven) and the USA (five).[17] Five of the German documents are relating to the five books, which can be found in Table 3, and were published by a German publishing house. Other documents were published or presented, for example, in the United Kingdom, China and Italy. A complete overview of the geographical distribution regarding the origins of publication can be found in Figure 5. The overview was based on the country in which the conference took place as well as the journals' and books' corresponding country of origin.

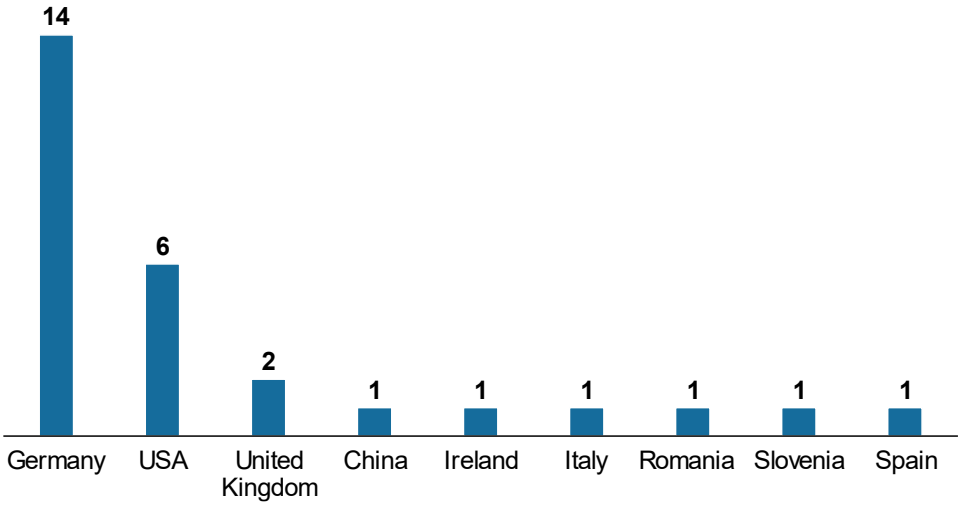

Figure 5: Distribution of Relevant Literature by Geographical Publication
Source: Own illustration.

As defined by Williams (2007), all documents have been assigned to either quantitative, qualitative or mixed methods, in case an explanation of the methodological approach was provided by the authors. The most common approach, which was applied within the 28 investigated documents, was of qualitative nature (18). Only three documents were based on quantitative methodological approaches and only two documents exploited an application of mixed methods with both quantitative and qualitative data. For the remaining five documents, the authors did not specify the

[17] Note that (mostly) English search terms were applied. Still out of identified literature, more research was published in Germany compared to the US. One potential explanation might be that in general, Europe is lacking large-scale digital companies compared to the US ("Europe's history explains why it will never produce a Google," 2018). Therefore, attention for CDO research might be lower in the US.

applied methodological approach.[18] As the research field is still relatively new, the distribution of applied methods is not surprising. Most researchers seem to clarify qualitative information such as characteristics of the CDO position for laying the conceptual and theoretical grounds before underpinning these results with quantitative research results. Therefore, exploited methods seem to be overall appropriate except for cases when corresponding information was not included. Figure 6 provides an overview of the applied methods.

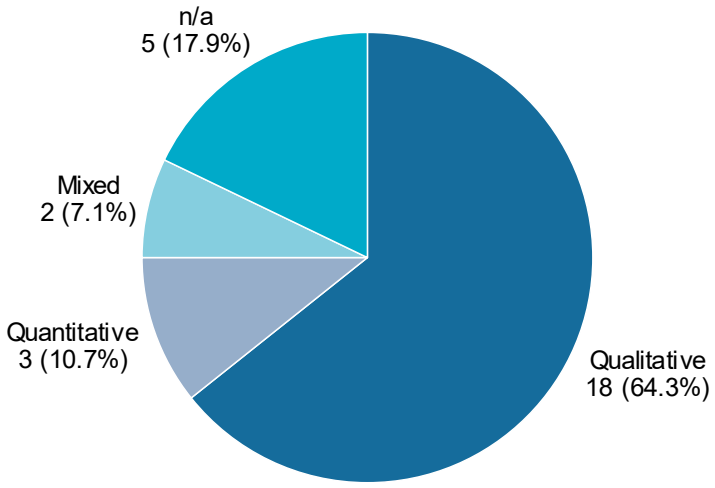

Figure 6: Distribution of Relevant Literature by Applied Method
Source: Own illustration.

Based on full-reading and collection of data by exploiting the before described coding book, all investigated literature was analyzed and categorized. The categorization for all 28 documents was guided by the discussed research objectives, topics and results. Three categories were derived and defined for reflecting the analyzed literature: (1) *Characterization of the CDO position and its need*, (2) *insights for the CDO position from other executive positions leading digital transformation* and (3) *antecedents and financial impact of CDOs*.

Overall, 18 documents were classified in the category *characterization of the CDO position and its need*. As most documents were based on qualitative research methods

[18] Due to the nature of the results, for which the authors did not specify the applied methodological approach, applied methods were presumably of qualitative nature.

such as multiple-case study (W. Becker & Schmid, 2019; Singh & Hess, 2017; Singh et al., 2019; Zisler et al., 2016), analysis of (exploratory) interviews and job advertisements (Haffke et al., 2016; Locoro & Ravarini, 2017; Tahvanainen & Luoma, 2018; Tumbas et al., 2017, 2018; Walchshofer & Riedl, 2017), synthesis of literature (Giebe, 2019; Ulrich & Lehmann, 2018), literature reviews (Kutnjak et al., 2019) or survey with quantitative (and qualitative) data (Catarino et al., 2018), the category mostly reflects qualitative information and results about the CDO position. The information and results include the CDO's tasks and responsibilities, required skills, competencies, experience and education as well as different role types, collaboration with other executives and organizational integration approaches of the position.

The category *insights for the CDO position from other executive positions leading digital transformation* consists of seven documents and contains information and results regarding the impact of digital transformation on other executives and the company's organization, especially for the case when no dedicated CDO position is established. Similar to the category *characterization of the CDO position and its need*, the described information can be characterized by its qualitative nature, as most exploited methodological approaches were either surveys (Capitani, 2018; Hoberg et al., 2018; Pabst von Ohain, 2019; Štemberger et al., 2019), interviews with surveys (Gerth & Peppard, 2016) or multiple-case studies (Matt et al., 2015).

Three documents have been allocated to the category *antecedents and financial impact of CDOs* as their authors discussed the performance impact of the CDO position. For measuring performance impact, the authors investigated market-based performance measures like Tobin's Q and abnormal stock market returns. Further, authors of one document discussed antecedents of CDO appointments as well in their analysis. Due to the quantitative nature of the authors' research objectives and desired results, event study methodology (Drechsler et al., 2019; Zhan & Mu, 2016), fixed effects regression and GEE regression modeling (Firk et al., 2019) were applied.

The following subsections provide detailed information and insights for each of the three categories.

2.4.2 Characterization of the Chief Digital Officer Position and its Need

An overview on existing literature, which describes the CDO position and its need can be found in Table 4 including a summary of investigated research questions, exploited theoretical frameworks, applied methodological approaches, analyzed data sets, derived results and potential topics for future research. It is important to note that not all papers provided information on all aspects with the same level of detail or partially not at all.

Literature	Summary
Haffke et al. (2016)	The authors aimed to answer how companies can delimit the role of the CDO from the role of the CIO and what drives the initial need for a CDO. They framed their research around the evolution of the CIO position, the increasing focus from business side on digital transformation and the emerging CDO role for digital innovation. They used an exploratory interview approach with CIOs and CDOs (if existing) or other business executives from 19 European companies of several industries. The interviews were semi-structured with interview guides and were conducted between February and May 2016. Based on their cases, they defined the CDO role and four specific CDO role types: Digital innovator, digital evangelist, digital coordinator and digital advocate. The CDO role types depend on implications of digitization as perceived by the organization and CIO role orientation. Further, they described the need for a CDO depending on several dimensions and argued for a business and IT driven governance framework for digitization initiatives. The authors suggested for future researches to include a third interviewee or to further study this topic by in-depth case studies.
Zisler et al. (2016)	The authors applied a multiple-case study approach based on semi-structured interviews with CDOs and other executives of five companies from several industries in order to derive a role concept of the CDO. They based their research on existing Upper Echelons theory for top management teams. Based on their research, they suggested that the CDO role change with the digital maturity level of the company: Phase 0, introduction phase, development phase and maturity phase. In order to be successful, they argued that the CDO should be placed on top management team (TMT) level for comprehensive acceptance and influence. They concluded by explaining the CDO's necessary skillset as well as required experiences.
Bülchmann (2017)	The author aimed to answer how companies can adapt to new challenges from digital transformation and what perspectives are emerging in this regard. Therefore, he described the digital transformation framework for identification of fields of actions for companies along six dimensions: vision, strategy, business processes, organization, prerequisites, culture and leadership. He concluded that companies require a digital leader for driving digital transformation, typically a newly hired CDO. Further, he elaborated on required skills and competencies as well as tasks of the CDO. He concluded by summarizing which aspects companies need to consider for hiring CDOs.
Locoro and Ravarini (2017)	The authors investigated aspects of digital transformation and its impact on the CIO and CDO roles from a socio-technical perspective. Therefore, they combined four models within one socio-technical model. They applied their model to content analysis (inductive and deductive thematic analysis) of interviews mostly with CIOs as well as transcripts of online interviews with mostly CDOs from Italy and America, which were conducted in 2016. They derived that the main differences between CDO and CIO are regarding the vision of digital business strategy and tech trends. They elaborated on required skills for the CDO position and argue that CIOs of digital-born companies (like start-ups) typically become the CDO of these companies.

Table 4: Existing Literature Describing the CDO Position and its Need
Source: Own illustration.

Literature	Summary
Mertens et al. (2017)	The authors elaborated on five phases of digital transformation as well as the necessity of digital transformation strategies including its four main elements: use of technology, structural change, changes in the value chain and financial aspects. They argued that CIOs are not always successful in digital transformation, therefore, the CDO position is required. Finally, they described tasks and skills which are relevant for the CDO position.
Singh and Hess (2017)	The authors investigated six company specific case studies along several dimensions in order to investigate the questions on what exactly CDOs do, and how they differ from their CxO colleagues as well as whether the CDO is a temporary role that will disappear in the future. Whereas the CDO's overall responsibility lies within digital initiatives, the CIO or head of IT drives strategic IT deployment and IT support. Therefore, they conducted 10 interviews with the companies' CDOs and partially CIO, CTO or managing director based on a semi-structured and open-ended questioning approach. From the case studies, they derived three main types of CDO roles: Entrepreneur, digital evangelist and coordinator. In addition, they reported skills and competencies which are relevant for CDOs. Finally, they described drivers for establishing a CDO position. They closed by summarizing lessons learned for organizations, CDOs, CIOs and whether the CDO position is a temporary phenomenon.
Tumbas et al. (2017)	The authors aimed to answer the question about what CDOs specifically do and why different organizations establish CDOs in order to provide guidance for organizations. They conducted exploratory interviews with open-ended questions with an iterative process of analyzing and coding data for the next interviews. In total 35 CDOs based on the LinkedIn group CDOclub were interviewed from America and Europa working in several industries. With this approach they derived three domains on which CDOs focus on for creating business value: Data analytics, digital innovation and customer engagement. In addition, three types of CDOs including key capabilities, primary objectives and reasons for establishing the role were defined: Digital accelerator, digital marketer and digital harmonizer. Further, reasons for when a CDO is necessary in an organization (potentially in addition to a CIO) were derived. They concluded that CDOs might evolve to become Chief Innovation Officers or re-merge with the CIO in the future.
Walchshofer and Riedl (2017)	The authors conducted a literature review on existing CDO research including consultancy reports and derived the research question whether the CDO management position is actually new or it only appears to be new. They investigated this question by analyzing 13 job advertisements for CDO positions in Germany, Austria and Switzerland (advertisements from January 2013 to April 2016) as well as by interviewing six CDOs in Germany and Austria with no focus on specific industries (interviews in March and April 2016). Their qualitative approach aimed to derive a definition of CDOs' tasks, skill requirements and organizational integration. Further, they compared their results to the CIO position based on existing CIO literature and derived similarities and differences in tasks and skill requirements.
Weinreich (2017)	The author described responsibilities for digital transformation based on three phases of digital transformation: Initial phase, transformation phase and complete integration phase. Main tasks and responsibilities of the CDO arise during the transformation phase of a company as they might become redundant after successful transformation.

Table 4 (continued): Existing Literature Describing the CDO Position and its Need
Source: Own illustration.

Literature	Summary

Catarino et al. (2018)	The authors suggested an evaluation of CDO and CIO responsibilities based on the COBIT 5 reponsible, accountable, consulted and informed (RACI) allocations for IT governance processes of CIOs. They suggested a RACI allocation for CDO and CIO and assessed their suggestion with a user-opinion study based on multiple choice, open-ended and scaled questions with 15 participants. Further, they interviewed participants on CDO and CIO characteristics and tasks. They derived a set of characteristics and tasks for both the CIO and CDO and suggested for future research to also include management processes from COBIT 5.
Lemke et al. (2018)	The authors described the impact of digital transformation on digital leadership and digital governance structures. Therefore, companies require "engaged leaders" with several skills, who lead digital governance structures CDO. They reported tasks and responsibilities of the CDO and in addition, they elaborated on the role of IT in digital transformation for both classical IT core systems and new innovative and digital systems.
Tahvanainen and Luoma (2018)	The authors aimed to answer what competencies are needed for the tasks of a Chief Digital Officer. They put the IT competency framework with four dimensions for both technical and business-oriented roles in IT in perspective to their literature review and applied an exploratory study with personal, semi-structured interviews regarding the IT competency framework, general tasks and roles of CDOs. They interviewed ten CDOs from Nordic companies across different industries between April and June 2017. They derived an overview of CDO activities and tasks as well as required competencies regarding the CDO position. They suggested further research, for example, by sampling outside of the Nordics region, assessing the influence of companies' digital maturity on CDO role and comparing the CDO with the change agent role instead of the CIO role.
Tumbas et al. (2018)	The authors aimed to clarify how CDOs establish legitimacy of their role in organizations with existing, well established IT units and CIOs by deriving conclusions from interviews with 35 CDOs and one early founder of a CDO community. Interviews were conducted between June and October 2015 and between October and November 2016. They applied an exploratory interview method with open-ended questions. They derived that CDO actions are defined along five dimensions: focus of management control, value orientation, goal achievement, reference field and location in value chain. In addition, they defined three approaches on how CDOs reconcile their activities with the activities of IT/CIOs, enact their identification as well as create legitimacy of their role: grafting, bridging and decoupling. Future research was suggested to include exploration of the digital logic of action in companies without a specific CDO role or examination of long-term dynamics as the CDO role might vanish or merge in the future.
Ulrich and Lehmann (2018)	The authors derived role types for CDOs and CIOs based on literature review of scientific articles and consultancy reports regarding both CIOs and CDOs. Overall, they included 84 CIO relevant documents and 21 CDO relevant documents in their analysis. They explained that CDOs can take six different role types whereas CIOs can take seven different role types. Five of these role types overlap, meaning that both CIOs and CDOs can be agility-oriented technologist, innovation driver, change agent, internal collaborator or external relationship driver. Looking at CDOs, they explained the additional role as transformation coordinator. CIOs can either take the role as cost-oriented technologist or as business-oriented strategist. For each role type they derived implications, chances and threats for CFOs.

Table 4 (continued): Existing Literature Describing the CDO Position and its Need
Source: Own illustration.

Literature	Summary

W. Becker and Schmid (2019)	The authors aimed to assess the CDO role in the context of digital transformation. They based their analysis on a role theory perspective and derive their results from 16 case studies with guideline-based and problem-centered CDO interviews between January and March 2017. The assessed companies were from different industries. They stated delimitations of the CDO role to other C-level executives and described tasks and responsibilities, obligations and rights of the CDO role as well as changes of the role within the interviewees' companies. Further, they elaborated on collaboration of CDOs with external consultants and the hierarchical position of the CDO and his/her team sizes. Finally, they suggested to further assess organizational design for future companies as well as responsibilities of TMT executives during digital transformation.
Giebe (2019)	The author aimed to answer the questions whether and to what extent a CDO can be the savior for the German banking sector in the age of digital transformation. Therefore, he conducted a literature review in order to derive knowledge on digital transformation in the German banking industry and the CDO role. He summarized CDO tasks and role focus based on the literature review. Finally, he highlights the similarity with the CIO position and the importance of putting the CDO on TMT level.
Kutnjak et al. (2019)	The authors applied a literature review approach for clarifying who the CDO actually is, what knowledge, skills and experience the CDO must have and how the CDO becomes successful. The derived their research objective from the need of a digital transformation leader, which is highlighted in digital transformation literature. Their search for relevant literature on WoS, Scopus, Google Scholar and Google yielded 15 relevant documents including articles, conference proceedings and consultancy reports. From there they summarized CDO perspectives, focus, tasks, characteristics, key skills and competencies as well as job requirements on education, experience or other characteristics.
Singh et al. (2019)	The authors examined different structural design parameters from the IT governance research context as well as TMT characteristics regarding digital transformation activities of CDOs. For this analysis they exploited a multi-case study approach with semi-structured and open-ended interviews with CDO and further interviewees based on snow-ball sampling per company. Results have been verified by within-case and cross-case analysis as well as inter-code reliability testing and secondary information. They derived a specification of horizontal and vertical structural design parameters and the interlinkage between them. Horizontally, central and decentral CDOs differ regarding two contingencies: the CDOs major tasks and the anchoring of the DT strategy. Vertically, CDOs differ in formal and informal coordination mechanisms. Further, they guided decision makers regarding CDO selection depending on the need of the company as well as support CDOs regarding importance of horizontal and vertical structural design parameters. They closed by showing limitations and potential future research.

Table 4 (continued): Existing Literature Describing the CDO Position and its Need
Source: Own illustration.

As described before, results of research, which can be clustered by the category *characterization of the CDO position and its need* covered several topics in different widths and depths. Key concepts, insights and results were allocated to either tasks and responsibilities, role types, skills, competencies, experience and education, collaboration with other executives and organizational integration as well as further

results will be discussed hereinafter by a description for each document and a combined view on the results.

Tasks, responsibilities and role types

From 18 documents, in which the authors described aspects of the CDO position, authors of 15 documents provided information on general tasks and responsibilities of the CDO.

According to the results of Haffke et al. (2016), the main objective of the CDO is to understand digital transformation from an industry perspective and to derive company specific effects and implications. The CDO is responsible for defining a comprehensive digital strategy, communicating the strategy within the company as well as driving and leading all necessary and associated aspects of digital transformation (Haffke et al., 2016). From their interviews Haffke et al. (2016), further derived that CDOs oftentimes cover responsibilities for digital sales channels and digital marketing from a business perspective, launch tools for digital collaboration, evangelistically convey new digital opportunities and threats, strengthen cross-company cultural change and create and lead digital innovation labs.

Zisler et al. (2016) put tasks and responsibilities of the CDO in perspective of the digital maturity level of the corresponding company, which they described by four phases. While in the initial phase, or phase zero, when a company initiates single, non-aligned digital projects and the CDO should aim to bundle these ongoing digital activities within their responsibilities as well as to establish a base for successful digital transformation, in the introduction phase the CDO should initiate and drive digital transformation and establish a new digital business model next to the existing business model (Zisler et al., 2016). During the development phase, the CDO aligns and transforms the overall company with digital structures and processes including the existing business model (Zisler et al., 2016). Finally, in the maturity phase, the CDO should anchor all of their competencies and skills within the company and develop digital competencies within all executives and employees, which ultimately makes the CDO redundant in the company (Zisler et al., 2016).

Based on a digital transformation framework, Bülchmann (2017) argued that the main task of the CDO is to balance and synchronize all stakeholders' interests across functions for overcoming silos within the company. Therefore, the CDO needs to be change manager, strategist, implementer and storyteller and should question existing processes and procedures from both strategic and operational perspectives (Bülchmann, 2017).

Locoro and Ravarini (2017) described a CDO's activities as the application of ultimate technologies and technological trends for transforming analog businesses into digital businesses. Further, they agreed with Westerman et al. (2014) on key responsibilities of CDOs such as defining a company-wide digital strategy, aligning digital activities, exploiting industry-specific opportunities of digital business models and pushing digital transformation of the companies' business models.

As highlighted by Mertens et al. (2017), the CDO is key responsible person for the company's transformation resulting from digital technologies. For satisfying this responsibility, the CDO should focus on cultural and strategic activities such as developing new digital products and services based on new information technology or fostering company-wide and cross-functional collaboration within the company (Mertens et al., 2017). In addition, they argued that the CDO also assumes responsibility for developing, enhancing and implementing a digital strategy.

Singh and Hess (2017) defined the CDO as the company's orchestrator of digital transformation, who in addition defines and implements a digital transformation strategy together with the top management team of the company. The CDO recognizes all available chances and opportunities arising from new digital technologies and encourages and leads corresponding digital corporate activities (Singh & Hess, 2017). Further, strengthening of cross-functional collaboration across all hierarchies by assuming authority for digital activities and initiatives across departments is within the main tasks of the CDO as their overall objective is to comprehensively and digitally transform the entire organization (Singh & Hess, 2017). Similar results of this article were presented on a conference by a pre-version of the article (Horlacher & Hess, 2016).

In their exploratory interviews with more than 30 CDOs, Tumbas et al. (2017) argued that the main objective of the CDO is to generate business value from various types of digital technologies. In order to do so, the CDO is continuously investigating new digital opportunities, scrutinizing the current business model and assessing the company's customer-centeredness (Tumbas et al., 2017). They highlighted that all interviewed CDOs orientate their tasks and responsibilities around the end-customer of the company and build upon insights from analyzing a variety of data and experimentation with digital technologies (Tumbas et al., 2017). As suggested by Tumbas et al. (2017), the described activities of the CDO can be grouped around three domains: data analytics, digital innovation and customer engagement.

Walchshofer and Riedl (2017) investigated job advertisements, conducted interviews with six CDOs and concluded similar results compared to previous research. They argued that the CDO is responsible for defining and implementing a digital strategy and for driving the digital transformation within the company. Therefore, the CDO constantly monitors digital and technological trends (Walchshofer & Riedl, 2017). Further tasks and responsibilities cover development of new disruptive business models and increase efficiency and agility in the company's structures and processes while always focusing on the customer journey (Walchshofer & Riedl, 2017). Besides cultural change, employee development and motivation, the CDO acts as leader of digital projects and initiatives including monitoring of digital projects' progress and success (Walchshofer & Riedl, 2017).

Similar to Zisler et al. (2016), Weinreich (2017) elaborated on different CDO tasks and responsibilities along three phases of companies' digital transformation. He argued that in the initial phase the CIO is responsible for digital transformation due to more technical aspects of implementing initial digital activities. As soon as the company's digital activities grow beyond technical aspects or the CIO is fully occupied by traditional IT related topics, the CDO is required to take over responsibility (Weinreich, 2017). Main tasks and responsibilities include developing business models and strategies, driving transformation and innovation of products, services and processes and anchoring digital business perspectives and transformation processes in the executive board (Weinreich, 2017). Further, he stated that the CDO should strengthen

cross-functional collaboration and reduce silos within the company. During the phase of complete integration, when the company is fully digitally transformed, the CDO is not required anymore (Weinreich, 2017). Weinreich (2017) highlighted that during his interviews most CDOs had their strengths and weaknesses concerning these multifaceted tasks. Therefore, these CDOs compensated their strengths and weaknesses by adding competent employees to their team (Weinreich, 2017). It is important to note that Zisler et al. (2016) exploited a slightly different phase model of digital transformation with four phases and deviating phase descriptions.

By conducting interviews and exploiting the IT governance processes and corresponding RACI allocations as defined as in COBIT 5,[19] Catarino et al. (2018) derived that the CDO is responsible for defining the company's digital strategy and vision based on the corporate strategy. Further, the CDO establishes a company-wide digital culture, drives the transformation towards digital and acts as change manager (Catarino et al., 2018). In addition, Catarino et al. (2018) concluded that the CDO focuses on value optimization, a governance framework for digital transformation and communication to stakeholders as defined as in COBIT 5.

Lemke et al. (2018) argued that digital transformation should be guided by a digital governance structure, which is typically led by the CDO. In this context, the CDO is responsible for driving cultural change within the company and coordinating between existing and new digital structures (Lemke et al., 2018).

According to the results of Tahvanainen and Luoma (2018) based on interviews with ten CDOs, the CDO's main focus lies on acting as change agent. Key responsibilities include implementation of a digital strategy, monitoring and coordination of digital projects and initiatives in the entire organization as well as ensuring company-wide collaboration during the change (Tahvanainen & Luoma, 2018). Further tasks of the CDO cover innovation management, support and update of the existing business model, products and services as well as development of new business models

[19] "COBIT 5 is the only business framework for the governance and management of enterprise IT […]. COBIT 5 incorporates the latest thinking in enterprise governance and management techniques, and provides globally accepted principles, practices, analytical tools and models to help increase the trust in, and value from, information systems." For further details, see https://cobitonline.isaca.org/.

(Tahvanainen & Luoma, 2018). Tahvanainen and Luoma (2018) also stated that developing customer experience, communicating aspects of digital transformation within the company and staying aware of new technologies count among the activities of the CDO.

The exploratory interviews of Tumbas et al. (2018) and their view on CDOs as institutional entrepreneurs unveiled that the activities of the CDO, which were also discovered by previous scholars, can be explained along five dimension: Focus of management control, value orientation, goal achievement, reference industry and position in the value chain. They argued that the CDO focuses their management control on strategically launching new projects initiated by digital technologies across several areas and departments of the company and linking ongoing IT projects with new digital initiatives. Regarding value orientation, the CDO aims to generate revenue streams from digital technologies for increasing top line performance of the company (Tumbas et al., 2018). The CDO achieves their goals by experimenting with digital content, products and services through starting and testing small-scale pilot projects before executing a comprehensive roll out (Tumbas et al., 2018). The authors further explained that the CDO exploits the field of technology start-ups and established digital companies for references by taking over guiding principles like avoidance of bureaucracy, iterative scaling of initiatives and fast execution, and even partnering with mature digital companies, if necessary (Tumbas et al., 2018). From a value chain perspective, the CDO's focus lies on the end customer and customer-facing processes for immediate impact generation for external customers (Tumbas et al., 2018).

Another approach to clustering tasks and responsibilities of the CDO, compared to the suggestion of Tumbas et al. (2018), is provided by W. Becker and Schmid (2019). They suggested that the CDO's tasks and responsibilities, which are also suggested by previous scholars, can be grouped along six (functional) areas: Strategic management, digitalization, IT, program management, marketing, and data (security). Strategic management activities include the implementation of strategies, advancing human resources (HR), pushing cultural change including breaking of barriers, performing merger and acquisition activities and conducting business analyses (W. Becker & Schmid, 2019). From a digitalization perspective, the CDO leads digital transformation

in the entire company, acts as consultant in the context of digital transformation, develops new digital business models, digitally transforms existing business models and promotes digital competencies in the company (W. Becker & Schmid, 2019). W. Becker and Schmid (2019) described website and system architecture related activities for the IT perspective and development of new products and processes, and management of projects for the program management perspective. Activities in the area of marketing include establishing new customer segments, market repositioning of the company, product and service marketing and customer support (W. Becker & Schmid, 2019). Further details regarding activities within the field of data (security) are not proposed by W. Becker and Schmid (2019). These results are also in line with a previous version of this article, which was presented on a conference by W. Becker et al. (2018) and which, in addition, they highlighted that the before described activities are not carried out by all CDOs in general, but instead depend on the size of the company (W. Becker et al., 2018).

Singh et al. (2019) reported three main areas of CDO tasks and activities, which were also in line with conclusions regarding three main CDO role types presented earlier by Singh and Hess (2017): change agent activities, innovation activities and holistic strategy activities. Regarding change agent activities they argued that by advising and motivating employees, the CDO focuses on driving the implementation of an existing digital transformation strategy across the company. Innovative CDO activities include applying new digital technologies in order to establish innovation within the company (Singh et al., 2019). The strategic CDO's activities cover the definition and implementation of a central digital transformation strategy for the entire company and all business units (Singh & Hess, 2017).

Authors of four documents took their analysis one step further and defined different role types of CDOs. They based the role types on tasks and responsibilities, which they derived from their analyses and which are similar to the results of researchers as described before.

Besides general and overarching activities as described previously, Haffke et al. (2016) defined four different CDO role types: digital innovator, digital evangelist, digitization coordinator and digital advocate. The digital innovator CDO constantly monitors and

assesses market trends in order to identify suitable and relevant innovation for the company's business (Haffke et al., 2016). Further, digital innovators are responsible for digital innovation labs for experimentation and prototyping, and strengthen an innovative culture, attitude and mindset regarding transformation across the company (Haffke et al., 2016). The digital evangelist role, instead, focuses on promoting opportunities and threats of digital transformation and hiring new employees with relevant skills for digital transformation (Haffke et al., 2016). CDOs finding themselves in the digital evangelist role also aim to improve digital competencies of business executives and cultivate the entire company about digital topics (Haffke et al., 2016). Similar to the digital innovator, the digital evangelist also strengthens cultural change within the company (Haffke et al., 2016). Regarding the digitization coordinator, Haffke et al. (2016) reported that their focus lies on the coordination of company-wide digital transformation activities and initiatives, and assuring overall alignment with the digital strategy. In addition, the digitization coordinator manages digital transformation projects and drives them towards a joint digital vision across all functions while maintaining collaboration across the company (Haffke et al., 2016). Similar to the previous two roles, but with fewer intensity, the digitization coordinator aims to foster cultural change within the company (Haffke et al., 2016). A CDO in the role of digital advocates focuses their activities on communicating the digital spirit across business and IT functions, and strengthens the collaboration of both functions (Haffke et al., 2016). Further, such a CDO seeks to determine digital needs and chances in close alignment with business and IT functions while assuring conformity of IT and digital business strategies (Haffke et al., 2016). The role type, which each individual CDO is assuming, is argued to depend on two dimensions: orientation of the CIO role and perceived implications of digital transformation by the company (Haffke et al., 2016). The CIO's orientation can either strongly focus on the supply of IT resources or in addition, also on exploring of IT innovations (Haffke et al., 2016). Regarding the second dimension, Haffke et al. (2016) described that companies perceive implications from digital transformation either low or high. The combination of both characteristics of the two dimensions yields the four different CDO role types.

Instead of four different CDO role types as suggested by Haffke et al. (2016), Singh and Hess (2017) described three distinct CDO role types: entrepreneur, digital evangelist and coordinator. The entrepreneur CDO, who is driven by a strong entrepreneurial spirit, customer focused and responsible for defining and leading the company's digital transformation, examines digital innovations and installs a digital transformation strategy within the company (Singh & Hess, 2017). Further, they promote applying and strategically exploiting new digital technologies to help their company innovate while even changing the entire business model, if necessary (Singh & Hess, 2017). A CDO with the role of a digital evangelist is focused on inspiring and convincing all employees of the company across all hierarchical levels to jointly achieve the company's cultural change (Singh & Hess, 2017). Further, Singh and Hess (2017) characterized the digital evangelist by their ambition to communicate the digital strategy company-wide and even support employees by dedicated trainings. As successful digital transformation requires all company's stakeholder to actively participate, the coordinator CDO's main task lies within defining and coordinating a controlled transformation from detached silo functions to cross-functional collaboration (Singh & Hess, 2017). The coordinator role therefore requires the CDO to align executives of all functions and departments and extinguish silo mentalities and approaches (Singh & Hess, 2017). Singh and Hess (2017) highlighted that all three role types plaid an important role in the daily work of each CDO from their case studies, but nevertheless each CDO focused on one primary role in particular. Different to the two suggested dimensions as reported by Haffke et al. (2016), Singh and Hess (2017) argue that the primary CDO role type depends on several factors such as company size, the digital mindset of employees, the level of digital transformation maturity (similar to Zisler et al. (2016) and Weinreich (2017)), the reporting structure of the CDO as well as expectations on the CDO role from the CDO themselves and from the TMT. A categorization based on different characteristics of each aspects, for example, as provided by Haffke et al. (2016), was not reported by Singh and Hess (2017).

Tumbas et al. (2017) reported three different CDO role types, which are partially in line with the previous authors' role type definitions: digital accelerator, digital harmonizer and digital marketer. These three role types are tightly connected to the suggested

three activity domains as described by Tumbas et al. (2017) before. The digital accelerator CDO focuses their activities around the digital innovation domain and acts as compliment to the IT function (Tumbas et al., 2017). Their main tasks are to push digital innovation and experiment with several new digital technologies (Tumbas et al., 2017). Tumbas et al. (2017) also reported that the role of a digital accelerator involves to quickly deliver results based on fast developing technologies and continuous experimentation with these technologies. The digital harmonizer's key domain is customer engagement, which means that for delivering high-quality customer experience, their focus is to harmonize and coordinate ongoing digital initiatives across the company and raise awareness for the strategic relevance of these activities (Tumbas et al., 2017). Therefore, a CDO fulfilling the digital harmonizer role needs to establish a holistic overview on all running digital activities, streamline them towards one common objective and harmonize digital innovation with existing company values (Tumbas et al., 2017). The third suggested role, the digital marketer, acts as complement to the marketing function and focuses their tasks and responsibilities on steering the company's digital marketing activities towards higher customer proximity by exploiting digital technologies and the data analytics domain (Tumbas et al., 2017). They further align offline and online marketing activities and exploit digital technologies to improve products, services and subsequentially customer relationship (Tumbas et al., 2017). As mentioned by Tumbas et al. (2017), their three role types show similarities to the role types as suggested by Singh and Hess (2017).

It is worth mentioning that Haffke et al. (2016), Tumbas et al. (2017) and Singh and Hess (2017) based their definitions of CDO roles types on exploratory interview and multiple-case study methodologies. This implies that they derived their results on data, which was collected and analyzed by themselves. In contrast, Ulrich and Lehmann (2018) reported CDO role types based on literature review of existing results from scientific and practice-orientated literature regarding the CDO (and CIO) position. Ulrich and Lehmann derived six different role types: agility-oriented technologist, innovation driver, change agent, internal collaborator, external relationship driver and transformation coordinator. The agility-oriented technologist focuses on integration of agile technologies across the company's existing IT architectures and processes for

improving the company's performance (Ulrich & Lehmann, 2018). By exploiting new methods and innovative technologies, they aim for reorganization and reorientation of IT (Ulrich & Lehmann, 2018). A CDO, who holds the role as innovation driver, exploits innovative technologies similar to the agility-oriented technologist, but their object is to enhance the degree of innovation as well as the innovation capability of the company (Ulrich & Lehmann, 2018). By identifying new business ideas and business solutions, the innovation driver develops new digital products, services and business models (Ulrich & Lehmann, 2018). Ulrich and Lehmann (2018) described the change agent CDO by their focus on proactively driving and promoting the company's change. For this, the change agent CDO needs to change culture and mentality of the entire company across all hierarchy levels, motivate, inspire and educate employees and recruit additional qualified employees for digital transformation (Ulrich & Lehmann, 2018). The internal collaborator role's main attention lies on developing and improving cross-functional, internal collaboration by continuous alignment and exchange with all departments and functions of the company (Ulrich & Lehmann, 2018). The role of the external relationship driver is characterized by Ulrich and Lehmann (2018) by the objective to build and improve relationships with external partner companies, suppliers and customers in order to increase the long-term commitment to the company. Finally, the transformation coordinator tasks and responsibilities are to coordinate, monitor and steer all company-wide digital projects and initiatives and to align them towards one common strategic direction (Ulrich & Lehmann, 2018). By this, the transformation coordinator creates transparency regarding ongoing activities in order to comprehensively and efficiently drive digital transformation of the company (Ulrich & Lehmann, 2018).

As described by most authors, the CDO can carry out many of the described tasks and responsibilities, but typically focuses on one of the before describe CDO role types (Haffke et al., 2016; Singh & Hess, 2017; Tumbas et al., 2017). Several suggestions were provided on how to determine the required CDO role type, such as the perceived implications from digital transformation by the company, the CIO orientation, the level of digital transformation maturity of the company or company size (Haffke et al., 2016; Singh & Hess, 2017). Still, the different role types might blend for different companies

and the specific requirements on a CDO seem to be dependent on each company's situation, needs and environment (Haffke et al., 2016; Singh & Hess, 2017; Tumbas et al., 2017).

By comparing the results on different CDO role types, it becomes clear that there are several similarities between the authors' suggestions. A mapping of each role description across all presented documents based on activities and responsibilities suggests defining three distinct CDO role types: innovator, communicator and collaborator. As illustrated in Table 5, all the authors' role types can be allocated to the three roles types. Still, there might remain some overlap between the different definitions. A description of each role type is presented below.

CDO role type	Haffke et al. (2016)	Singh and Hess (2017)	Tumbas et al. (2017)	Ulrich and Lehmann (2018)
Innovator	▪ Digital innovator	▪ Entrepreneur	▪ Digital accelerator	▪ Agility-oriented technologist ▪ Innovation driver
Communicator	▪ Digital evangelist	▪ Digital evangelist	▪ Digital marketer	▪ Change agent ▪ External relationship driver
Collaborator	▪ Digitization coordinator ▪ Digital advocate	▪ Coordinator	▪ Digital harmonizer	▪ Internal collaborator ▪ Transformation coordinator

Table 5: Mapping of Different CDO Role Type Definitions
Source: Own illustration.

The innovator CDO (comparable with digital innovator (Haffke et al., 2016), entrepreneur (Singh & Hess, 2017), digital accelerator (Tumbas et al., 2017), agility-oriented technologist and innovation driver (Ulrich & Lehmann, 2018)) is responsible for identification of innovations for the company, spreading the innovative spirit and mindset, as well as experimentation and prototyping with innovative technologies for improving existing IT architectures and developing new products, services or business models. Their objective is to increase the degree of innovation and the innovation capability of the company with their entrepreneurial spirit and to exploit new agile methods and innovative technologies.

The communicator CDO (similar to digital evangelist (Haffke et al., 2016; Singh & Hess, 2017), digital marketer (Tumbas et al., 2017), change agent and external relationship driver (Ulrich & Lehmann, 2018)) focuses on promoting opportunities and threats of digital transformation, recruiting new employees with a digital skillset or educating and training employees and executives about digital culture, competencies and change. Further, they strengthen and inspire about cultural change within the company across all hierarchical levels, functions and departments as well as communicate the digital transformation strategy company wide. They aim to build and improve relationships with external partner companies, suppliers and customers by steering the company's offline and online digital marketing activities and improving existing products and services.

The collaborator CDO (analogous to digitization coordinator and digital advocate (Haffke et al., 2016), coordinator (Singh & Hess, 2017), digital harmonizer (Tumbas et al., 2017), internal collaborator and transformation coordinator (Ulrich & Lehmann, 2018)) aims to coordinate, align and lead all company-wide digital transformation activities, initiatives and projects in order to assure overall alignment with the digital transformation strategy and to streamline them towards one common digital vision. For this goal, they bring together, and advocate involved functions from business and IT side to proactively participate in digital transformation, improve cross-functional, internal collaboration for overcoming detached silos and harmonize digital innovation with existing company values.

Comparing the definition of each role type for innovator, communicator and collaborator to the overall description of CDO tasks and responsibilities from before shows that the role types do not cover all CDO activities. For example, the definition and implementation of the digital transformation strategy is not specifically a responsibility for one of the role types. Instead, not covered activities can be interpreted as tasks, which are most likely part of all CDOs' tasks and responsibilities.

Therefore, an analysis of all mentioned activities, tasks and responsibilities, which were described before either for general CDOs or specific CDO role types, was conducted in order to derive the most important and the most frequently conducted tasks and responsibilities. Overall, more than 150 different activities have been

mentioned across the investigated documents by all authors, which were mapped and categorized to almost 40 different activities. Figure 7 provides an overview of the 14 most frequently described activities of CDOs, which sum up to almost 75% of mentioned activities. The remaining activities, categorized as other activities at the bottom of Figure 7, account for ca. 25% of explained activities, which have been described before, and are not displayed for the sake of simplicity of the figure.[20]

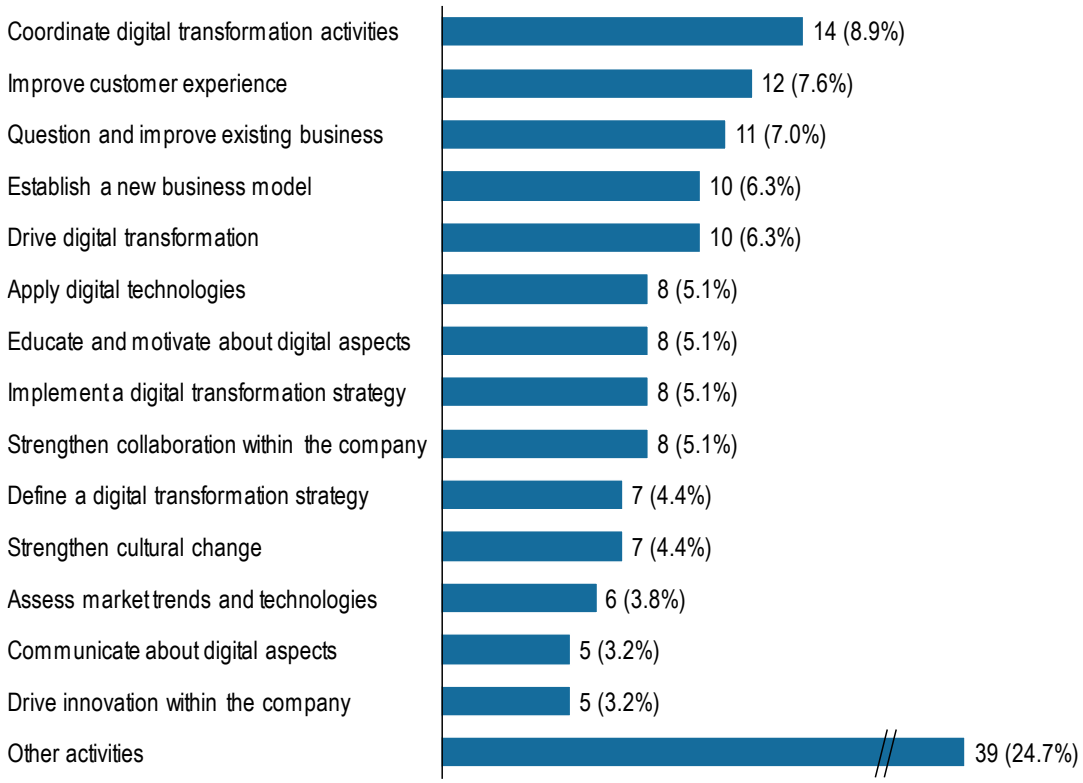

Figure 7: Most Frequently Mentioned CDO Tasks and Responsibilities
Source: Own illustration.

From the analysis, it becomes clear that authors emphasized most about the importance of the CDO's responsibility for coordinating digital transformation activities. This responsibility ranges from coordinating, bundling and aligning all ongoing digital activities under their authority (W. Becker & Schmid, 2019; Haffke et al., 2016; Locoro & Ravarini, 2017; Singh & Hess, 2017; Tahvanainen & Luoma, 2018; Ulrich & Lehmann, 2018; Zisler et al., 2016), creating transparency about ongoing digital

[20] For a full list of derived tasks and responsibilities, see Table A1 in appendix A.

activities (Tumbas et al., 2017) and streamlining them towards one common strategic direction (Haffke et al., 2016; Tumbas et al., 2017; Ulrich & Lehmann, 2018) to leading and encouraging new digital initiatives (Singh & Hess, 2017) and linking and harmonizing them with ongoing IT projects and company values (Tumbas et al., 2017, 2018).

The second most mentioned responsibility centers around the customer of the company. Not only do authors mention a general need for customer focusing (Singh & Hess, 2017; Tumbas et al., 2017, 2018), but also to develop customer experience and customer journey (Tahvanainen & Luoma, 2018; Walchshofer & Riedl, 2017) based on an assessment of the company's customer-centeredness (Tumbas et al., 2017), improved customer relationship management and support (W. Becker & Schmid, 2019; Tumbas et al., 2017; Ulrich & Lehmann, 2018) and higher customer proximity (Tumbas et al., 2017) for creating immediate customer impact (Tumbas et al., 2018) and long-term commitment to the company (Ulrich & Lehmann, 2018).

As displayed in Figure 7, further important activities include the questioning and improving of the existing business, for example, by aligning, transforming and improving existing processes and structures (Bülchmann, 2017; Walchshofer & Riedl, 2017; Weinreich, 2017; Zisler et al., 2016), and the establishment of new business models, for example, by developing new digital products and services (W. Becker & Schmid, 2019; Mertens et al., 2017; Ulrich & Lehmann, 2018).

Overall, the list of described activities, tasks and responsibilities of the CDO as presented before is very extensive and mostly free of contradicting or implausible results. Despite slightly different definitions of various CDO role types, most authors seem to derive similar results on CDO tasks and responsibilities.

One major activity for which the authors seem to have dissenting opinions concerns the digital transformation strategy. Some authors share the opinion that it is the CDO's responsibility to only implement, but not necessarily define the digital transformation strategy (W. Becker & Schmid, 2019; Tahvanainen & Luoma, 2018). Other authors argue for both definition and implementation of the digital transformation strategy to be part of the CDO's responsibilities (Haffke et al., 2016; Mertens et al., 2017; Singh et

al., 2019; Walchshofer & Riedl, 2017). As more authors argue for both activities to be part of the CDO position, it appears to make sense to have the same person in charge for defining and implementing the digital transformation strategy. While in general it does not necessarily need to be the CDO, who defines and implements the digital transformation strategy, for example, in firms without a CDO, also the CEO or CIO could be responsible for both activities, Matt et al. (2015) highlighted the importance of assigning both activities to the same person. Hess et al. (2016) explained that the success of a digital transformation strategy is dependent on the support of the CEO, who oftentimes is fully responsible on the one side and delegates the execution of the digital transformation strategy to a senior executive on the other side. As with the different CDO role types, the scope of tasks and responsibilities regarding the digital transformation strategy presumably also depends on the specific situation of the company.

Another ambiguity seems to lie within the interpretation of driving digital transformation. Several authors described this specific responsibility for the CDO position, but a clear definition of driving digital transformation was not presented (Catarino et al., 2018; Haffke et al., 2016; Singh & Hess, 2017; Ulrich & Lehmann, 2018; Walchshofer & Riedl, 2017; Zisler et al., 2016). While some authors further mentioned that driving the digital transformation includes leading, promoting and assuming responsibility for it (W. Becker & Schmid, 2019; Mertens et al., 2017; Singh & Hess, 2017; Ulrich & Lehmann, 2018), a clear definition was still not provided. Nevertheless, one could argue that the overall list of tasks and responsibilities reflects the activity of driving digital transformation and a distinct definition might not be required after all.

As many of the described tasks and responsibilities require a certain set of skills, competencies, experience and education, a corresponding description of those can be found hereinafter.

Skills, competencies, experience and education

Out of 18 documents, which contain descriptions regarding the CDO position, authors of nine documents specifically discussed relevant skills, experience and education.

Zisler et al. (2016) reported that for connecting the conventional world with the digital world, the CDO needs to be experienced in the field of marketing and information technology in order to be able to consider technological and customer related aspects. In addition, interpersonal and strategic skills are relevant for the CDO position for changing the organization and its processes on the one hand, but also for convincing employees of the digital transformation's relevance on the other hand (Zisler et al., 2016). For optimizing processes, improving customer experience and establishing of new business models, the CDO also requires skills for understanding customer needs and technology competencies (Zisler et al., 2016).

According to Bülchmann (2017), the CDO needs not only technical competencies for developing new digital business models, but also charisma and leadership skills for aligning interests of several stakeholders during that process. Further, the author argued that the CDO should have experienced situations of crises by which they were able to gather experience in resilience and mental flexibility. The CDO position also demands profound knowledge in the field of marketing, e-commerce, social media as well as mobile and digital technologies and big data, and in addition, knowledge regarding traditional value chains in production and service provider industries (Bülchmann, 2017). Varied experience from technology or IT companies, strategy consulting and other relevant operative environments were also reported as relevant for the CDO position (Bülchmann, 2017).

Based on the results from Locoro and Ravarini (2017), the CDO should possess skills in managing conflicts and tensions within the company. In line with Zisler et al. (2016), Locoro and Ravarini also reported that the CDO requires interpersonal skills. Further, technological leadership skills and the capability to overcome automation tasks were mentioned as relevant for the CDO position (Locoro & Ravarini, 2017).

According to Singh and Hess (2017), five key skills and competencies are relevant for the CDO position. In order to develop new products and services, the CDO needs to have profound IT competencies regarding IT applications, IT infrastructure and possibilities to upgrade or modify both (Singh & Hess, 2017). As the CDO position involves transforming existing business, knowledge about the principles of different departments and functions of the company and, in this context, comprehensive

strategic, transformation and change management competencies are required (Singh & Hess, 2017). Further, the CDO needs to possess inspirational skills as they motivate and consult employees and the top management team of the company about digital transformation (Singh & Hess, 2017). Additionally, Singh and Hess (2017) reported that digital pioneering skills and competencies for high level visionary thinking support the CDO to develop the company's digital future. They also stated that transformation of traditional companies oftentimes faces setbacks, which is the reason for the CDO for being able to perform under pressure and possessing resilience skills. As described before, Singh and Hess provided three different CDO role types for which they allocated the most relevant key competencies per role. Still, they argued that all competencies are important for all CDO types.

In line with their suggested three domains of activities and CDO role types, Tumbas et al. (2017) described relevant skills and competencies for each. For the digital innovation domain, they reported that capabilities in agile approaches are relevant for the CDO in order to develop innovation based on iteration and experimentation. Regarding the data analytics domain, Tumbas et al. described that the CDO should possess data analysis skills such that they can exploit internal and external data. As basis for activities in the customer engagement domain, the CDO needs to be able to interpret and understand customer experience and its connection to digital technologies (Tumbas et al., 2017).

Walchshofer and Riedl (2017) reported that the CDO should have graduated with a technical or economic university degree or instead have gained similar knowledge based on several years of professional experience. In addition, the CDO needs to possess basic technical understanding for information and communication technologies, based on their university degree or professional experience (Walchshofer & Riedl, 2017). Walchshofer and Riedl (2017) described required skills in business oriented thinking including knowledge in the fields of sales, marketing, HR and business process management. The CDO requires digital know-how and knowledge about current technological trends, depending on the industry (Walchshofer & Riedl, 2017). Experience in implementing digital transformation strategies and change management as well as empathy, negotiation and mediation skills,

assertiveness and a high frustration tolerance are further mentioned for the CDO position (Walchshofer & Riedl, 2017). The CDO also requires skills to overcome functional silos by being mentally flexible, open minded, agile and innovative (Walchshofer & Riedl, 2017). Moreover, Walchshofer and Riedl (2017) highlighted communication skills, leadership experience and motivational skills for performing the CDO position.

Weinreich (2017) reported that for strategic development of new and existing business models, the CDO requires skills in strategic thinking. As this process involves incorporation of innovative technologies for creating new products and services, the CDO should bring along technical competencies, knowledge in product development and process management as well as understanding for the field of marketing and data analytics (Weinreich, 2017). For convincing top management team members of digital transformation and new business models, Weinreich (2017) described that the CDO needs strong communication skills and knowledge in change management. He also stated that as the face for the company's digital transformation, the CDO would benefit from being charming.

Based on their interviews, Catarino et al. (2018) derived several characteristics and skills for describing the CDO position. The CDO should be business-oriented, visionary and problem solving (Catarino et al., 2018). Further, the CDO requires leadership skills, strategic thinking skills and relationship building competencies (Catarino et al., 2018). Catarino et al. (2018) further stated that the CDO should be willing to take risks, capable to assess rewards and possess knowledge about lean and design thinking.

Tahvanainen and Luoma (2018) categorized CDO competencies based on personal competencies, professional competencies, business competencies and technical competencies. Regarding personal competencies, they reported that the CDO should have skills in visionary thinking, inspirational skills and perseverance as well as a positive mindset, flexibility, reliability and a passion for learning. In the field of professional competencies, the CDO requires leadership skills, strategic thinking skills, interpersonal skills, communication skills and problem solving skills (Tahvanainen & Luoma, 2018). In addition, change management skills, team player skills, self-organizational skills, analytical skills, facilitation skills and understanding the customer

are further important professional competencies (Tahvanainen & Luoma, 2018). Concerning business competencies, the CDIO should have knowledge about business processes and concepts and their execution, the company's business model and business domain (Tahvanainen & Luoma, 2018). From a technical competency perspective, Tahvanainen and Luoma (2018) described the importance of project management skills and specialized technical knowledge, as well as general know-how about technologies and their impact, about development methods and architectures.

Overall, all authors mentioned more than 100 (not unique) skills, competencies, experiences and education characteristics, which are relevant for the CDO position. All authors of the nine relevant documents reported about skills and competencies, whereas only few described required experiences (Bülchmann, 2017; Walchshofer & Riedl, 2017; Zisler et al., 2016) and only Walchshofer and Riedl (2017) highlighted educational requirements.

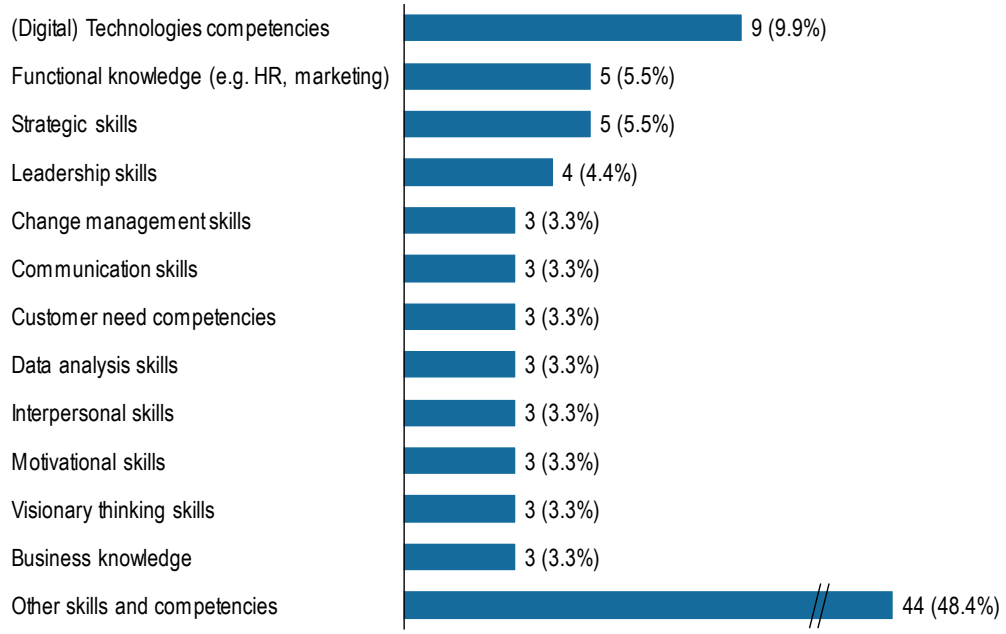

Figure 8: Most Frequently Mentioned CDO Skills and Competencies
Source: Own illustration.

As many authors listed similar results on skills and competencies, an overview of the twelve most mentioned skills and competencies, which sum up to almost 50% of all mentioned skills and competencies, can be found in Figure 8. Further skills and competencies, as described before, were summarized as other skills and

competencies at the bottom of Figure 8 in order to keep the figure simple enough, yet showing the most frequently mentioned skills and competencies.[21]

In the description of all relevant activities of the CDO position, it became clear that many activities include digital technologies. This is also reflected in the required skills in competencies as many authors highlighted that for corresponding activities including digital technologies, the CDO needs not only general digital and technology competencies (Bülchmann, 2017; Tahvanainen & Luoma, 2018; Walchshofer & Riedl, 2017; Zisler et al., 2016), they also require competencies in digital pioneering (Singh & Hess, 2017), knowledge about current digital trends (Walchshofer & Riedl, 2017) and technical competencies for developing new digital business models (Bülchmann, 2017; Tahvanainen & Luoma, 2018; Weinreich, 2017).

As the CDO was also described to strengthen collaboration between stakeholders, several authors mentioned the need for functional knowledge. Bülchmann (2017), Walchshofer and Riedl (2017), and Weinreich (2017) mentioned that the CDO requires knowledge in the field of marketing and e-commerce. Walchshofer and Riedl (2017) also reported knowledge in the field of HR as relevant, whereas Singh and Hess (2017) considered knowledge about the principles of the company's departments and functions as important competencies for the CDO position.

Further important competencies for the CDO position include strategic skills (Catarino et al., 2018; Singh & Hess, 2017; Tahvanainen & Luoma, 2018; Weinreich, 2017; Zisler et al., 2016), leadership skills (Bülchmann, 2017; Catarino et al., 2018; Locoro & Ravarini, 2017; Tahvanainen & Luoma, 2018) and change management skills (Singh & Hess, 2017; Tahvanainen & Luoma, 2018; Weinreich, 2017).

For full effectiveness of the CDO position and its main objective to digitally transform the company, the right integration of the position into the organization is necessary. This does not only include the best integration, for example, into or between departments, but also the ideal reporting structure for the position, such as reporting to the CEO. Based on the organizational integration, there also follow implications for

[21] For a full list of derived skills and competencies, see Table A2 in appendix A.

the collaboration with other executives, such as with CIO or CFO. In the following, these aspects will be further discussed.

Collaboration with other executives and organizational integration

Overall, authors of 11 documents commented on the organizational integration of the CDO in the company or the collaboration with other executives like the CIO.

Haffke et al. (2016) highlighted that the CDO is defined as business role and therefore, not as IT role. Rather, the authors argued that the CDO becomes an ambassador for the IT function and digital subject areas on the business side, which is strengthening IT within the company, especially for companies, which have a CIO, who is not directly reporting to the CEO. Therefore, CDO as business side representative and CIO as head of the IT function need to work closely together on understanding each other's requirements, developing an IT landscape, which is capable of handling the digital transformation, establishing a governance framework for digital activities and initiatives, and handling conflicts resulting from traditional or daily requests on IT from different stakeholders and from the CDO's requests on IT (Haffke et al., 2016). Based on their interviews, Haffke et al. (2016) also described that the CDO typically reports to the CEO, and underlined that in the case of placing the CDO with direct reporting to the CIO, the CDO is not mandated to function as collaborator and ambassador between business and IT.

Similarly, Zisler et al. (2016) reported that the CDO should not be placed below CIO or CMO, because based on this organizational implementation the CDO would not be accepted enough from all executives as well as would not have enough authority to implement digital initiatives. Further, the CDO would not be able to consider both technical and customer related perspectives as they would be bound to one field only (Zisler et al., 2016). Instead, the CDO should be placed on top management level independently of both IT function and marketing function (Zisler et al., 2016).

As stressed by Bülchmann (2017), closeness between CDO and CEO is important for the CDO's ability to influence the company's policy. CDO and CEO should be jointly responsible for developing and implementing the digital transformation strategy (Bülchmann, 2017).

Singh and Hess (2017) stated that digital transformation, and consequently the CDO, requires commitment from the top management team. Therefore, the CDO should be directly reporting to the CEO and participate in top management team meetings (Singh & Hess, 2017). Otherwise, the CDO is not equipped with sufficient authority for implementing company-wide digital initiatives (Singh & Hess, 2017). Singh and Hess (2017) also argued that the CDO strengthens the CIO reputation and authority, which is why the CIO and CDO should aim to extensively cooperate and work closely together. They also mentioned that compared to heads of individual digital business units, the CDO assumes a wider role by being responsible for the company's overall digital transformation.

According to Tumbas et al. (2017), the CIO oftentimes is caught up with traditional IT function related activities focused on enterprise systems and IT infrastructure. Therefore, they argued that the CIO's workload does not allow them to experiment with digital innovations, which is more and more required from the business side and subsequentially causes tensions between business and IT functions (Henderson & Venkatraman, 1993). The CDO, as additional layer between business and IT functions, serves as buffer and helps reducing tensions and conflicts and can be interpreted similarly to the argumentation of Haffke et al. (2016) as compliment to the IT function (Tumbas et al., 2018).

In line with previous arguments, Walchshofer and Riedl (2017) stated that the CDO should be hierarchically assigned to the CEO due to the strategic importance of digital transformation and the ability to address the topic on top management team level. They further argued that as the CDO needs to collaborate with other functions as well as establish collaboration, they have to closely align with top management team, CIO and all functions across the company.

In line with the argument of Tumbas et al. (2017), Tahvanainen & Luoma (2018) derived that the CDO is allocated between business and IT functions. As business owner for digital transformation projects, the CDO should be positioned on top management team level (Tahvanainen & Luoma, 2018).

In accordance with the previous authors, Tumbas et al. (2018) again highlighted the placement of the CDO position between IT and marketing. Further, they reported three different approaches for the CDO to interact with existing functions and professions within the company: grafting, bridging and decoupling. By grafting, the CDO aims to tightly align new digital projects and their capabilities closely to existing organizational functions and their mode of operations (Tumbas et al., 2018). The bridging approach relies on connecting existing functional units in order to establish a new digital initiative (Tumbas et al., 2018). The third approach, decoupling, is based on insulation and separation of new digital initiatives from existing functions for fast attainment of new digital initiatives (Tumbas et al., 2018).

Ulrich and Lehmann (2018) reported implications for the CFO from the CDO's activities and objectives. They argued that there might arise conflicts regarding a potential low focus on costs regarding digital initiatives. Therefore, they highlighted the importance of communicating cost expectations from both CDO and CFO. Similarly, as soon as new digital business models are established, expectations on rentability have to be clarified as well (Tumbas et al., 2018). For monitoring and steering of digital initiatives and the associated cost or rentability, CFO and CDO should establish a controlling framework for the economic efficiency of these projects (Tumbas et al., 2018). Further, due to new digital technologies also in the finance function, CDO and CFO need to clarify responsibilities regarding hiring qualified employees as well as training and motivating of existing employees in the finance function (Tumbas et al., 2018).

Based on the results of W. Becker and Schmid (2019), the CDO should be placed either on top management team level or at least one level below with direct reporting to the executive board of the company. They also mentioned that in several cases the CDO seeks collaboration with external consultants for implementing the digital transformation of the company.

Singh et al. (2019) reported that for connecting employees of different hierarchical levels and functions across the company, who independently work on implementing digital initiatives, the CDO can exploit several formal and informal coordination mechanisms. While formal coordination mechanisms facilitate communication with digital transformation stakeholders and information of decision-making bodies,

informal coordination mechanisms are relevant for idea generating and brainstorming activities as well as sharing information on strategic topics regarding digital transformation with employees (Singh et al., 2019). Formal coordination mechanisms include, for example, meetings, steering committees or councils on top management team level as well as cross CxO meetings (Singh et al., 2019).[22] Informal coordination mechanisms, on the other hand, cover, for example, regular cross-functional exchanges, start-up pitches for idea generation as well as informal information exchanges with employees via the intranet or newsletters as well as trainings and seminars (Singh et al., 2019). Singh et. al (2019) further mentioned that these informal mechanisms differ across the phase of digital transformation: innovation, during implementation and after implementation.

Across all authors, there appears to be consensus regarding the ideal organizational position of the CDO on top management team level, ideally with direct reporting to the CEO in order to strengthen the authority of the CDO and to ensure full support by the CEO (W. Becker & Schmid, 2019; Bülchmann, 2017; Haffke et al., 2016; Singh & Hess, 2017; Walchshofer & Riedl, 2017; Zisler et al., 2016). This result is also in line with previous research regarding the importance of the position within the organizational structure and the corresponding stronger organizational influence due to a higher formal status (Brass, 1984; Finkelstein, 1992; Hambrick, 1981; Tushman & Romanelli, 1983). In addition, the authors also agreed on the functional position of the CDO independently of and between business functions like marketing and IT functions, but overall still as a business function (Haffke et al., 2016; Tahvanainen & Luoma, 2018; Tumbas et al., 2017, 2018; Zisler et al., 2016). As highlighted by Tumbas et al. (2018), it is important for the CDO to carve out space for themselves and their units. Further, many authors emphasized the relevance of close collaboration between the CDO and all other functions, especially with the CEO and CIO, and even with external consultants (W. Becker & Schmid, 2019; Bülchmann, 2017; Haffke et al., 2016; Singh & Hess, 2017; Singh et al., 2019; Tumbas et al., 2017, 2018; Ulrich & Lehmann, 2018; Walchshofer & Riedl, 2017).

[22] CxO refers to any C-level position, such as CDO, CIO, CEO, CFO, etc.

Further results

Out of 18 documents within the category CDO position, authors of five documents mentioned different reasons and aspects for a company's need for a dedicated CDO and situations when a CDO might not be required.

Haffke et al. (2016) reported that the company's need for a CDO mainly depends on four different factors. As the CDO's key objective is to digitally transform the company, the actual pressure and need for digital transformation itself becomes one factor for establishing the CDO position (Haffke et al., 2016). The pressure to digitally transform is oftentimes driven by external conditions, such as customers' needs and behaviors, competitors' succession with digital technologies and disruption by new market players with digital business models (Haffke et al., 2016). Other companies might also simply want to become the digital market leader within their segment or industry (Haffke et al., 2016). As second factor Haffke et al. (2016) described that depending on company specific characteristics some companies require a dedicated person for orchestrating the digital transformation while other companies are able to face these challenges without an additional executive, for example, by installing a digital steering committee including selected existing executives. They stated company specifics such as company size, previous company experience with digital initiatives and the company's culture. Further, they argued that depending on the CIO role profile and reputation, there might not be the necessity for an additional CDO. A CIO, who is customer centered, strategically involved, well perceived by business executives and actively exploring digital innovation, might be acting as CDO themselves (Haffke et al., 2016). The fourth factor influencing the need for a CDO is described to be the focus area, which is most affected by the digital transformation (Haffke et al., 2016). Companies, for which the focus area is externally around sales, marketing or customer services, the need for a CDO tends to be higher in contrast to companies, for which the implications of digital transformation are focused on internal areas such as logistics or operations (Haffke et al., 2016).

Similarly, Locoro and Ravarini (2017) reported that especially in companies, which are already digital as they were born digital, there might not need to be a reason for

establishing a dedicated CDO position. Instead, in these companies, they argued that a CIO themselves can perform the CDO's activities as well.

Alike Haffke et al. (2016), Singh and Hess (2017) defined two drivers, which determine the need for a CDO. They argued that companies with low external market pressure to digitally transform as well as low internal complexity for coordinating digital transformation activities, a CDO is not necessarily required. In very complex companies, which experience high pressure from the market to initiate digital transformation, they recommend establishing a dedicated CDO.

Tumbas et al. (2017) stated that several reasons could lead to establishing a separate CDO position within the company. They reported that these reasons include a high workload of the IT function due to comprehensive IT infrastructure projects or a weak political position of the IT function, and therefore no free capacities of the CIO. Another reason could be a lack of innovative methods within the marketing function and no relationship of trust between the IT and marketing function (Tumbas et al., 2017). Tumbas et al. (2017) further mentioned that due to the existence of several isolated or local digital activities without a common strategic orientation, a CDO might be required to bundle these efforts towards one joint vision. On the other hand, they reported that for companies with a CIO, who has capacity for both maintaining traditional IT related projects and driving fast-pace digital initiatives, also known as ambidexterity in IT (Gregory et al., 2015), a dedicated CDO might not be required. Tumbas et al. also highlighted the importance of the CIO's previous years achievements in establishing integrated processes, data transparency and information management systems, which act as basis for all digital initiatives, independently of the person in charge for digital transformation, CDO or CIO respectively.

Similarly, Weinreich (2017) reported that due to their technological IT competencies, the CIO in general might be a valid option for handling digital transformation within the company. They stressed that in that case the CIO can only succeed if either the digital initiatives stay limited to mostly technological challenges and are based on clearly defined projects, or the CIO is able to be detached from traditional IT related activities in order to fully focus on the digital transformation only.

An overview of described factors, which determine the need for a CDO, can be found in Figure 9 below. While only one factor depends on external aspects, namely the pressure to digitally transform from the market and competitors, all other factors depend on the specific situation of each company.

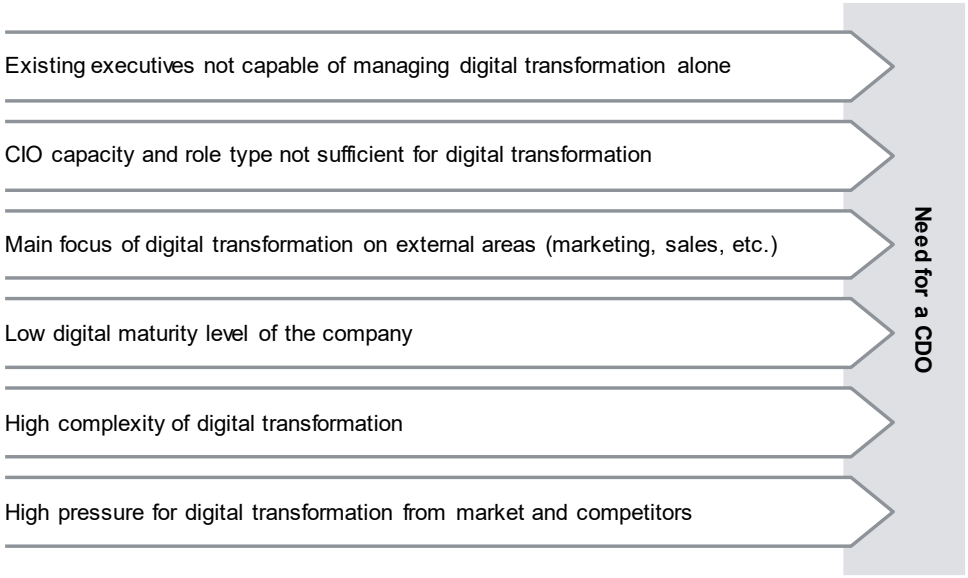

Figure 9: Factors for Determining the Need for a CDO
Source: Own illustration.

Several authors also highlighted the possibility that the CDO position might only be of temporary nature (Bülchmann, 2017; Tumbas et al., 2017; Walchshofer & Riedl, 2017; Zisler et al., 2016). Zisler et al. (2016) argued based on their described digital maturity levels of the company, especially in the last phase, namely the maturity phase, that the CDO ideally enabled the entire company and all employees with digital competencies and the company is fully digitally transformed, implying that the CDO themselves might not be required anymore. In line with this argumentation, Bülchmann (2017) added that after successfully transforming the company, the CDO might gain responsibility for newly developed branches of business or achieve a leading position within business development of a company. Tumbas et al. (2017) and Walchshofer and Riedl (2017) further mentioned the possibility that CDO position and CIO position (re-) merge and

not both roles are required anymore as the requirements on both positions might not be distinguishable from each other after digitally transforming the company.[23]

Concluding comments

Two documents, which have been allocated to the CDO position category, were literature reviews and did not provide any additional relevant information or results, except for also including information from practitioners' reports such as consultancy firms, compared to the other authors' efforts as described before, who derived results from interviews, case studies or other types of analysis (Giebe, 2019; Kutnjak et al., 2019). Therefore, these two documents have not been further discussed, but still mentioned for completeness regarding existing CDO literature.

A comparison of collected and processed data of all before mentioned documents, if provided by the authors, shows that several authors based their analysis of information from CDOs or similar positions only (W. Becker & Schmid, 2019; Tahvanainen & Luoma, 2018; Tumbas et al., 2017, 2018; Walchshofer & Riedl, 2017). One could argue that based on the one-sided view on CDOs' perspectives on, for example, tasks and responsibilities or skills, education and experiences, the results might not reflect the full picture, meaning the perspective of an entire company on the position is not reflected. But since other authors also examined the perspective of IT executives, such as the CIO, and other executives, such as HR mangers or the CEO, perspectives from other areas of the company have been provided as well (Arora et al., 2020; Catarino et al., 2018; Haffke et al., 2016; Locoro & Ravarini, 2017; Singh et al., 2019; Ulrich & Lehmann, 2018; Zisler et al., 2016). Results, which incorporated a broader perspective, could be argued to be interpretable with more general validity. Nevertheless, by jointly considering and interpreting all documents, there were mostly no contradicting results identified, except reported otherwise. Therefore, the provided overview on the current results regarding the CDO position can to a certain extent be regarded as generally valid. Further, as several authors exploited different type of methodologies, such as multiple-case study designs, the generalizability of results was

[23] See section 2.5 for a discussion on the development of the CIO role.

improved as for example highlighted by Singh et al. (2019). A similar argumentation holds for the amount of interview partners or investigated companies. While some authors aimed to derive detailed insights based on few cases or interviews (Singh et al., 2019; Tahvanainen & Luoma, 2018; Zisler et al., 2016), other authors aimed to provide results based on a on a higher amount of analyzed interviews or cases (W. Becker & Schmid, 2019; Haffke et al., 2016; Tumbas et al., 2017, 2018; Ulrich & Lehmann, 2018). Authors of four documents unfortunately did not provide insights regarding the investigated research population or data set, and therefore, the general validity cannot be assessed for these (Bülchmann, 2017; Lemke et al., 2018; Mertens et al., 2017; Weinreich, 2017). Regarding geographical focus, no focus was identified among all investigated documents, since some authors either focused on Germany (and Austria and Switzerland) (Bülchmann, 2017; Giebe, 2019; Walchshofer & Riedl, 2017), the European Nordics (Tahvanainen & Luoma, 2018), Europe and America (Haffke et al., 2016; Tumbas et al., 2017) or a mix of several countries like Italy, Portugal and Netherlands (Catarino et al., 2018; Locoro & Ravarini, 2017). Several other authors did not specifically mention the geographic focus of the companies, but based on the size of the companies, it can be assumed that these were mostly active on international level. Similarly, no specific industry focus was prioritized by the authors, as most authors aimed to achieve broader results by considering companies from various industries (W. Becker & Schmid, 2019; Catarino et al., 2018; Haffke et al., 2016; Locoro & Ravarini, 2017; Singh & Hess, 2017; Singh et al., 2019; Tahvanainen & Luoma, 2018; Tumbas et al., 2017, 2018; Walchshofer & Riedl, 2017; Weinreich, 2017; Zisler et al., 2016). Other authors did not further specify the underlying industries of their data (Bülchmann, 2017; Giebe, 2019; Kutnjak et al., 2019; Lemke et al., 2018; Mertens et al., 2017; Ulrich & Lehmann, 2018).

Two documents, which have not been consider in the review due to their work-in-progress or research-in-progress status, promised additional relevant insights regarding the CDO position (Engesmo & Panteli, 2019; Horlacher, 2016). Horlacher (2016) reported initial results regarding her analysis of the dyadic CDO and CIO relationship including factors, which strengthen their relationship. These factors include a clear definition of both roles and their responsibilities, the importance of a mutual

understanding for each other's position and an open communication between both (Horlacher, 2016). Engesmo and Panteli (2019) focused on their research question about the CDO's approach for enabling digital transformation in traditional pre-digital organizations and their impact on IT departments and IT leadership. Based on their initial results, they reported that the CDO should collaborate with other executive such as IT and marketing executives. For both documents (Engesmo & Panteli, 2019; Horlacher, 2016), additional results were not available, but should be considered in future reviews, in case final versions will be published.

2.4.3 Insights for the Chief Digital Officer Position from Other Executive Positions Leading Digital Transformation

Literature, which describes insights for the CDO position from other executive positions regarding the digital transformation of companies is summarized in Table 6. Similar to before, the overview includes a summary of investigated research questions, exploited theoretical frameworks, applied methodological approaches, analyzed data sets, derived relevant results and potential topics for future research, in case the information was provided or at least partially provided by the authors.

Literature	Summary
Hesse (2015)	The author described the impact of digital transformation on the CFO role, corresponding role requirements as well as on Finance and Controlling functions in general at the example of the retail industry. He explained responsibilities and tasks of the CFO in context of digital transformation as well as the relevance of collaboration with the IT function.
Matt et al. (2015)	The authors provided an overview of the relation of IT strategy or business strategy and digital transformation strategy. By combining literature analysis, multiple-case studies and interviews, they derived four key dimensions of digital transformation strategies: use of technologies, change in value creation, structural changes and financial aspects. In addition, they provided procedural aspects of digital transformation strategies and highlighted important aspects regarding the digital transformation.
Gerth and Peppard (2016)	The authors presented causes for CIO derailment due to digital transformation and corresponding implications, which can be generalized for the responsible executive regarding digital transformation. They based their research on a combination of results from their previously published studies and the therein used data from a period of eight years of research. This covers interviews of 130 CIOs, CDOs or other non-IT executives as well as a survey with 675 CIOs from several industries and regions. They derived that like CIOs, even CDOs can struggle to be effective in driving digital transformation if dynamics of derailment are not considered and presented identified causes. They concluded by proposing solutions for both CIOs and CEOs to overcome derailment.
Capitani (2018)	The author aimed to analyze the current and future role of the CIO as well as the role the CIO plays in digital transformation. He based his analysis on survey results from 2016, which covered questions on digital transformation and its impact on information communication technology and CIO activities. The survey was conducted with 100 CIOs from Italian major companies across several industries. He derived ten lessons learned regarding digital transformation. He concluded that CIOs, and not CDOs, should be assuming the leadership role in digital transformation due to possible overlaps of both functions and resulting potential conflicts.
Hoberg et al. (2018)	The authors analyzed challenges, issues and required skills regarding digital transformation and reasons for digital transformation based on an online survey with 116 CIOs, other C-level executives or other below C-level from international SAP clients from several industries. The survey was conducted between March 2017 and April 2017. They argued that digital transformation is often driven by the its threat for existing business models and highlighted the importance of the IT function and the collaboration of IT and business functions as strategic partners. They derived obstacles for digital and elaborated on required skills.

Table 6: Existing Literature Describing Insights for the CDO Position from Other Executive Positions Leading Digital Transformation
Source: Own illustration.

Literature	Summary
Pabst von Ohain (2019)	The author aimed to derive a set of attributes of the ideal digital leader for driving digital transformation. He based his investigation on an explorative approach by conducting a survey as well as a three-stage process and semantic coding scheme methodology and data structures for extraction of theoretical dimensions. For investigation he targeted both start-ups and established companies resulting in 120 and 26 employees, leaders and founders from established companies and startups respectively, who participated in the survey. They derived four key attributes of the ideal Digital Leader of which each represents several sub-dimensions. Further, he described a guideline for identifying digital leaders and how to exploit digital leader attributes.
Indihar Štemberger et al. (2019)	They authors exploited the framework of service-dominant logic as well as a five-level digital maturity level model in order to derive combinations and interplay of key actors in digital transformation, their roles and responsibilities and aspects leading to high digital maturity. Therefore, they conducted a survey in summer of 2017 with CIOs, business executives or business managers from 181 Slovenian large and medium size companies. They derived six patterns of digital transformation regarding key actors, their roles, the strategy and their interplay. Further, they described evolutionary paths to transition to a group with higher digital maturity and explained corresponding barriers. They suggested future research regarding the root reason for the increasing focus of IT on the technical role instead of the business role as well as regarding the identification of different dimension of digital transformation and its actors considering contingency theory.

Table 6 (continued): Existing Literature Describing Insights for the CDO Position from Other Executive Positions Leading Digital Transformation
Source: Own illustration.

Documents, which have been allocated to the category *insights for the CDO position from other executive positions leading digital transformation*, contain information regarding implications from digital transformation on executives, which are not the CDO and are responsible for driving digital transformation, and implications for the company itself, such as collaboration models between stakeholders. Further, documents have been allocated to this category, if they did not provide information regarding the CDO only, but rather relevant general information for the dedicated executive in this context. Literature was searched for and allocated to the category in order to consider results and opinions from authors, who assume another executive should be responsible for the digital transformation, but nevertheless these results also remain valid and provide useful insights for the CDO position itself.

Hesse (2015) reported implications from digital transformation for the CFO position, while assuming the CFO is the main responsible person for driving the digital transformation. He described that due to diverse challenges from digital transformation, the CFO requires strong communication skills, strategic skills and

social competence in order to convince the management board of the necessary transformation. Further, the CFO requires profound knowledge about IT and should be interested in trends regarding digital technologies for developing new digital business models (Hesse, 2015). In addition, knowledge in marketing and supply chain management supports the CFO navigating digital transformation (Hesse, 2015). Hesse (2015) argued that since the CFO aims to generate value creation potential from new business models and from digitally transforming existing business models, close alignment with other top management team members is required, especially with the CIO. He also mentioned the importance of changing customer focus, exploiting big data and today's data availability. All described CFO's competencies and activities, as driver of digital transformation and argued by Hesse (2015), are very similar to the results from scholars, who specifically researched the CDO position, as described in the previous section. Since the digital transformation of a company in general requires similar procedures, the corresponding tasks and responsibilities as well as skills and competencies seem to be independent of the executive person, who is in charge of digital transformation. Hesse (2015) also highlighted that it is important for the CFO to carve out space from their traditional functional activities, for example, by delegating tasks to other employees, and therefore to be able to give sufficient attention to the digital transformation. This is in line with results regarding the need for a CDO, specifically when the CIO is not able to focus enough on digital initiatives and instead is caught up with traditional IT-related activities (Weinreich, 2017).

Based on their research, Matt et al. (2015) concluded that independently of the person in charge for digital transformation, such as CIO, CEO or CDO, and in line with previous scholars' results, this person requires certain skills and experience, and is occupied by several tasks and activities. It is important for the dedicated person to be experienced in conducting transformational projects and to be skilled in transformational leadership for overcoming potential resistance against digital transformation from within the company as well as for bringing together relevant stakeholders, which are affected by digital transformation (Matt et al., 2015). Further, it is important to continuously assess the underlying digital transformation strategy and its assumptions for potential adjustment requirements by involving both internal and external experts, if necessary

(Matt et al., 2015). In addition, Matt et al. (2015) emphasized the relevance of assigning responsibilities for the overall digital transformation process to one person only, including responsibilities for defining and implementing a digital transformation strategy. They also described four key dimensions of a digital transformation strategy, which need to be considered by the person, who is accountable for the digital transformation: application of new digital technologies, adjustments of value creation, resulting structural changes and the financials implications from digital transformation.

Gerth and Peppard (2016) argued that the CIO, which they defined as responsible person for the company's use of IT and digital transformation, oftentimes is not sufficient for the company's digital transformation and therefore, the corresponding responsibility is transferred to the CDO. In order to understand the CIO's derailment, they interviewed and surveyed CIOs and derived five causes for their loss of authority and responsibility. Gerth and Peppard also highlighted that even the CDO needs to consider the same causes for derailment in order to effectively driving digital transformation. First, it is crucial to understand the current type of transition phase in order to meet associated expectations from the CEO and the entire top management team (Gerth & Peppard, 2016). Another cause for derailment is the ambiguity in defining success of delivering projects either on projects metrices such as fulfillment of budget, time and other requirements, or on business metrices, such as realization of strategic or operational benefits (Gerth & Peppard, 2016). Therefore, defining a common understanding for a project's success is required. Further, it is most likely that all top management team members have different expectations regarding the outcome of digital transformation and therefore also regarding the corresponding responsible person's role. Similar to project success, a joint understand should be established across all stakeholders (Gerth & Peppard, 2016). Also, individual relationship management with top management team members should be considered for avoiding derailment as each executive might require a different interaction focus and style for gaining their support and for establishing an environment for collaboration (Gerth & Peppard, 2016). Finally, the responsible for digital transformation needs to recognize the cultural change capacity of the company in order to drive the required change with the best fitting pace (Gerth & Peppard, 2016). As stated before, these causes for

derailment are valid for both CDO and CIO, depending on the responsibility for digital transformation. Nevertheless, by acknowledging these causes in their tasks and activities, derailment might be avoided.

Similar to Gerth and Peppard (2016), Capitani (2018) investigated implications form digital transformation for the CIO and derived lessons learned for digital transformation based on their survey results with CIOs. Some of the results can also be transferred to the CDO position and are consistent with results from research as presented in the previous section. Capitani (2018) reported that digital transformation not only requires technological innovation, but also creation of digital customer experience, reorganization of internal processes towards digital collaboration between different company functions and optimization of existing business models or development of new digital business models. They further mentioned the necessity of the CEO's and top management team's involvement as well as soft skills for successfully spreading the digital culture across the company and effectively managing its digital transformation. Therefore, it is also crucial to establish an environment of internal collaboration across all functions, especially IT and business functions, for developing digital transformation projects. As Gerth and Peppard (2016), Capitani (2018) also reported the need for adapting evaluation metrices for the success of digital projects such that not only cost driven aspects are considered, but also aspects regarding delivered business benefits. Further, they mentioned that success of digital transformation also depends on included employees and their skills and competences, which involves either hiring new qualified employees or training existing employees with digital skills, or sometimes even partnering with external parties.

Hoberg et al. (2018) derived skills and competencies, which are relevant for conducting digital transformation projects, but did not specify a dedicated person, who should possess these skills and competencies. Instead, they argued that it is the top management team combined, which is responsible for the digital transformation and therefore, it is their responsibility to ensure the availability of required competencies. Hoberg et al. derived that is important to have competencies in change management and entrepreneurship as well as technological skills such as in digital security, big data analytics and cloud computing. Further, competencies with the internet of things,

business networks or products and service integration are reported as relevant (Hoberg et al., 2018).[24] Hoberg et al. (2018) highlighted the importance of strategic collaboration between business and IT functions and their joint efforts for defining the company's digital transformation strategy. In addition, they mentioned that the IT function should be considered to be the leading role in this process.

According to the results of Pabst von Ohain (2019), the digital leader, independently of CDO, CIO or another executive position, which is responsible for digital transformation, requires attributes or characteristics in empathy, innovation, openness and agility, of which each can be described by a set of subdimensions. An empathic digital leader is characterized by being trustworthy, communicative, motivating, enthusiastic, respectful and coaching (Pabst von Ohain, 2019). Competencies in visionaryism, technology-orientation, customer-orientation and willingness to take risks, are summing up to the innovation attribute (Pabst von Ohain, 2019). Pabst von Ohain (2019) explained that openness is described by transparency and curiosity while fastness and agility were combined to the fourth attribute. Overall, several of these characteristics were also mentioned by scholars, who described the CDO position and corresponding CDO role types. Further, Pabst von Ohain (2019) elaborated on the use of these attributes. As the objective is to digitally transform the entire company, listed attributes should be established within all employees. Therefore, by identifying gaps between the ideal attribute profile and the company's employees, dedicated training for filling these gaps should be exploited (Pabst von Ohain, 2019).

Based on their survey results, Štemberger et al. (2019) identified different organizational patterns of digital transformation and analyzed digital maturity levels of each. They derived that the best environment for digital transformation is built upon a partnership between business and IT function, especially the top management team including the CIO and the IT department. Štemberger et al. also pointed out that in the

[24] With a variety of definitions, the internet of things can be understood as "[an] open and comprehensive network of intelligent objects that have the capacity to auto-organize, share information, data and resources, reacting and acting in face of situations and changes in the environment" (Madakam et al., 2015, p. 165). With the interconnection of more and more digitalized objects, the internet of things becomes increasingly important. For further information see, for example, Wortmann and Flüchter (2015), Harwood and Garry (2017) or Ben-Daya et al. (2019).

case of a CIO, who is involved in and contributing to changing business processes, and a top management team, which is actively driving digital transformation, an additional CDO position is not necessarily required. Especially when neither business nor IT are actively engaged with digital transformation activities, a CDO becomes even more important and should be established as orchestrator of digital transformation within the company (Štemberger et al., 2019). Further, in cases when the business function is dominating digital transformation without actively involving the IT function, Štemberger et al. (2019) suggested to increase the strategic influence of the IT function. Potentially, in that case, the CDO can function as IT ambassador and strengthen the position of the IT function as suggested by Haffke et al. (2016). Overall, Štemberger et al. (2019) highlighted the importance of clearly defining all stakeholders' responsibilities for digital transformation.

Despite the authors' different scopes of research, namely by not focusing their research on the CDO position and instead assuming that another top management team member, such as the CFO or CIO, should be responsible for digital transformation, the overall results head into the same direction compared to results from the previous section. Instead, additional evidence was provided that, independently of who is responsible for the digital transformation, corresponding activities, required competencies, collaboration models with other executives and organizational implications as derived by the authors are overall valid. In addition, this evidence strengthens the comprehensive description of the CDO position from the previous section. Obviously, by considering research regarding CFO and CIO, there arise different opinions about who should be key responsible for the digital transformation within a company, but that discussion was not part of the intended research objective.

2.4.4 Antecedents and Financial Impact of Chief Digital Officers

The third category *antecedents and financial impact of CDOs* discusses results and insights from authors, who investigated the CDO impact on the performance of the company. Relevant literature for this category is described in Table 7. In case the information was provided or at least partially provided, the table includes a summary

of investigated research questions, exploited theoretical frameworks, applied methodological approaches, analyzed data sets, derived relevant results and potential topics for future research.

Literature	Summary
Zhan and Mu (2016)	The authors aimed to investigate the shareholder value effects of CDO announcements by applying an event study methodology. Therefore, they collected companies, which announced a CDO between 2004 and 2015, are publicly traded in America and do not show confounding information and estimate abnormal returns based on the CRSP US index. They performed subsampling analysis in order to test their hypotheses, which were confirmed. Finally, they suggested for future scholars to include regression in this analysis as well as to perform this assessment on individual level or industry level.
Drechsler et al. (2019)	The authors investigated the effect of CDO appointment announcements on investors and stock markets. Therefore, they combined signaling theory and financial market efficiency by applying an event study methodology for deriving cumulative abnormal stock returns based on several stock indices depending on the fit of each stock as basis for their analysis. They collected 135 CDO appointments between 2002 and 2018 of companies in North America and Europe, which are publicly traded and without confounding events within the event window. In case of multiple CDO appointments within 18 months for the same firm, only the first CDO appointment was considered. Based on subsampling analysis they tested and confirmed their hypotheses. They concluded by suggesting further research regarding additional measures on the individual and organizational level such as organizations' size, revenue, or operating countries or the strategic nature of CDOs' position as well as the hierarchical level of CDOs. Further, they suggested to explore long-term effects by using measures of organizational performance or alternative measures of CDOs' success, such as CDOs' compensation relative to other managerial positions.
Firk et al. (2019)	The authors investigated antecedences and performance consequences of CDO appointments in the context of challenges and peculiarities of digital transformation, the role of the CDO as centralized responsible for digital transformation as well as contingency theory. For analysis of CDO antecedences, they applied a general estimating equations (GEE) regression model with logit link function of the binomial family with correlation structure. For performance implications, they conducted a firm-fixed effects regression on Tobin's Q. Overall, 919 companies, with yearly, longitudinal data from 2010 to 2017 within S&P 500 and MSCI Europe indices are part of the analysis. They tested for transformation urgency based on intangibles and digital entrants in the industry as well as coordination effort based on diversification and low digital readiness as independent variables. They controlled by variables such as board size, CEO age, or level of institutional ownership. Their results mostly supported their hypotheses. They concluded by suggesting further research, for example, by adopting an institutional lens to firm's responses to the pressure of digital transformation for identification of sociologic motives of firms for CDO appointments or by including a measure for CDO success and investigation of tensions between CDO and CEO incentives.

Table 7: Existing Literature Describing Antecedents and Financial Impact of CDOs
Source: Own illustration.

Literature, which has been allocated to the category *antecedents and financial impact of CDOs,* focuses on research objectives regarding measuring the performance impact of the CDO position and in addition, company environments, which support the appointment of a CDO. As described in the following, two major approaches have been applied so far for measuring the performance impact, yet different perspectives were investigated.

Zhan and Mu (2016) investigated the CDO impact based on an event study approach for CDO appointments and an analysis of mean abnormal returns for the appointment date. They hypothesized that the stock market reaction will be negative for companies which already employed a CIO, and therefore CDO and CIO might be exposed to risk of overlapping positions. Further Zhan and Mu argued that company specific factors influence the CDO position and therefore formulated the hypotheses that both company size and company prior performance will have a negative moderating effect on the risk of overlapping positions between CIO and CDO. This means that they hypothesized that for smaller companies and companies with a lower prior performance respectively, the negative effect of the position overlap, in case a CIO exists in the company, will be greater (Zhan & Mu, 2016). Zhan and Mu (2016) applied subsampling analysis and found support for all three hypotheses. Further, they investigated the full sample for significance of abnormal returns on the CDO appointment date yet derived that these were insignificant. Overall, the study does not include robustness testing (Zhan & Mu, 2016), for example, by considering another estimation period for estimating the abnormal returns for each company, by analyzing cumulative abnormal returns or by investigating more than one market index for estimation of abnormal returns (Chen & Cheng, 2006; McWilliams & Siegel, 1997; Park, 2004). By considering cumulative abnormal returns, the researcher might be controlling for unprecise collected data regarding the CDO appointment date itself, for spreading of information regarding the CDO appointment earlier than the first published corresponding news and for potential delays in adjustments of the market to the released news. Regarding the discussion of test statistics, Zhan and Mu (2016) reported several test statistics like Wilcoxon signed-rank test and generalized sign test, but only discussed few of them across their discussion of results. Finally, it is important

to mention that the authors not only accepted Chief Digital Officer appointments, but also appointments of Chief Data Officers and vice presidents of analytics or Chief Data Scientists for their overall data sample.

Similar to Zhan and Mu (2016), Drechsler et al. (2019) applied an event study methodology for examining the impact of announcing the CDO appointment on stock market reactions. Therefore, they hypothesized that the announcement of the CDO appointment will have a positive effect on the stock market performance in terms of abnormal stock returns. Further, Drechsler et al. defined a specialist and generalist CDO role profile and formulated that the abnormal stock return will be larger for CDO appointments, when the CDO assumes the specialist role, because a generalist CDO might not be tailored to the company specific requirements regarding digital transformation. As Zhan and Mu (2016), they also hypothesized that the presence of a CIO will negatively affect the abnormal stock return regarding the CDO appointment. Two additional hypotheses concern the educational background and professional experience of the CDO (Drechsler et al., 2019). Drechsler et al. (2019) argued that announcements of CDO appointments will be negatively perceived in case the CDO possess an educational background in science, technology, engineering or mathematics, and a profound professional IT experience respectively, as they argued that business knowledge is more important for aligning business and IT. For investigating their hypotheses, they analyzed cumulative abnormal stock returns for several event windows for the first hypothesis regarding the general impact of the CDO appointment, and based on these results, they applied subsampling for the other four hypotheses. While hypotheses two to five were supported, hypothesis one was only supported partially for the event window from the actual event to two days after the event (Drechsler et al., 2019). Other event windows covering several days before the actual event did not result in significance (Drechsler et al., 2019). For further analyzing the results regarding different event windows, Drechsler et al. (2019) also investigated different time periods by splitting their sample in two halves and derived significance for earlier announcements of CDO positions, but not for the later period. Further, they also checked for robustness by applying different estimation windows for the abnormal returns, which yielded the same results. By following the approach of Bose and Leung

(2019), they considered several market portfolios for estimating each companies' abnormal return as their data set contained North American and European companies and selected the market portfolio with the best explanatory power depending on the company's country. Patell tests and generalized sign tests were applied for significance testing and were reported sufficiently throughout the document (Drechsler et al., 2019).

While Firk et al. (2019) also investigated the market performance similar to Zhan and Mu (2016) and Drechsler et al. (2019), Firk et al. based their analysis on another performance measure and methodological approach. They applied a within firm fixed effects regression model including a correction factor based on a first-stage probit model estimating the likelihood to employ a CDO in order to consider potential bias from time-variant aspects. Based on this approach, they tested their hypothesis that given the presence of a CDO, the performance implications are positively moderated by transformation urgency and coordination effort. Here, the measure transformation urgency was based on the number of new digital entrants in the relevant industry as well as dependency on intangible assets, for which high values are interpreted as high transformation urgency for the company (Firk et al., 2019). Further, coordination effort was defined as level of diversification measured by product market and geographical diversification, and digital readiness of the company's country of origin based on a network readiness index (Firk et al., 2019). A higher level of diversification and low digital readiness are resulting in an overall high coordination effort (Firk et al., 2019). Based on their analysis, Firk et al. (2019) derived that the presence of a CDO in the company has a positive impact on the company's performance. Further, they derived that both internal aspects of each hypotheses, namely positive moderating effects of a higher dependency on intangible assets and high level of diversification, are supported. On the other hand, their results show that the external aspects of their hypotheses, new digital entrants in the industry and digital readiness of the company's country, are not supported. In addition, Firk et al. investigated influencing factors that might determine the presence of the CDO in a company. Therefore, they hypothesized that both transformation urgency and coordination effort of digital transformation, as described before, will increase the likelihood of CDO presence. For analyzing their hypotheses, Firk et al. applied a generalized estimating equations (GEE) model with a

logit link function due to the binary scale of the investigated variable CDO presence. Based on their model, they found support for their hypotheses. While reporting Wald-chi square for the GEE model and adjusted R^2 for the within firm fixed effects regression, no corresponding comments were provided (Firk et al., 2019). For testing robustness, several GEE specifications were investigated, which yielded similar results (Firk et al., 2019).

The authors' hypotheses and results are mostly in line with the results from literature of the category *CDO position*. Not only did Zhan and Mu (2016) and Drechsler et al. (2019) hypothesize the negative impact of the existence of a CIO on the CDO performance impact, but also Haffke et al. (2016) and Tumbas et al. (2017) argued that a CDO is only required in the company in case the CIO is fully occupied by traditional IT related activities and therefore has no capacity for digital transformation or in case the CIO's role profile is not sufficient for digital transformation. As derived by Zhan and Mu (2016), company specific factors as the company's size and its previous year performance increase the effect of CIO presence on the CDO performance impact, Haffke et al. (2016) also reported that company characteristics determine the need for the CDO, such as only medium to large size companies benefit from a CDO. Still Haffke et al. (2016) did not provide the linkage to the effect of also employing a CIO. Drechsler et al. (2019) also hypothesized the positive effect of a specialist CDO on the stock market's reaction regarding the CDO appointment, which is in line with the argument of Haffke et al. (2016), who argued that the need for a CDO depends on their addressed focus area. The definition of Drechsler et al. (2019) for a specialized CDO is also similar to the definition of different role types as described in section 2.4.2, like a specialization in digital marketing or digital innovation. Although many authors reported about the importance of business related skills and experience (Catarino et al., 2018; Tahvanainen & Luoma, 2018; Walchshofer & Riedl, 2017; Zisler et al., 2016) as well as defined the CDO as business function (Haffke et al., 2016; Tahvanainen & Luoma, 2018; Tumbas et al., 2017, 2018; Zisler et al., 2016), the hypotheses of Drechsler et al. (2019) regarding the negative impact of a STEM education or professional experience in IT are not fully supported by the qualitative arguments described in section 2.4.2. Several authors also highlighted the importance of technical

experience and knowledge for successfully conducting digital transformation (Bülchmann, 2017; Singh & Hess, 2017; Walchshofer & Riedl, 2017; Weinreich, 2017; Zisler et al., 2016). Still, the results of Drechsler et al. (2019) might stress that business related knowledge tends to be more valuable for the CDO compared to IT related knowledge. Similar to the results of Firk et al. (2019) regarding the positive impact of high internal coordination efforts on the performance impact of the CDO as well as the likelihood of establishing a CDO, Singh and Hess (2017) also argued that high internal complexity increases the need for the CDO. While both Singh and Hess (2017) and Haffke et al. (2016) derived that external pressure for digital transformation increases the need for the CDO, Firk et al. (2019) on the one hand found support for their hypotheses that strong external influencing factors positively impact the likelihood of CDO existence, but on the other hand derived, opposing to their initial hypotheses, that these external factors are not positively driving the impact of the CDO on company performance.

So far, only Zhan and Mu (2016) and Drechsler et al. (2019) investigated the effect of CIO existence on the impact of announcing CDO appointments. As Zhan and Mu (2016) exploited a broader scope regarding their data set, by also considering Chief Data Officers for example, and only abnormal stock returns opposing to cumulative abnormal stock returns, a detailed comparison with the results of Drechsler et al. (2019) is only feasible to a certain extent. Nevertheless, Zhan and Mu found significance for both negative impact of CIO presence with a mean abnormal stock return of -0.35% and p-value ≤ 0.05 and positive impact of CIO absence with a mean abnormal stock return of 0.61% and p-value ≤ 0.05, Drechsler et al. only found support for the positive impact of CIO absence with a cumulative abnormal stock return of 0.41% between the event date and two days afterwards with p-value ≤ 0.05. Although the sample size of Zhan and Mu included 59 companies with a CIO and 38 companies without a CIO and the sample size of Drechsler et al. 22 companies with a CIO and 79 companies without a CIO, they derived very similar results in this regard. Following these results, the existence of CIO while appointing a CDO should be thoroughly considered by practitioners, if the overall benefits of having both position outweighs the negative impact of this constellation.

Overall, the analysis of quantitative implications of the CDO has only been investigated within three documents (Drechsler et al., 2019; Firk et al., 2019; Zhan & Mu, 2016). Especially the main focus was lying on market-based performance measures, (cumulative) abnormal stock returns closely around the CDO appointment date and Tobin's Q (Drechsler et al., 2019; Firk et al., 2019; Zhan & Mu, 2016). It is noticeable that so far only conference proceedings have been published regarding this topic, while journal articles have not yet been released. This further highlights the early stage of research in the field of the CDO literature.

2.4.5 Concluding Remarks

A substantial amount of research has been conducted regarding the CDO position, especially about relevant tasks, activities and responsibilities, and required competencies, skills and experience. Even a set of different CDO role types has been identified by some researchers. Other researchers investigated in the direction of organizational implementation of the CDO, the collaboration of the CDO with other stakeholders of the company regarding digital transformation and also potential reasons for establishing a CDO in the first place. Beyond these insights, few scholars researched the performance implications of the CDO and supporting conditions for establishing the CDO in this context. From a theoretical perspective, scholars based their research on theoretical grounds, for example, by combining existing theoretical models, exploiting role theory, upper echelons theory, contingency theory, signaling theory or other theoretical frameworks. Other researchers approached their research objective from an open and unpreoccupied angle without a theoretical framework and instead based their analyses on explorational grounds.

In line with discussed research opportunities in the field of individual top management team member research in the introductory section (Menz, 2012), Figure 10 provides an overview of the current status within the field of CDO research and potential areas for future research.

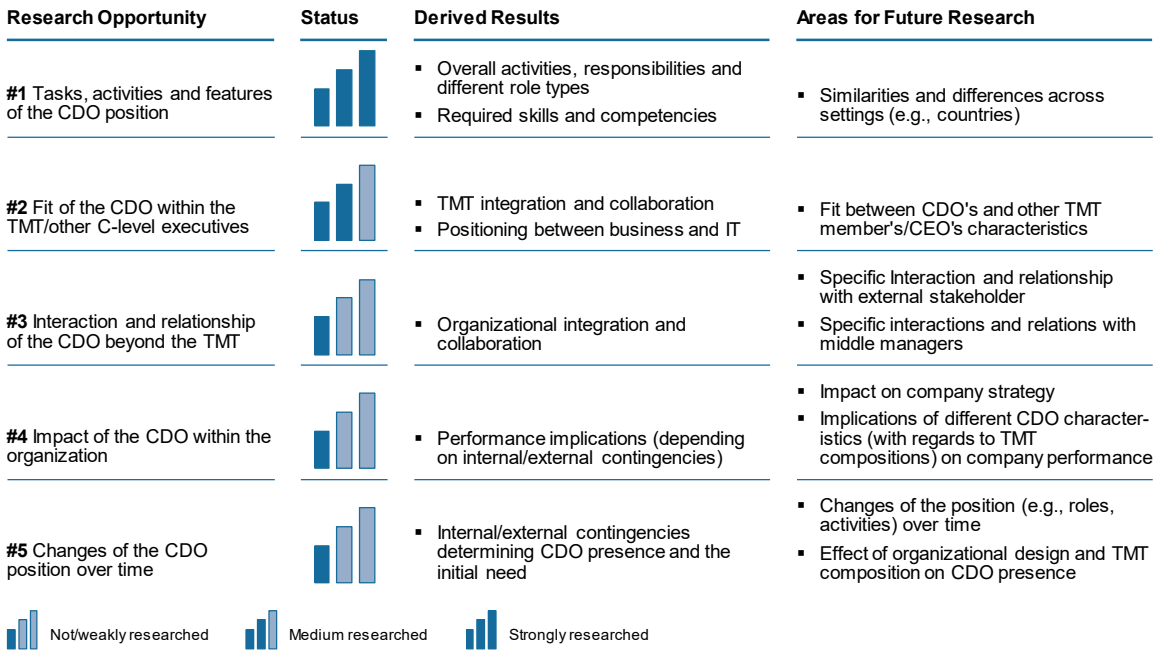

Figure 10: Status-quo of CDO Research
Source: Own illustration, based on Friedrich and Menz (2012).

Despite already existing results as described throughout previous sections and as summarized in Figure 10, the research field around the CDO is still subject to further research efforts and still at the beginning. Since some researchers identified the risk of overlapping positions between the CDO and the CIO based on qualitative methods and therefore argued that not always a CDO is required, the same question has not yet been analyzed on a larger scale, for example, by including quantitative data. Future research could thus analyze the situation of CIO and CDO coexistence (or another C-level executive than the CIO as displayed in research opportunity #2), based on different CDO and CIO role types as argued by Haffke et al. (2016) and Tumbas et al. (2017), for example, similar to the approaches of Zhan and Mu (2016) and Drechsler et al. (2019), who investigated company performance implications in this scenario. Since this approach would require insights from within company, it might be difficult to assess different CDO and CIO role types. Further, most scholars focused so far on the performance impact of the CDO with a short-term perspective, while long-term implications on company performance would require additional attention from researchers. For example, scholars might examine companies, which established a CDO, in comparison to companies, which did not employ a CDO. Also as described as

before, different opinions regarding requirements in educational background and professional experience in IT were derived. Additional research might help clarifying this situation and suggest scenarios when some characteristics are more important than others, for example, in combination with different CDO role types as displayed in Table 5. Similarly, company internal and external factors that might affect implications from the CDO on company performance, as previously mentioned, would require further assessment. As several scholars also highlighted the importance of top management team support regarding digital transformation within the company, and especially support from the CEO, future research might investigate CDO performance implications given different top management team or CEO conditions, or the CDO and CEO relationship. Overall, only little research has been conducted regarding financial implications of the CDO on the company, for example, similar hypotheses were not yet assessed based on different data sets. Therefore, more research is required in the field of CDO impact on performance aspects of a company in order to strengthen the corresponding still under-research scientific understanding (research opportunities #2 and #4).

In a similar vein, scholars should also focus their attention on the interaction of the CDO with stakeholders beyond the top management team (research opportunity #3). As uncovered by the review, the organizational integration and collaboration of CDOs was discussed in literature, relationships with external shareholder or the company's middle require further attention. Besides performance implications of CDOs and the fit with other top management team members, only little research has been conducted in deriving factors that influence CDO presence within the company (research opportunity #5). Although Firk et al. (2019) shed initial light on some internal and externa contingencies, which affect CDO presence, additional research is required in order to further analyze the relationship between a company's contingencies and the existence of a CDO. Further, it remains uncovered, if there is a link between a company's top management team members, especially of relevant members for digital transformation, and CDO presence. Also, as no clear view exists on which C-level executive should be responsible for digital transformation, either CDO, CIO or another executive, future scholars could investigate and compare different companies, of which some

transferred the responsibility regarding digital transformation to the CDO while some companies transferred the corresponding responsibility to the CIO or another executive. As highlighted by Vial (2019), investigating different top management team structures and their actions and decision in digital transformation might further help understanding the implications of CDOs.

Finally, CDOs are profoundly researched regarding their activities, responsibilities and competencies (research opportunity #1). Further research efforts might be directed towards differences and similarities across varying settings. Overall, described potential research objectives could help better integrating the CDO position into the overall context of digital transformation and top management team research.

Lastly, it is worth mentioning that in this research context, relevant main vocabulary has been established. Although some researchers use Chief Digitalization Officer for the abbreviation CDO, for example, Pabst von Ohain (2019), the vast majority of researchers refers to the CDO position by Chief Digital Officer. Other potential terminologies for this position, e.g., Chief Digital Executive, have not been observed. Similarly, only few scholars, such as Haffke et al. (2016) or Drechsler et al. (2019), discuss the CDO topic in the context of digitization and digital strategies, but most researchers rather call the overall process digital transformation and digital transformation strategy respectively. Other main vocabulary in this context, such as top management team, were without modification. For reporting results in previous or following sections, the more frequently used terms are utilized.

Before addressing research question two and three, some of before derived results on CDOs will be discussed in perspective to existing top management team research in the next section. Since other C-level executives appear to be potentially capable of managing digital transformation without requiring support from a CDO, a comparison with relevant executives might be helpful to distinguish different roles. In addition, providing a view on several executive positions next to the CDO position helps to highlight possible overlaps between each of them, which might lead to sources of conflicts and thus should be considered carefully.

2.5 Chief Digital Officer Position in the Context of Existing Top Management Team Research

From the previous section, it became clear that a company's options for engaging an executive with digital transformation are not limited to CDOs only, but also other executives are discussed to be suitable for digitally transforming the company. While some authors argue that these options also include executives from affected business units (Hess et al., 2016), many other scholars discuss the possibility to entrust CIOs with digital transformation, not at least also due to the technical component of digital transformation arising from new technologies (e.g., Capitani, 2018; Gerth & Peppard, 2016; Hoberg et al., 2018). In any case, close alignment between CIO and the responsible executive is required in order to ensure alignment with the prevailing IT infrastructure (Hess et al., 2016). Due to technical components of digital transformation, a comparison of the CDO position with other technical-related top management team members seems reasonable. Yet as highlighted before, digital transformation also includes rather strategic and transformation-related activities (Vial, 2019). Thus, such a comparison also requires considering relevant C-level executives from those specific fields.[25] In this context, Singh and Hess (2017) distinguish between executives with a similar set of responsibilities compared to the CDO position. Their comparison includes not only CIO (Chun & Mooney, 2009), but also Chief Data Officer, Chief Innovation Officer and Chief Strategy Officer (Singh & Hess, 2017). Another technology-oriented C-level executive is the Chief Technology Officer (Adler & Ferdows, 1990; Medcof, 2008). In addition, it seems to be reasonable to also consider Chief Transformation Officers (Gorter et al., 2016; Klasen, 2019), as by their title only, they seem to be accountable for transformational activities in general within companies.

[25] Note that the expectation of this comparison (i.e., of CDO and other selected C-level executives) is not to be fully exhaustive. Instead, it should only provide an overview based on some (of potentially many) literature sources for each C-level executive. Especially, no systematic review on other C-level positions than the CDO position has been conducted. Thus, this comparison might not be complete in the sense of available literature. Also, other C-level executives, which are not discussed here, might be useful to be included in future comparisons.

As one of the more frequently discussed top management team members in literature within the past years (Chun & Mooney, 2009), CIOs are highlighted as potential responsible for digital transformation by several authors (e.g., Capitani, 2018; Gerth & Peppard, 2016; Hoberg et al., 2018). Originally introduced to companies as executive for data processing and technology management as early as in the 1950s, today CIOs are responsible for providing and supporting IT infrastructure (Chun & Mooney, 2009). Thereby, CIOs lay the grounds for effective business operations and enable companies to change processes and strategies by exploiting IT (Chun & Mooney, 2009). In comparison, Chief Data Officers are rather focused on data management and lead initiatives based on data analytics, data governance, data quality, data architecture and even define a data strategy (Y. Lee et al., 2014). In addition, Chief Data Officers not only conduct data preparation for external reports, oversee compliance and establish data governance, they also exploit big data for business strategy (Y. Lee et al., 2014). Also with technical focus, Chief Technology Officers aim to integrate technology into a company's strategy, products, production processes and IT (Adler & Ferdows, 1990). Further, Chief Technology Officers are substantial for leading technological innovation within a company ensuring effective operations within research and development (R&D) departments (Medcof, 2008). Less technical orientated, but still thriving for implementation of novel ideas, is the Chief Innovation Officer (Di Fiore, 2014). Without focusing explicitly on digital technologies, Chief Innovation Officers help to strategically innovate the organization, its products and services by identifying new market opportunities, corporate idea generating and promoting market best practices (Di Fiore, 2014). Without a pure technological focus, Chief Strategy Officers are responsible for a company's overall strategy (Menz & Scheef, 2014). Chief Strategy Officers actively manage a company's strategy process and its execution of strategic activities, like corporate or business development (Menz & Scheef, 2014). Finally, Chief Transformation Officers are responsible for managing transformational corporate projects, which are, opposing to a CDO's field of expertise, not necessarily driven by digital technologies (Klasen, 2019). Still, similar to CDOs, by orchestrating complex process, which involves many discrete initiatives, and acting as face of the transformation project, Chief Transformation Officers ensure the success

of the project (Gorter et al., 2016). Figure 11 summarizes responsibilities and activities of each described C-level manager.

Chief Digital Officer	Chief Information Officer	Chief Data Officer	Chief Technology Officer	Chief Innovation Officer	Chief Strategy Officer	Chief Transformation Officer
▪ Coordinating digital transformation activities ▪ Improvement of customer experience (by digital technologies) ▪ Improving existing and establishing new business models and strategies	▪ Providing and supporting IT infrastructure ▪ Ensuring effective business operations ▪ Enabling change for processes and strategies by exploiting IT	▪ Managing data ▪ Focusing on data analytics, governance, architecture ▪ Exploiting big data for business strategy and conducting data preparation for external reports	▪ Integrating technology into company ▪ Leading technological innovation within a company ▪ Ensuring effective operations within R&D units	▪ Implementing novel ideas and best practices ▪ Identifying new market opportunities ▪ Strategically innovating the organization, its products and services (no digital technologies focus)	▪ Defining for a company's overall strategy ▪ Managing a company's strategy process ▪ Executing strategic activities, like corporate or business development	▪ Managing transformational corporate projects (not necessarily driven by digital technologies) ▪ Orchestrating complex process and initiatives ▪ Acting as face of transformation projects

Figure 11: Key Responsibilities and Activities of Selected C-level Executives
Source: Own illustration, based on Singh and Hess (2017), Chun and Mooney (2009), Lee et al. (2014), Adler and Ferdows (1990), Medcof (2008), Di Fiore (2014), Menz and Scheef (2014), Klasen (2019), Gorter et al. (2016).

Although all of the C-level positions have a strategic character, their strategic orientations differ due to different scopes of responsibilities. Still, many similarities can be identified across all of the positions. When comparing the results from section 2.4.2 regarding tasks and responsibilities of CDOs, it becomes clear that CDOs might combine some aspects of other described C-level executives. Yet, CDOs distinguish themselves by their focus on digital technologies and initiatives in combination with strategic and transformational responsibilities as part of digital transformation.

While there are similarities between several C-level executive positions and the CDO, many authors highlight and discuss especially the potential functional overlap of CIO and CDO (e.g., Giebe, 2019; Singh & Hess, 2017; Tumbas et al., 2017; Walchshofer & Riedl, 2017; Zhan & Mu, 2016). As the potential closeness of both positions suggests that one position is redundant, a closer examination of how the CIO position developed during the last years becomes reasonable in order to assess the future development of both. According to Ross and Feeny (1999), and Chun and Mooney (2009), CIOs developed with increasing credibility and organizational learning from functional IT heads, who are responsible for developing new systems and aligning the system with the needs of its users, towards business visionaries, who are driving strategy based

on applications of information systems and their capabilities (stage 1 to stage 3 in Figure 12). Building on this evolutionary pathway, especially of Chun and Mooney (2009), Haffke et al. (2016) argue that until today, CIOs developed one stage further towards an ambidextrous CIO (stage 4 in Figure 12). This means that CIOs are required to provide both traditional IT related services, like maintaining and managing the existing IT infrastructure (supply-side leadership), as well as CDO-like activities such as close collaboration with other executives for driving the company's strategy and processes (demand-side leadership) (Haffke et al., 2016). As both aspects become more and more comprehensive and both sides might not be sufficiently coverable by one executive, the CIO role eventually might part into two (Chun & Mooney, 2009; Haffke et al., 2016). Thus, Haffke et al. (2016) suggest by adding a fifth stage to the model that in the digital era, a CIO will be more focused on handling the existing IT landscape such that agility and adaptiveness are ensured, i.e., transitioning to its traditional CIO role. Simultaneously, the exploration of IT for business strategic purposes will be transferred to the CDO (Haffke et al., 2016). Yet, once IT related capabilities are permanently installed within the company and different business executives have taken over IT leadership responsibilities, CIOs might have the opportunity to transition into the CDO role, or at least focus more on digital transformation related aspects (Haffke et al., 2016). This is also in line with other scholars' results. Several authors pointed out that the CDO role might re-merge with the CIO position in the future (or even vanish), as the CIO might adopt their responsibilities (Bülchmann, 2017; Tumbas et al., 2017, 2018; Walchshofer & Riedl, 2017; Zisler et al., 2016). This means that independent of the title designation, CDO responsibilities will be either part of the CIO role (or potentially vice versa) or both roles might be present working in close alignment. Figure 12 provides an overview of the potential development paths of CIO and CDO. Thus, future scholars might investigate further developments of both CIO role and CDO role in order to identify whether both are still needed, or one role might be sufficient.

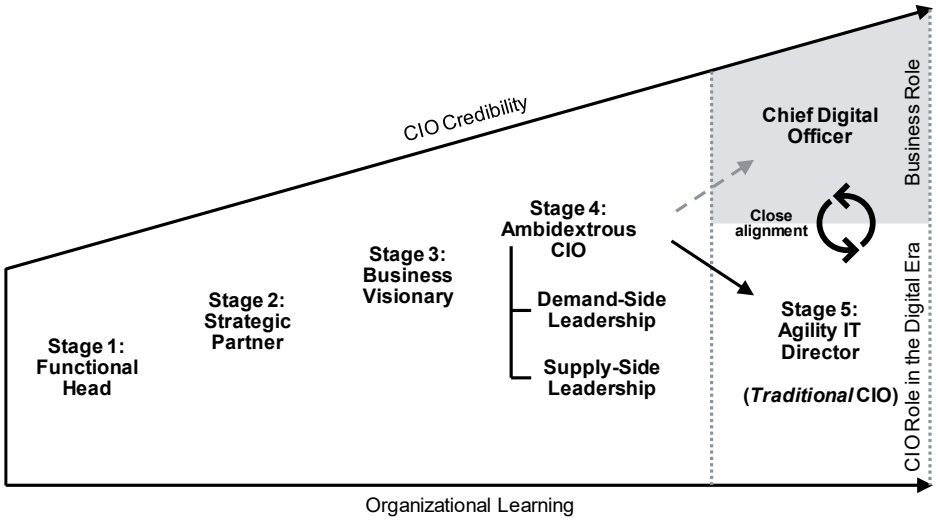

Figure 12: The Continued Evolutionary Pathway of the CIO and CDO Role
Source: Adapted from Haffke et al. (2016).

In the following chapters, research questions two and three will be further discussed. Especially, the next chapter will discuss the implications from findings of the systematic literature review for each research question, i.e., both research questions two and three will be aligned in more detail with existing results in order to uncover unexplored fields within CDO research. Following that, a theoretical framework will be derived from which hypotheses will be developed in order to answer both remaining research questions.

3. Theoretical Framework and Hypotheses Development[26]

3.1 Detailing of Research Questions Two and Three

As pointed out in section 2.1, one objective of the systematic literature review was to refine both research questions two and three, which were initially proposed in the introduction in section 1.1 and recalled in the following:

(2) Which factors influence CDO presence within a company?

(3) What is the impact of a CDO on company performance?

Addressed research subjects are on the one hand factors, which influence CDO presence within a company, and on the other hand implications of a CDO on the performance of companies. From section 2.4, it becomes clear that both research questions have only been addressed little so far by scholars. Still, in order to provide novel insights regarding both research subjects, further developing and fine graining research question two and three becomes reasonable. Thus, both research questions will first be conceptualized based on theory and relevant literature within this chapter, and second empirically assessed based on quantitative data and statistical models in the following chapters.

Regarding CDO presence, only Firk et al. (2019) investigated how transformation urgency (i.e., intangibles and digital entrants in the industry) and coordination effort (i.e., diversification and low digital readiness) affect CDO presence within companies. As unveiled by the systematic literature review and displayed in Figure 10 (research opportunity #5), the influence of relevant top management team member compositions and their characteristics were not studied by scholars yet. As highlighted in the introduction, the definition of a digital transformation strategy lies typically within a CEO's authority (Hess et al., 2016). Yet, CEOs delegate the actual execution of digital

[26] Several parts of this chapter were used word by word (potentially with the exception of a few words) or with rearrangements (in order to match style and format of this thesis) for the preparation of a scientific paper. Affected paragraphs have been marked with an asterisk (*) at the end. In addition, some marked paragraphs were further enriched by explanations, which had not been used for the described paper. For further information regarding publication outlets and corresponding status, see the Foreword on page II.

transformation to either CDO, CIO or another executive (Hess et al., 2016). Thus, a CEO appears to have access to a wide range of options for selecting a C-level manager for conducting digital transformation. Still, it remains unclear which factors determine the decision of a CEO to specifically appoint a CDO to their top management team. According to Hambrick and Mason (1984), characteristics of executives like the CEO strongly influence their decisions and actions. With the CEO as one of the most relevant top management team members, recalling research opportunity #5 from Figure 10 suggests to investigate which of a CEO's characteristics influence their decision to appoint a CDO. Therefore, this thesis strives for studying CEO characteristics as influencing factors of relevant top management team members on CDO presence. Further, as shown in Figure 10, the relationship of CDO presence, and organizational and environmental components, such as company size or industry related factors, were mostly uncovered by current research so far as well.[27] Thus, this thesis also aims to answer whether such contingency related factors are relevant for CDO presence or not.

In terms of a CDO's implications on company performance, Figure 10 (research opportunity #4) and results of the systematic literature review show that different CDO characteristics have only been studied little by scholars so far. Only Drechsler et al. (2019) conducted an initial assessment regarding the influence of some CDO characteristics on stock market returns. Thus, the question remains open for further clarification whether certain characteristics of a CDO are favorable over others in terms of (longer term) company performance. Especially, the impact of several combinations of such CDO characteristics with varying other C-level structures on company performance remains unidentified (Haffke et al., 2016; Vial, 2019). As pointed out before, the CEO shapes the strategic direction of digitally transforming companies

[27] Note that the study by Kunisch et al. (2020), which investigates CDO presence based on an explorative approach, was published after conducting the systematic literature review. This means that a systematic review of this study was not performed. Still, the results and approaches are considered further throughout this thesis, i.e., this thesis extends such results, for example, by exploiting different data sets. By their analysis, Kunisch et al. (2020) found evidence for the influence of some organizational and environmental factors on CDO presence (similarly to Firk et al. (2019) as part of their control variables). Opposing to their work, this thesis aims at testing relevance of similar factors based on theoretical grounds. In addition, the relationship of such factors and CDO performance implications will be added in this thesis.

(Hess et al., 2016). While either CDO or CIO might be responsible for operative aspects of digital transformation (Hess et al., 2016), especially since a strict line between both positions seems difficult to be drawn as pointed out before, it is highly important that both work in close collaboration and with clearly defined responsibilities, in case both positions exist within the company (Locoro & Ravarini, 2017; Singh et al., 2019; Tumbas et al., 2017). Thus, this thesis investigates how different compositions of CDO, CIO and CEO, defined as the digital transformation's main protagonists, positively or negatively affect company performance. Further, the relationship of described organizational and environmental components with the impact of a CDO on company performance remains mostly uncovered as well.[28] Therefore, the influence of contingency related factors on CDO performance implications will be investigated. In sum, research questions two and three can be adapted as follows:[29]

(2) Which CEO characteristics, and organizational and environmental company factors influence CDO presence within a company?

(3) What is the impact of a CDO on company performance? Especially, are different CDO characteristics, various company contingencies (organizational and environmental) and varying C-level structures of CDO, CEO and CIO favorable over others?[30]

In the following, the theoretical framework for addressing both adapted research questions will be presented.

3.2 Overview Theoretical Framework

In order to answer adapted research questions two and three, a holistic theoretical framework has been developed as foundation for this thesis. On the one hand, the theoretical framework is designed to investigate how individual CEO characteristics as well as a company's contingencies interfere with CDO presence. For this matter, this

[28] Note that Firk et al. (2019) indirectly accounted for such factors as part of their study's control variables. Yet, Firk et al. (2019) did not specifically test for such relationships, whereas in this thesis suitable theory and methodology are applied.
[29] Note that when referring to research questions two and three anywhere throughout the thesis beyond this paragraph, the here presented adapted research questions are referred to.
[30] In terms of CDO implications on company performance.

thesis adopts viewpoints of upper echelons theory and contingency theory. On the other hand, theory has been chosen in order to assess how the CDO in general but also in relation to several CDO characteristics, compositions of CDO, CEO and CIO as well as organizational and environmental company factors impact company performance. The basis for these assessments lies within human capital theory, resource-based view and, again, contingency theory. An overview of the thesis' theoretical framework and the connection of its elements for assessing proposed research questions two and three can be found in Figure 13.

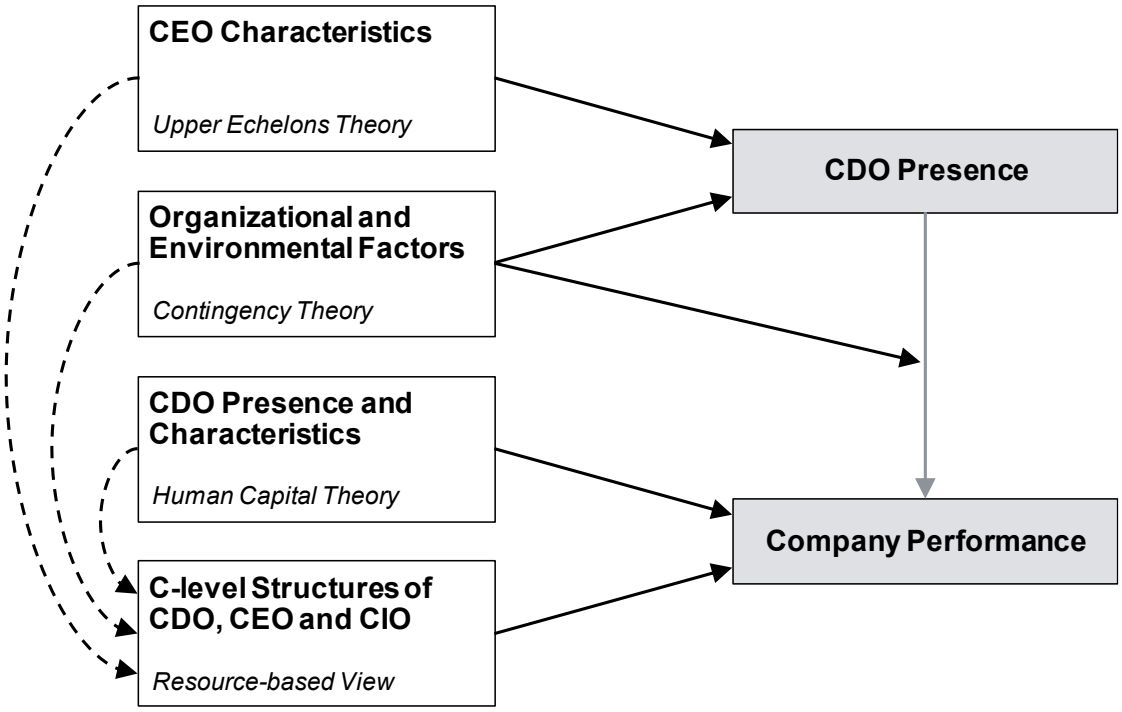

Figure 13: Overview Theoretical Framework
Source: Own illustration.
Note: The relationship between CDO presence and company performance is highlighted in grey as the theoretical relationship between both is addressed by human capital theory. The dotted lines indicate that relevant characteristics of CDO, CEO and CIO are jointly examined regarding the impact on company performance from a resource-based view perspective.

Evolving from the initial publication by Hambrick and Mason, upper echelons theory argues that company decisions and actions are crucially shaped by members of the top management team (Hambrick & Mason, 1984). As top managers base their activities on how they perceive each individual situation (Schmid & Dauth, 2014) and perception itself is influenced by each manager's personality, values and experiences,

such characteristics also affect their decisions and actions (Hambrick, 2007). Next to the influence of a top manager's individual characteristics, contingency theory proposes that top managers also aim to achieve an ideal fit between a company's structural characteristics and its contingencies reflecting the situation (Burns & Stalker, 1961; Donaldson, 2001; Lawrence & Lorsch, 1967; Woodward, 1965). Depending on the situation, such contingencies, which might be of environmental or organizational nature, affect choices of top managers as well (Burns & Stalker, 1961; Child, 1975). In addition, such contingencies are argued to also impact organizational outcomes like company performance (Lawrence & Lorsch, 1967; Nath & Mahajan, 2008). Next to company contingencies, it is also the top management team, which impacts company performance (Hambrick, 2007). Following human capital theory, the organizational human capital of the company, represented by a top manager's characteristics, affects the competitive advantage of the company and therefore, impacts the organizational outcome (G. S. Becker, 1964). In order to account for multiple characteristics, the resource-based view argues about the relevance and influence of all combined (human capital) resources on company performance (Barney, 1991).

In the following, each theory will be introduced in more detail and applied for hypotheses development. Therefore, relevant literature in the field and especially results from the systematic literature review will be used as basis together with each theoretical viewpoint in order to derive appropriate hypotheses for answering both research questions two (see section 3.3) and three (see section 3.4) as described before.

3.3 Influencing Factors for Chief Digital Officer Presence

3.3.1 Upper Echelons Theory

Starting with the publication of Hambrick's and Mason's upper echelons theory in 1984, research on top managers and their characteristics continuously gained interest from scholars and practitioners (Hambrick & Mason, 1984). Upper echelons theory suggests that top managers play a substantial role in defining company activities and forming major organizational outcomes (Carpenter et al., 2004; Hambrick & Mason, 1984). Top managers' actions are based on their individual perception of each present situation

(Schmid & Dauth, 2014), as the underlying concept of upper echelons theory argues that complexity and uncertainty of situations lead to mere interpretation, but not objective judgement of such situations (Carpenter et al., 2004). Eventually, the basis of upper echelons theory is grounded on the premise of bounded rationality (Cyert & March, 1963; March & Simon, 1958). Individual perception is theorized to be dependent on and influenced by a top manager's personality, values and experiences due to the attributes' affection on their field of vision, selective awareness and interpretation (Hambrick, 2007). Especially when conventional psychometric data on personal values and cognitive bases and is difficult to obtain, information on executives, such as company and industry tenure, or educational backgrounds, can be used in order to derive predictions on their respective actions (Hambrick, 2007). Despite the loss of insights regarding social and psychological processes, substantial evidence was provided that this approach generates reliable predictions (Hambrick, 2007). In the context of digital transformation, strategic decision-making about the initiation of digital transformation and the decision whether to employ a CDO, is influenced by individual top managers' perception of the company situation (Gerth & Peppard, 2016; Haffke et al., 2016).*

Following the upper echelons theory perspective, C-level executives derive their decision to adopt a CDO within the company based on their individual perception of the prevailing company situation.[31] Since a key responsible for the company's strategic decision-making is the CEO (Hambrick & Cannella, 2004; Menz & Scheef, 2014), the choice to employ a CDO is significantly shaped by the CEO.[32] Therefore, a CEO's perception of the company's situation, when facing digital transformation, is a key force in the decision-making process of hiring a CDO or not. Thus, (partial) focus of this thesis' examination lies on CEOs' characteristics as these are relevant in terms of

[31] As mentioned, for example, by Haffke et al. (2016), perceived implications from digital transformation drive the need and role type of CDOs for companies, which underlines the upper echelons theory perspective in this context. Still, it should be mentioned that other scholars, like Hambrick and Cannella (2004) or Menz and Scheef (2014), approached such research questions by solely assuming a contingency theory perspective.

[32] Filling of (new) positions might be subject to further controlling mechanisms, such as approval by board of directors, supervisory board, nomination committees or major shareholders. For the sake of simplicity and due to potential limitations in observing such mechanisms, the focus of this thesis' analyses lies on the CEO in the context of decisions about CDO appointments.*

deciding for employing a CDO within the company. In other words, the argument follows that some CEOs decide to hire a CDO, based on how their specific characteristics let them perceive the company's situation in the setting of digital transformation.*

As derived by G. Wang et al. (2016), research of the past three decades provides a substantial amount of evidence for the significant influence of CEOs' characteristics on their strategic actions. Such actions are manifold and might range from acquisition and diversification related measures to innovation and strategic change (G. Wang et al., 2016). Yet, depending on the type of strategic action and the situation which a CEO faces, some characteristics are more influential than others (Hambrick & Mason, 1984; G. Wang et al., 2016). In the context of changes to top management team compositions by the CEO, such as hiring a CDO, the relationship of different CEO characteristics and this decision still requires further attention by scholars (G. Wang et al., 2016). Thus, characteristics, which appear to be relevant in the situation of CDO employment decisions, will be selected carefully and studied in more detail.

In the following several characteristics will be argued for, which might be relevant regarding the CEO's perception of their company, when facing digital transformation, and thus might lead to the CEO's decision for a CDO appointment. Relevant factors include the CEO's limited familiarity with the company, when being hired from outside of the company, the CEO's willingness to change the top management team when being early in the tenure and the CEO's lacking technological affinity due to an educational background without a technical focus. These characteristics are oftentimes studied in the context of upper echelons theory or appointment decisions (Georgakakis et al., 2018; Hambrick & Cannella, 2004; Hambrick & Mason, 1984; Menz & Scheef, 2014; Nath & Mahajan, 2008; Shi et al., 2018).*

A CEO's familiarity with their company drives their understanding of the organization, its products and technologies (Hambrick & Cannella, 2004; Harris & Helfat, 1997). While rising through different ranks and varying business areas within the company for several years provides essential access to internal networks and operational expertise (Michel & Hambrick, 1992), CEOs, who joined the company from outside, may lack company specific knowledge, connections and operational insights as gaining such

proficiencies requires a severe amount of time (Gabarro, 1987). Since digital transformation involves judging based on company specific situations, for example how to integrate new and existing processes (Hess et al., 2016), CEOs from outside of the company might observe the company's situation as highly complex and unpredictably challenging due to their limited knowledge about internal structures (Hambrick & Cannella, 2004; Singh et al., 2019). As mentioned before, such challenges and complexity include dissolving decoupled organizational silos (Singh & Hess, 2017) or linking existing competencies by acting as intermediary (Tumbas et al., 2017). As these tasks are typically attributed to the CDO position (Singh & Hess, 2017; Tumbas et al., 2017), outsider CEOs might perceive the need for appointing a CDO such that arising hurdles can be addressed appropriately. Thus, due to their limited awareness of the company specific situation, it can be argued that company outsider CEOs tend to decide in favor of creating a CDO position when facing digital transformation.*

A CEO's openness towards strategic change strongly varies depending on their tenure as CEO within the focal company. With increasing tenure within the top management team, the willingness to initiate strategic change declines (Wiersema & Bantel, 1992) and comfort with committing to the company's strategic status quo grows (Finkelstein & Hambrick, 1990) potentially leading to inertia and barriers when facing digital transformation (Vial, 2019; Westerman, Bonnet, & McAfee, 2014). On the other hand, previous research shows that CEOs, who recently joined the firm, demonstrate more openness towards strategically redirecting a company (Bigley & Wiersema, 2002; Weng & Lin, 2014). Such strategic redirections of new CEOs commonly imply changes to the top management team composition of the company (Finkelstein & Hambrick, 1990; Hutzschenreuter et al., 2012). Thus, when strategically redirecting the company in digital transformation, short tenure CEOs might perceive the creation of a dedicated CDO position as appropriate adoption of the C-level team, since the CDO position is dedicated to drive digital transformation (Singh & Hess, 2017). Therefore, one can argue that when short tenure CEOs face digital transformation, they are in favor of creating a CDO position as their perception of the company and of CDOs satisfies their needs when changing the top management team composition.*

As already argued by Hambrick and Mason (1984), the educational background of executives indicates their skill and knowledge base as ground for their decision-making. Not only the level of education, but the type of education is relevant in decision processes (Hitt & Tyler, 1991). This means that the type of a CEO's educational background severely impacts their perception of the need for a CDO as well (Singh et al., 2019). As digital transformation includes the adoption and combination of technologies in the fields of computing, information, communication and connectivity (Vial, 2019), one can argument that having no knowledge in these areas based on a corresponding educational degree might be disadvantageous for conducting digital transformation. CEOs without an education in science, technology, engineering or mathematics (STEM) might perceive digital transformation as complex or challenging due to their lacking technological affinity. Thus, technological aspects and their implications of digital transformation are potentially less predictable for CEOs with another degree such as a business-related degree (i.e., no STEM background), which will positively influence their decision to hire a CDO (Singh et al., 2019). This leads to formulating the first hypothesis:*

> *Hypothesis 1: The likelihood of having a CDO within the company will be influenced by a CEO's perception of the company situation. CEOs are more likely to perceive the necessity for a CDO, when (a) being a company outsider, (b) being early tenure and (c) having no STEM background.**

Upper echelons theory provides a well-established framework for examination of top managers' characteristics on strategic decisions (Hambrick, 2007). Scholars also provided evidence that top managers do matter in terms of organizational outcome. For example, Marcel (2009) derived that the existence of a COO has positive impact on company performance quantified by traditional performance measures, return on assets and market-to-book ratio. In contrast, several authors concluded that individual top managers' decisions are not, or at least only to a certain extent, related to the operational performance of companies. As an example, the study from Kanashiro and Rivera (2019) revealed that the adoption of a Chief Sustainability Officer for improving environmental performance of the company is not leading to the desired result. Therefore, skeptics frequently raise arguments that the interlinkage between a top

manager's characteristics and organizational outcome, i.e., company performance, cannot be theorized by the upper echelons perspective alone (Hambrick, 2007; McIntyre et al., 2007; Pettigrew, 1992). This means that despite the fact that individual top manager characteristics are influencing their activities and choices (Carpenter et al., 2004; Marcel, 2009; Nadkarni & Herrmann, 2010), upper echelons theory's explanatory power of the connection between these characteristics and the organizational outcome is limited (Kanashiro & Rivera, 2019; Nielsen, 2010; Pettigrew, 1992; Shrader & Siegel, 2007). In line with Hambrick's (2007) argumentation, understanding implications for company performance requires not only the investigation of an individual's characteristics, but also the joint examination of an executive group's characteristics, as this approach "… often yields better explanations of organizational outcomes" (p. 334). Thus, the following analysis will not focus merely on how CDO presence interferes with company performance, but in addition, also on how the CDO's characteristics as well as the digital transformation protagonists' characteristics jointly affect company performance, especially when considering different combinations of their characteristics. Further, pursuing this path of research was also recommended by Hambrick (2007) as part of his update on the original article on upper echelons theory from 1984 (Hambrick & Mason, 1984), in which he argues for future scholars to study combined effects of several executive characteristics on shaping company outcomes, like performance.*

In order to complement the upper echelons perspective and to shed light on implications of digital transformation protagonists on company performance, the theoretical lens will be extended by human capital theory and the resource-based view. By extending the theoretical point of view by human capital theory, it is possible to account for the contribution of a top manager's characteristics, i.e., the organizational human capital of the company, to the competitive advantage and therefore, to the organizational outcome (G. S. Becker, 1964). In addition, the resource-based view allows to draw conclusions from the composition of varying human capital characteristics compositions, and their joint impact on the competitive advantage, as the resource-based view argues about the importance and influence of all combined (human capital) resources on company performance (Barney, 1991). This approach

follows other examples of extending upper echelons theory by additional theoretical levels (Kanashiro & Rivera, 2019; Nielsen, 2010). This is also in line with current research, which addresses company performance implications of executives and corresponding theoretical foundations by a more exhaustive approach. While recent scholars in this field considered, for example, studying more fine-grained relationships of executives and the top management team (Georgakakis et al., 2017), developing new explanatory models through integration of different theoretical aspects (Liu et al., 2018) or synthesizing prior empirical results for theory testing (G. Wang et al., 2016), the approach of this thesis for analyzing implications of executives on company performance with a more comprehensive theoretical perspective was selected. Described theoretical concepts will be discussed in section 3.4, after debating the relevance of contingency related factors in relation to CDO presence in the next section.*

Despite a CEO's set of characteristics, it is also a company's situational factors, which influence the decision making of a company, its top management team and especially of the CEO when considering employing a CDO. When facing high complexity from within the company or the surrounding environment, i.e., the industry, in addition to digital transformation, the support provided by an additional top management team member, namely the CDO, might be required even more. This means that such factors potentially influence the likelihood of CDO presence within the company as well. Therefore, the theoretical framework will be extended by the viewpoints of contingency theory in order to address this line of thought (Burns & Stalker, 1961; Lawrence & Lorsch, 1967).

3.3.2 Contingency Theory

Starting with research by Burns and Stalker (1961), Woodward (1965) and Lawrence and Lorsch (1967), contingency theory provides a major theoretical view used to understand organizations (Donaldson, 2001). At its core, contingency theory argues that a company's effectiveness depends on the fit of its characteristics, like its structure, to contingencies, which reflect the company's situation (Burns & Stalker, 1961; Donaldson, 2001; Lawrence & Lorsch, 1967; Woodward, 1965). Such

contingencies range from environmental conditions of the company (Burns & Stalker, 1961) and organizational size (Child, 1975) to organizational strategy (Chandler, 1969). This means that companies and especially its top management team might try to achieve an optimal alignment or match of its structural choices and its strategical, environmental and organizational contingencies as some choices might be more beneficial for some companies than they would be for others (Donaldson, 2001; Lawrence & Lorsch, 1967; Nath & Mahajan, 2008).

Similar to the argument before, it is the CEO as head of the top management team, who is a key responsible for a company's decision making and structural choices (Hambrick & Cannella, 2004; Menz & Scheef, 2014). As mentioned before, a CEO's perception of the company's situation in digital transformation shapes their decision making processes (Hambrick & Mason, 1984). In addition, top executives like CEOs are also boundedly rational due to constraints from high demands on their workload and from limited processing capabilities (Cyert & March, 1963; March & Simon, 1958; Nath & Mahajan, 2008). Thus, facing oftentimes complex and uncertain conditions, CEOs structural choices and decision are also aimed at improving such conditions, especially when these conditions arise from a certain domain, and consequently aid their decision making (Hambrick & Cannella, 2004; Nath & Mahajan, 2008). As extending the top management team by a CDO represents such structural choices, contingency factors, which influence complexity and uncertainty of the company, also affect the decision of the CEO to employ a CDO. In literature, several scholars choose an approach including the application of contingency theory to explaining structural changes of the executive team, especially like employing functional or individual top management team members as response to environmental and organizational contingencies (Hambrick & Cannella, 2004; Marcel, 2009; Nath & Mahajan, 2008; D. M. Zorn, 2004). For example, the study of Zorn (2004) provided insights regarding increasing CFO presence in top management teams in companies with high uncertainty arising from financial reporting requirements. Similarly, Nath and Mahajan (2008) investigated how contingencies, which increase uncertainty and complexity within the top management team, affect CMO presence within companies.

Following these examples, contingencies, which increase complexity and uncertainty within the top management team and especially for the CEO, will be studied in terms of their influence on CDO presence. Like approaches of previous scholars, it is relevant to examine contingencies, which are related to some extant to the domain, which causes uncertainty and complexity, i.e., related to the domain of the investigated subject (Nath & Mahajan, 2008; D. M. Zorn, 2004). Subsequently, when studying contingencies affecting CDO presence due to complexity for the top management team and the CEO, it is critical to investigate contingencies, which lie in or around the domain of CDOs. In other words, conditions, which are related to the potential area of tasks and responsibilities of CDOs, should be examined. In the following, relevant contingencies will be derived. These commonly studied factors include the size of a company, the industry in which companies operate as well as existing relevant experience in the top management team, potentially provided by a CIO (Chaganti & Sambharya, 1987; Child, 1975; Hambrick & Cannella, 2004; Keck & Tushman, 1993; Lawrence & Lorsch, 1967; Menz & Scheef, 2014; Nath & Mahajan, 2008; Roh et al., 2016; D. M. Zorn, 2004). This choice of relevant contingencies departs from already chosen tracks by Firk et al. (2019) as identified in the systematic literature review, in order to provide novel results in CDO research.

As highlighted in the introduction, companies face a wide range of different required activities and challenges when conducting digital transformation (Vial, 2019). Unveiled by the systematic literature review and summarized in Figure 7, related tasks and responsibilities (oftentimes conducted by CDOs) in digital transformation are manifold, of which several are tailored around the coordination and management of digital transformation activities within the entire organization. For making digital transformation a success, it is important (among many other activities) to strengthen collaboration within the organization, implement cultural change and communicate about digital aspects (see Figure 7). This means that many tasks of digital transformation are directly related to the organization itself. While these activities might be less demanding in small organizations, the complexity of such activities increases significantly with the size of the company. For example, fostering collaboration becomes more demanding within larger companies, as it involves more employees

embedded in larger organizational structures and more complex hierarchical layers (Child, 1975). Since the high level of complexity resulting from associated responsibilities of such activities in larger companies adds to the already challenging responsibilities of CEOs, many companies and CEOs establish a CDO position (Donaldson, 2001; Singh & Hess, 2017). Thus, CEOs might be more likely to employ a CDO within the top management team when facing higher levels of complexity from digital transformation activities as a result of larger company sizes.

Next to organizational activities, digital transformation is also heavily shaped by the company's environment, i.e., the industry. Varying environmental conditions of companies can lead to higher complexity and task demands for CEOs (Hambrick & Cannella, 2004; Lawrence & Lorsch, 1967). Especially industries with high dynamics require more attention due to large demand from fast information processing (Eisenhardt & Bourgeois, 1988). One factor for describing high dynamism of an industry is rapid growth as an industry's growth might imply changing customer preferences or disruptive competitors (Hambrick & Cannella, 2004; Porter, 1980). In the context of pressure for digital transformation, companies face complexity from evolving customer behavior, new market entrants with disruptive business models and competitors, which might already master digital advances (Haffke et al., 2016). Therefore, CEOs are subject to demanding complexity from changing industry conditions when facing digital transformation. Consequently, one can argue that CEOs, who's companies operate in industries with stronger sales growth, are exposed to higher complexity and thus, following the same argument as before, are more likely to entrust a CDO with conducting digital transformation.

Finally, structural contingencies in form of existing expertise and experience within a company's top management team affects structural decisions of top management teams and especially of CEOs as well (Chaganti & Sambharya, 1987; Keck & Tushman, 1993; Nath & Mahajan, 2008). As pointed out before in section 2.5, many scholars argued for the potential overlap of the CDO position with the CIO position (e.g., Giebe, 2019; Singh & Hess, 2017; Tumbas et al., 2017; Walchshofer & Riedl, 2017; Zhan & Mu, 2016). In other words, this means that a CIO might already provide the company with necessary skills and competencies in order to successfully manage

digital transformation. Thus, from a contingency perspective, a CDO might not be required in companies, which already employ a CIO. Further, since CIOs might be well aware of the threat of newly created CDO positions alongside them (Gerth & Peppard, 2016), they might even encourage the top management team and the CEO to not employ a CDO and instead, entrust them with the challenges of digital transformation. Thus following a similar line of argument as Nath and Mahajan (2008), it could be assumed that CEOs of companies, which already possess a CIO within their top management team, are less likely to employ a CDO for digitally transforming the company. Combining all arguments from before, the second hypothesis follows:

> *Hypothesis 2: The likelihood of having a CDO within the company will be influenced by organizational and environmental company factors. CEOs are more likely to perceive the necessity for a CDO, when working in a (a) more complex company (large size), which operates in a (b) higher dynamic industry (stronger sales growth), and (c) when not having a CIO in their team.*

As pointed out in the end of section 3.3.1, the following sections will address human capital theory and the resource-based view in order to address implications of digital transformation protagonists on company performance, as complementing theoretical view for relevant characteristics of CEOs derived from upper echelons theory. Since contingency related factors are not only investigated in research related to an executive's presence within the company, but also commonly addressed in relation to such an executive's impact on company performance, derived contingency factors will also be put in perspective to a CDO's performance implications. Thus, the discussion of human capital theory and the resource-based view will be followed by an argument for the relationship between relevant contingency related factors and CDO presence in the context of company performance.

3.4 Performance Implications of Chief Digital Officers

3.4.1 Human Capital Theory

Organizational human capital, such as experiences, education, knowledge and skills of organizational members, has been of scholars' interest for a severe amount of time

(Crook et al., 2011). Argued by human capital theory, company productivity and resulting company performance is relying on company-specific skills and knowledge of its employees as their human capital may contribute to the competitive advantage of the company (G. S. Becker, 1964; Rosen, 1987). Especially human capital of C-level executives is of particular importance as they make strategic decisions for the future development of the company (Hambrick & Mason, 1984; Patzelt, 2010). Top executives and their human capital are a vital resource, which may turn into positive company value by achieving a competitive advantage (Bailey & Helfat, 2003).*

While human capital alone is not guaranteeing superior organizational performance, the company's competitive advantage is increasing with a higher level of competency and skill, which is suitable for achieving defined strategic objectives (Patzelt, 2010). As the perfectly qualified top manager und correspondingly superior human capital is typically rare (Castanias & Helfat, 1991; Crook et al., 2011), it is difficult for competing companies to replicate or acquire superior human capital, at least only at a high level of additional cost (Coff, 2002). In other words, companies with superior human capital, which is aligned with the strategic objective, should be able to achieve a competitive advantage and thus improve operational outcome (Crook et al., 2011; Shrader & Siegel, 2007).*

As the objective of digital transformation is to change or create new business models (Matt et al., 2015), superior human capital, which is fitting the strategic direction, technological requirements and entrepreneurial spirit of digital transformation, is contributing to the competitive advantage of these companies. Yet, such superior human capital resources are most often a scarce good (Patzelt, 2010). Arguably, the superior human capital for conducting digital transformation might be transferred into the company by hiring a CDO, in case the CIO is not able to provide required human capital for digital transformation (Haffke et al., 2016).*

Thus, CDOs incorporate a suitable resource for conducting digital transformation and leverage a company's digital resources for creating distinctive value (Bharadwaj et al., 2013; Singh & Hess, 2017). Following human capital theory, this implies that CDOs as human capital resources contribute towards the competitive advantage of companies und act as catalyst for increasing company performance. Moreover, scholars argued

that in environments with continuously increasing knowledge intensity, such as digital transformation environments, suitable human capital resources play an increasingly important role (Bosma et al., 2004; Unger et al., 2011). Thus, one can argue that CDOs have a positive impact on the organizational outcome of companies, i.e., company performance.*

Yet as discussed before, the level of a CDO's suitability in order to achieve superior human capital, depends on their experiences, education and knowledge (Crook et al., 2011; Shrader & Siegel, 2007). Following the call from Kanashiro and Rivera (2019), this thesis specifically investigates the C-level executive's characteristics in order to draw more fine-grained conclusions regarding organizational outcome. In the following this thesis investigates a CDO's affiliation with the company and industry before assuming the CDO position, and their educational background.*

When companies require new knowledge, a common approach is to hire additional employees with corresponding experience and skills from the external labor market (Hong, 2020). Especially in changing external environments, companies employ new C-level executives from outside of the company as an effective adaptive mechanism to cope with associated changes and challenges (Chatterjee et al., 2001). While this approach not only adds new perspectives and connections to outside environments, existing organizational assumptions and views will become challenged and new interpretations will be established (Chatterjee et al., 2001; Virany et al., 1992). By employing a CDO from outside of the company, one can claim that companies improve their human capital resources. Following human capital theory, outsider CDOs thus contribute to increasing organizational performance.*

Still, according to executive succession literature, new C-level executives might be favored when being familiar with the focal company's industry (Weng & Lin, 2014). In the same industry, executives are confronted with similar environmental conditions and are more efficient with exploiting their set of skills within the focal company (Huff, 1982; Weng & Lin, 2014). Therefore, on can assume that CDOs contribute their full potential and achieve competitive advantage for the company, when being hired from a similar industry.*

As argued by human capital theory, an executive's educational background is tightly connected to their impact on organizational outcome (G. S. Becker, 1964). While not only a CEO with a STEM background might be more comfortable with digital transformation, one can also argue that a CDO with an educational background in STEM is more proficient with understanding and applying technological innovations within the company as well. Accordingly, a CDO with a degree in STEM is able to provide superior human capital for the company improving the company's competitive advantage. Following the argumentation as before, CDOs educated in a field of science, technology, engineering, mathematics or similar, are positively contributing to and increasing organizational outcome. The third hypothesis follows:*

> *Hypothesis 3: The presence of a CDO will (a) positively impact company performance. CDOs will impact company performance more positively (or less negatively), when (b) being a company outsider, (c) being an industry insider and (d) having a STEM background.**

As discussed before, it is not only the CDO and their characteristics alone, which impact company performance. In addition, company performance is jointly affected by a CDO's characteristics and the digital transformation protagonists' characteristics, namely CDO, CEO and CIO. Especially, consideration of different combinations of these characteristics, i.e., varying human capital characteristics, is required in order to derive more fine-grained results. Thus, drawing on the resource-based view allows to discuss the importance and influence of all combined (human capital) resources on company performance (Barney, 1991).

3.4.2 Resource-based View

Digital transformation not only implies the adaption of existing business models, but also cultural change, alignment of structures and processes as well as effort and contribution of the entire organization (Kohli & Melville, 2019; Matt et al., 2015). Success of digital transformation and resulting outcomes depend also on all organizational members and their alignment on the digital vision (Fitzgerald et al., 2013). Since achieving mutual cooperation within the organization might encounter severe obstacles, support from all C-level executives is substantial (Matt et al., 2015).

Achieving successful digital transformation depends on the overall human capital resources of the company, and especially of involved C-level executives.*

According to the resource-based view, company-specific resources and their heterogeneous distribution among companies are the major source for a company's sustainable competitive advantage (Barney, 1991; Castanias & Helfat, 1991; Crook et al., 2011; Lippman & Rumelt, 1982). Scholars argue especially human capital resources, i.e., embedded knowledge in organizational members, to be most likely to strengthen competitive advantages due to its imperfectly imitable and universally valuable nature (Coff, 1997, 2002; Crook et al., 2011; Kogut & Zander, 1992). Especially, diversity in collective human capital, which therefore is difficult to replicate and simultaneously limited, allows for value generation and improved company performance (Nyberg et al., 2012; Richard, 2000). The top management team, as embodiment of human capital resource, is elementary for achieving competitive advantage (Castanias & Helfat, 1991).*

Diversified human capital resources should also be complementary in order to achieve value creation and robust hurdles for imitation (Auh & Menguc, 2006; Banker et al., 2011; Dierickx & Cool, 1989; Stieglitz & Heine, 2007). In contrast to complementation, Barney (1991) highlights that not all human capital of a company fulfills a relevant strategic purpose. Some human capital resources may not be relevant for competitive advantage, or even lead to a reduction of effectiveness and efficiency, and consequently harm the organizational outcome (Barney, 1991). While it is important to possess and acquire complementary human capital resources, companies should pay attention to avoid irrelevant, contradictory human capital.*

In the context of digital transformation, C-level executives should carefully assess their level of digital literacy and technological competencies in order to compensate potential identified resource gaps (Hess et al., 2016). For exploiting digital innovation, organizational change theory emphasizes that C-level executives are also required to concentrate efforts on change itself (Seo et al., 2004). Successful utilization of technological innovation is also dependent on addressing change at a company's mode of operation by organizational learning and change management competencies (Kohli & Melville, 2019). While change management may be part of CEOs' or CIOs'

competencies (Chun & Mooney, 2009), in digital transforming companies, scholars argued that it typically is CDOs, who enable the organization for transformation by exploiting their change management and transformation skills (Singh & Hess, 2017; Tumbas et al., 2017). Thus, it is crucial for companies to define and evaluate required competencies and, if necessary, complement their C-level team by a CDO for achieving appropriate human capital resources and sustainable competitive advantage. This means that several combinations of CDO, CEO and CIO as main digital transformation protagonists are favorable over others in order to derive sustainable competitive advantage and increased company performance. Therefore, it becomes necessary to investigate the joint contribution of C-level digital transformation protagonists, i.e., the different structural compositions of CEO, CIO and CDO characteristics (Vial, 2019).*

As already noted, a CIO's main focus lies on the company's IT landscape and traditional technology related areas (Chun & Mooney, 2009). Accordingly, companies with a CIO, who is capable to cover technological aspects of digital transformation, might not require an additional executive with a technological focus area. Especially, for ideally compensating a CIO, if existing in the company and who might not be able to provide transformational skills due to their main attention on traditional IT, additional human capital in form of a CDO without a STEM background might be required. As non-STEM background CDOs might be more proficient with change management and transformation management related competencies as well as other business-related knowledge, one can propose that CIO and non-STEM background CDO result in complementary human capital (Singh et al., 2019). As a consequence, both executives will benefit from clearly defined duties with a lower risk of overlapping activities (Catarino et al., 2018; Haffke et al., 2016), and thus with a lower risk of harming the organization (Barney, 1991). In line with the resource-based view, complementary human capital is more difficult to imitate for competitors leading to a sustainable competitive advantage and ultimately to increasing company performance. The first part of the fourth hypothesis follows:*

> *Hypothesis 4a: A non-STEM background CDO will have a more positive (or less negative) impact on company performance, when being complemented by a CIO.**

However, since CEOs with a degree outside of STEM are hypothesized to be more likely to hire a CDO for integrating digital expertise within the company (Singh et al., 2019), it is arguable that in that case, the CDO should possess a background in STEM. Following the thought of Hambrick and Cannella (2004), CDOs with a STEM background are able to assure full enrichment of the CEOs lacking technological competencies due to their background outside of STEM. While this implies a complementary set of human capital resources for the focal company, replication of such fitting human capital by other companies becomes more difficult leading to sustainable competitive advantage. Similar as before, if both executives possess an educational background in STEM, the CEO will potentially take the lead in digital transformation implying less impact of the CDO position (Singh et al., 2019). Thus, by the resource-based view, the composition of a CDO's technological affinity due to their educational background and a CEO's academic knowledge outside of STEM, provide complementary assets for the company leading to increasing company performance. Accordingly, the following can be stated:*

> *Hypothesis 4b: A STEM background CDO will have a more positive (or less negative) impact on company performance, when being complemented by a CEO with a non-STEM background.**

From upper echelons theory, the hypothesis followed that early tenure CEOs will be more likely to hire a CDO as they are more open towards strategic change (Wiersema & Bantel, 1992). Similar to the assumption of Hambrick and Cannella (2004), it is arguable that the willingness of CEOs in an early tenure to hire a CDO also implies that such CEOs provide an environment of support for their CDOs regarding digital transformation as they approve of strategically redirection the company (Bigley & Wiersema, 2002; Weng & Lin, 2014). On the other hand, long tenure CEOs typically tend to block major change of the company by sticking to its strategic status quo (Finkelstein & Hambrick, 1990), which implies that a CDO's ability to initiate and drive digital transformation is limited. As highlighted by Barney (1991), limited freedom of movement for CDOs might imply less effectiveness and consequently harm for company performance. Accordingly Singh et al. (2019) stated that if CEOs don't drive and embrace digital transformation, expected results won't be delivered. Therefore,

one might argue that CDOs and early tenure CEOs are valuable and complementing human capital resources resulting in value generation and growing company performance. The third part of the hypothesis follows:*

*Hypothesis 4c: The CDO will have a more positive (or less negative) impact on company performance, when being complemented by a CEO, who is early in their tenure.**

Finally and as argued before, CEOs, who joined the company from outside may lack company internal networks and knowledge (Gabarro, 1987). In line with the argument of Singh et al. (2019), by employing a CDO, who is a company insider and has access to company specific knowledge and contacts, this disadvantage might be leveled out. In case a company insider CDO is not available, a CDO from the same industry might still be familiar with the company, its competitors and suppliers and at least provide profound industry knowledge for complementing the company outsider CEO (Weng & Lin, 2014). Following the same argument as before, it therefore follows that company insider CDOs, or at least industry insider CDOs, are able to combine company and industry related expertise with the advantages of the CEO's unbiasedness from being a company outsider. Due to the limited nature of this human capital resource composition, competing companies may find it challenging to imitate this constellation. Subsequently, the joint human capital resources of CDO and CEO in both described cases lead to sustainable competitive advantage. Thus, following the argument from the resource-based view, this will lead to increasing organizational performance. Accordingly, the last parts of the fourth hypothesis follow:*

*Hypothesis 4d: A company insider CDO will have a more positive (or less negative) impact on company performance, when being complemented by a CEO, who is a company outsider.**

*Hypothesis 4e: An industry insider CDO will have a more positive (or less negative) impact on company performance, when being complemented by a CEO, who is a company outsider.**

While a CDO's implications on company performance are assumed to depend on the complementary fit of their characteristics with human capital of other relevant C-level executives as they jointly contribute more or less to the competitive advantage of the

company, a CDO's impact within the company is also contingent upon the company's environmental and organizational conditions. Thus, a contingency perspective on CDOs and their ability to improve company performance will be derived in the following.

3.4.3 Contingency Theory

In section 3.3.2, contingency theory was introduced, and several industry and company related factors discussed, which might affect CDO presence in companies. Following the logic of contingency theory, the impact of a CDO on company performance is dependent on the level of derived fit with environmental and organizational contingencies (Lawrence & Lorsch, 1967). This means that to the extent that companies and CEOs face such environmental and organizational conditions, which promote CDO presence within companies, CDO presence will also help them to increase company performance as CDOs are present for managing such conditions.

For all but one of the derived contingencies, this effect is expected. As highlighted before and derived based on the resource-based perspective, the impact of CDOs in the presence of a CIO within the company not only depends on the mere presence of CDOs, but on different human capital characteristics of the CDO. Thus, the fact of CIO presence is not further considered in the light of contingency theory and CDO company performance implications. Overall, a similar line of argumentation was chosen by previous scholars, who assessed the impact of functional top management team member presence on company performance (Menz & Scheef, 2014; Nath & Mahajan, 2008).

Recalling from before, the presence of CDOs within a company's top management team was hypothesized to be contingent upon the company's complexity resulting from a larger size as well as a more dynamic industry facing stronger sales growth. Thus, companies facing such conditions are expected to perform better in terms of company performance when a CDO is present within the top management team. Summing up, the following fifth and last hypothesis follows:

> *Hypothesis 5: The CDO will have a more positive (or less negative) impact on company performance, when working in a (a) more complex company (large size), which operates in a (b) higher dynamic industry (stronger sales growth).*

In order to test and assess derived hypothesis, the remainder of this thesis is structured as follows. While chapter 4 will address hypotheses one and two, which are related to CDO presence, chapter 5 will focus on hypotheses regarding a CDO's performance implication, i.e., hypotheses three, four and five. Within each chapter, suitable methodologies will be presented and applied, and results will be discussed.

4. Research Question Two: Factors Influencing Chief Digital Officer Presence in Companies[33]

4.1 Objective

Recalling from previous sections and the results from the systematic literature review, research on CDO presence within companies is limited as it has been addressed only little so far by scholars (see Figure 10, research opportunity #5). Authors like Firk et al. (2019) and Kunisch et al. (2020) shed initial light on some antecedents of CDO presence, yet a holistic view needs to be derived and requires further attention. In order to extend current research, initially proposed research question two has been adjusted to the following:

(2) Which CEO characteristics, and organizational and environmental company factors influence CDO presence within a company?

By answering this research question the objective of this chapter is to derive additional insights regarding CDO presence from an upper echelons und contingency theory perspective. As laid out before, the focus of this thesis' analyses will lie on CEO characteristics as determining factors for CDO presence in the upper echelons context, since decision making regarding employing new top management team members is expected to depend on the CEO's perception of the company and thus on their characteristics. In addition, further attention will be targeted on environmental and organizational conditions of the company as driving factors for CEOs and companies to cope with certain situational aspects of digitally transforming companies.

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[33] Several parts of this chapter were used word by word (potentially with the exception of a few words) or with rearrangements (in order to match style and format of this thesis) for the preparation of a scientific paper. Affected paragraphs have been marked with an asterisk (*) at the end. In addition, some marked paragraphs were further enriched by explanations, which had not been used for the described paper. For further information regarding publication outlets and corresponding status, see the Foreword on page II.
Further, selected results of this chapter (incl. their discussion and visualization) were used for the preparation of the scientific paper as well. As no paragraphs considering these results were used word-by-word or with rearrangements as explained above, dedicated markings with an asterisk were not inserted. Related tables and figures were not marked as well.

Since the variable of interest, namely CDO presence, is of binary nature, meaning that companies either possess a CDO within their top management team or not, as well as the overall data basis consists of a panel structure (which will be discussed in the next section), a generalized estimating equations (GEE) model was chosen, which allows for addressing implications of a binary dependent variable, i.e., a binomial distribution, and correlation within responses of subjects, i.e., several measurements for companies over time (Liang & Zeger, 1986; Zeger & Liang, 1986). In the context of studying executive appointment decisions, this approach was commonly chosen by previous scholars (e.g., Hambrick & Cannella, 2004; Menz & Scheef, 2014; Nath & Mahajan, 2008). Further, GEE models are also appropriate when included covariates are partially constant over time, such as characteristics of top management team members (Kolev & McNamara, 2020). In the following the approach for data gathering will be presented and all collected data will be introduced. Following that, the methodology of GEE models will be introduced in section 4.3.

4.2 Sample Selection and Data Description

4.2.1 Data Gathering Process

The analyses of this chapter (and the next chapter) are based on a sample of companies listed in the S&P 500 index,[34] which consists of the 500 largest companies by market capitalization in the United States (US), due to accessibility of data and reporting standards of publicly traded US companies. In order to create a longitudinal large-scale sample for our analysis, company data from 2007 to 2019 will be investigated. As not all companies conducted their initial public offering in 2007, the panel data is not perfectly balanced. All company data was drawn from S&P Capital IQ and missing data was complemented based on publicly available data such as 10-K reports. For collection of demographic data on CEOs and CDOs, publicly available data (e.g. 10-K, 10-Q), company websites, information published in news articles (researched with Factiva) and information from LinkedIn was used. After excluding

[34] The sample includes all companies, which were listed in the S&P 500 index as of 02.04.2020 following a similar approach as Menz and Scheef (2014).*

those companies with missing information or unusable date (e.g. for one company it was not possible to identify the CDO's tenure, thus the company was excluded from the sample), the overall sample consists of 491 companies, of which 147 employed a CDO at least once during the selected time period. Out of the 147 CDO companies, 17 companies had two CDOs during the observed period. The final sample comprises 5,988 company-years spanning a time period of 13 years, meaning a comprehensive set of panel data. Panel data (or longitudinal data) consists of repeated observations on the same cross section of, for example, individuals, households, firms, or cities over time (Wooldridge, 2002).*

4.2.2 Description of Measures

CDO existence. For identification of all employed CDOs among companies of the sample, the same sources were used as described before, and the following research strategy was applied. It was searched for "Chief Digital Officer" (and abbreviation) together with each company name. In line with previous top management team research, other titles representing the CDO position were also allowed as many companies used different titles (Kanashiro & Rivera, 2019; Menz & Scheef, 2014; Shi et al., 2018). Thus, the search terms "(Vice) President Digital" and "Head of Digital" were used as well. In order to ensure that only positions were included, which are comparable to the CDO position, all available data for each potential CDO was examined and excluded, for example, if the position was not acting on a global company and international level or described activities were not in line with results describing the CDO position as derived as part of the systematic literature review (e.g., Singh & Hess, 2017; Tumbas et al., 2017). Further CDOs were excluded, if an existing employee just gained the additional title CDO or similar. For example, CDOs were only included as "Chief Digital Officer", if they were not also CIO or CMO(e.g. if a CIO was later named CDO in addition to being CIO). The variable *CDO existence* was then coded as one, if there was an executive officer (or similar), which was dedicated to digital transformation for each company-year and zero otherwise.*

In preparation for testing the upper echelons theory related hypothesis one regarding the influence of CEO characteristics on CDO presence as derived as in section 3.3.1,

the following set of independent variables was defined. *CEO company outsider* was set to one, if the CEO assumed the position from outside of the company, i.e., the CEO was with another company before being named CEO in the focal company, and zero otherwise (Schmid & Dauth, 2014). *CEO tenure* was measured as number of years since the CEO assumed their current position, starting from zero for the year of taking office (Zhang & Rajagopalan, 2010). Further, *CEO STEM background* was defined as dummy variable set to one, if at least one educational degree of the CEO was within STEM, and zero otherwise (Drechsler et al., 2019).*

Further independent variables were operationalized for investigating hypothesis two (see section 3.3.2) regarding the influence of contingency related conditions of the company on CDO presence. First, the variable *industry revenue growth* was measured as median revenue growth for each industry based on the two-digit global industry classification standard (*GICS*), between the last year and the current year among all companies within this sample, which will be described below (similar to Hambrick & Cannella, 2004). Further, *company size* of a company was calculated as the natural logarithm of book value of assets (A. A. Cannella et al., 2008). Finally, the independent variable *CIO presence* was set to one in case companies reported a CIO in their 10-K filings, and zero otherwise (Zhan & Mu, 2016).*

Following previous research in the top management team literature, an extensive set of variables was included to the analyses in order to control for potential factors that might affect the propensity of having a CDO. *Company age* was operationalized as number of years since foundation of the company (Campbell & Vera, 2010). *Risk* was initialized as annualized standard deviation of daily stock price returns for each company-year (M. Li & Roberts, 2018). Further, a company's number of *segments* was included as well (M. Li & Roberts, 2018). The analyses were also controlled for a company's previous year performance. For operationalizing company performance, two performance measures commonly used in literature were included, *Tobin's Q*,[35] approximated as market capitalization plus book value of debt, all divided by book

[35] Tobin's Q describes the ratio of the market value of company assets to their replacement costs (Tobin, 1969).

value of assets (Coles et al., 2008), and return on assets (*ROA*), measured by net income over total assets (Belenzon et al., 2019; Hambrick & Cannella, 2004). Thus, a company's previous performance, i.e., *previous ROA* and *previous Tobin's Q*, was added by including either the lagged corresponding value of *ROA* and *Tobin's* Q (Hambrick & Cannella, 2004; M. L. Zorn et al., 2017).[36] *Revenue growth* between the previous year and the current year was added as well (Hambrick & Cannella, 2004). Further, *leverage* was included and calculated as book value of liabilities divided by book value of assets (M. Li & Roberts, 2018). It was also controlled for *CEO age* (Belenzon et al., 2019). Finally, *CEO gender* was defined as one in case the CEO was male and as two in case the CEO was female, and included in the model as controlling factor a well (Schmid & Dauth, 2014).*

Next to company specific features, industry related controls were also included as the adoption of a CDO within the company might be influenced by other industry and competitor related factors. Thus, *previous industry ROA* and *previous industry Tobin's Q* were operationalized as median values for each industry and year of lagged *ROA* and lagged *Tobin's Q* respectively based on the two-digit *GICS*, and either of both were used within the models as described below (Hambrick & Cannella, 2004). Finally, a continuous *year* variable was included as well in order to account for time effects (Menz & Scheef, 2014) as well as the two-digit *GICS* for general industry trends as individual dummy variables per industry (Hambrick & Cannella, 2004).[37] Overall, all control variables are commonly used in the context of top management team research, especially regarding appointment decisions of individual top management team members, and were therefore included for the analyses within this (and the next) chapter. For addressing reverse causality, all time-varying independent and control variables are lagged by one year (Menz & Scheef, 2014).*[38]

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[36] As highlighted, for example, by Aboramadan (2021), there are many different measures for company performance, which are used throughout (top management team) literature. Examples include employment growth (Hmieleski & Ensley, 2007), net cash flow (Ensley & Hmieleski, 2005), profitability (Amason et al., 2006) or capital raised at the initial public offering (Zimmerman, 2008). In this study, *ROA* and *Tobin's Q* have been selected arbitrarily while assuring the inclusion of one market based external measure and one company based internal measure.

[37] As it can be observed in section 4.5.1, CDO adoption rates differ across time and industry. Thus, accounting for time and industry trends by including them in the models is required.

[38] The reasoning for this approach, i.e., endogeneity, will be discussed below in section 4.5.2.

Table 8 provides an overview of variables included in models for testing hypotheses one and two, but also for assessing hypothesis three, four and five in chapter 5. As an appropriate approach for investigating the presented type of dependent variable and panel data structure, the methodology of GEE models is commonly exploited, which will be described in the following.

Variable	Operationalization	Exemplary studies using similar variables
Dependent variable		
CDO existence	1 = Yes 0 = No	Menz and Scheef (2014), Roh et al. (2016)
Independent variable		
CEO company outsider	1 = joined as CEO from outside 0 = otherwise	P. M. Lee and James (2007), Schmid and Dauth (2014)
CEO tenure	Years since assuming CEO position	Zhang and Rajagopalan (2010), Weng and Lin (2014)
CEO STEM background	1 = background in STEM 0 = otherwise	D. M. Zorn (2004), Drechsler et al. (2019)
Industry revenue growth	Median of industry revenue growth	Hambrick and Cannella (2004), Nath and Mahajan (2008)
Company size	Natural logarithm of total assets	A. A. Cannella et al. (2008), Campbell and Vera (2010)
CIO presence	1 = Yes 0 = No	Zhan and Mu (2016), Kunisch et al. (2020)
Control variable		
Company age	Years since company foundation	Campbell and Vera (2010), Belenzon et al. (2019)
Risk	Annualized standard deviation of daily stock returns	M. Li and Roberts (2018), Bose and Leung (2019)
Segments	Number of segments	Coles et al. (2008), M. Li and Roberts (2018)
ROA	Net income divided by total assets	Hambrick and Cannella (2004), Belenzon et al. (2019)
Tobin's Q	Market capitalization plus value of debt, all divided by total assets	Coles et al. (2008), Nath and Mahajan (2008)
Revenue growth	Yearly growth in total revenue	Mian (2001), Hambrick and Cannella (2004)
Leverage	Total liabilities divided by total assets	Coles et al. (2008), M. Li and Roberts (2018)
CEO age	Years since birth	Nadkarni and Herrmann (2010), Belenzon et al. (2019)
CEO gender	2 = female 1 = male	Schmid and Dauth (2014), Kolev and McNamara (2020)
Industry ROA	Median of industry ROA	Michel and Hambrick (1992), Hambrick and Cannella (2004)
Industry Tobin's Q	Median of industry Tobin's Q	Hambrick and Cannella (2004), Bose and Leung (2019)
Year	Year	Menz and Scheef (2014), M. L. Zorn et al. (2017)
GICS (Industry)	Two-digit GICS industry sector	Hambrick and Cannella (2004), Sanders and Tuschke (2007)

Table 8: Overview Variables Included in Models for Hypotheses Testing
Source: Own illustration.

4.3 An Introduction to Generalized Estimating Equations Models

In organizational research, scholars oftentimes had to face the issue of applying non-ideal methodologies for analyzing their data, because the response variable, or dependent variable, of their data set is generally not following a normal (also known as Gaussian) distribution (Ballinger, 2004). Such variables of interest could be, for example, turnover intentions, innovations, absenteeism or decision making (Ballinger, 2004), like it is the case for the analyses of this chapter, i.e., CDO presence. Although non-normal distributed data could be transformed or aggregate in order to achieve an approximately normal distributed dependent variable, such approaches entail drawbacks regarding analytical precision and interpretation (Ballinger, 2004; Gardner et al., 1995; Harrison, 2002). An additional problem arises when the analyzed data is characterized by correlation within investigated subjects as it is typically the case for data clustered by subgroups or longitudinal data, which in terms of this thesis is panel data as described before (Ballinger, 2004). Without going into technical details regarding estimation methods of statistical models like ordinary least squares (OLS) or maximum likelihood estimation, neglecting correlations within studied subjects might result in incorrect estimations of the regression model parameters as these might be, for example, less efficient (Ballinger, 2004; Diggle et al., 2002).[39] As confidence in regression results is essential, scholars should focus on methodologies, which result in both efficient and unbiased parameter estimates (McCullagh & Nelder, 1989). Thus, an application of regular pooled OLS regression or distribution adjusted regression (e.g., logit regression), might not be sufficient enough when analyzing longitudinal data with a non-normally distributed random variable.[40]

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[39] For further information about and properties of the OLS estimator and maximum likelihood estimator, see, for example, Studenmund (2014) and Wooldridge (2002).

[40] Note that there are many more approaches to or nuances for analyzing statistical models, especially based on longitudinal data, for example, generalized linear mixed models for (continuous) longitudinal data (e.g., Gardiner et al., 2009; Zeger et al., 1988). Yet, as the focus of this thesis is not to discuss several statistical approaches to data analysis, other statistical methods/models will not be further discussed. In addition, this thesis follows a common approach in top management team literature when discussing executive appointment decisions by applying GEE models (e.g., Hambrick & Cannella, 2004; Menz & Scheef, 2014; Nath & Mahajan, 2008).

Developed by Liang and Zeger (1986) and Zeger and Liang (1986), GEE models account for correlation of the dependent variable within investigated subjects and allow for analyzing dependent variables that are not normally distributed. Thus, GEE models are able to provide more efficient and unbiased regression estimates when analyzing non-normal dependent variables based on longitudinal data or repeated measurements (Liang & Zeger, 1986; Zeger & Liang, 1986). GEE models are an extension of generalized linear models (GLM), which provide the grounds for analyzing dependent variables that are non-normally distributed by exploiting the quasi-likelihood method and an iterative estimation approach (McCullagh & Nelder, 1989; Nelder & Wedderburn, 1972), in the sense of also accounting for correlation structures of the dependent variable within studied subjects (M. Wang, 2014). Therefore, GEE models can be applied for hypothesis testing regarding the influence of covariates on binomially or other exponentially distributed dependent variables (such as Poisson or Gamma distributions) within studied subjects, for example, within a company over multiple or repeated measurements across time (Ballinger, 2004; Liang & Zeger, 1986; Zeger & Liang, 1986). For this thesis, the focus lies on GEE models, which produce a population average or marginal (expectation) model (Ballinger, 2004; Zeger et al., 1988).[41] Marginal models provide regression coefficients, which describe the population average response for observations defined by the same covariates to changes of these covariates, i.e., as a function of covariates (Ballinger, 2004; Zeger et al., 1988).

In simple terms and like many other models, the approach of this method is to study longitudinal data for an outcome of a subject at a certain time as a function of covariates (Zeger et al., 1988). Thus, for giving a brief overview and understanding regarding the concept of GEE models, assume that a panel data set consists of N different subjects. For each subject i (for $i = 1, \ldots, N$), suppose that there are T

[41] Alternatively, GEE models are also applicable for investigating mixed generalized linear models, also known as subject-specific models (Zeger et al., 1988). Yet, for the sake of simplicity and without drifting into technical details, subject-specific models will not be further discussed here. Also, by adopting a population average GEE model, less strict assumptions have to be made (which will be discussed below), for example, compared to mixed models and thus, potentially result in more useful approximations (Hubbard et al., 2010).

observations,[42] where $Y_{i,j}$ represents the j-th response (for $j = 1, \ldots, T$), i.e., the dependent variable, and $X_{i,j}$ denotes a $p \times 1$ vector of covariates, such as independent and control variables (i.e., p equals the amount of covariates).[43] Further, let $Y_i = (Y_{i,j}, \ldots, Y_{i,T})'$ denote the $T \times 1$ vector of responses for subject i with the mean (or expectation) vector $\mu_i = (\mu_{i,1}, \ldots, \mu_{i,T})'$ where $\mu_{i,j}$ is the corresponding j-th mean. It is assumed that responses are independent across subjects but correlated within subjects. The marginal model defines the relationship between the mean $\mu_{i,j}$ and the covariates $X_{i,j}$ as

$$g(\mu_{i,j}) = X_{i,j}^{'} \beta \,, \tag{1}$$

where g is a known function and commonly referred to as the link function, and β is the unknown $p \times 1$ vector of regression coefficients with true value β_0. Further, the conditional variance of $Y_{i,j}$ given $X_{i,j}$ is defined as

$$Var(Y_{i,j} \mid X_{i,j}) = v(\mu_{i,j})\, \phi \,, \tag{2}$$

where v is a known variance function of $\mu_{i,j}$ and ϕ is called the scale parameter. Note that depending on the distribution of the dependent variable $Y_{i,j}$, the scale parameter ϕ might be estimated throughout the estimation procedure.[44] Then, the variance-covariance matrix of Y_i defined as

$$V_i = \phi\, A_i^{1/2}\, R_i(\alpha)\, A_i^{1/2} \,, \tag{3}$$

with $A_i = Diag\{ v(\mu_{1,j}), \ldots, v(\mu_{i,T}) \}$ being a diagonal matrix. $R_i(\alpha)$ denotes the so-called working correlation structure, which describes the pattern of the measurement

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[42] This assumption would also be generalizable to varying amounts of measurements n_i per subject i (for $i = 1, \ldots, N$) (M. Wang, 2014). Also note that in the case of panel data, i.e., repeated measurements over time, the assumption on the amount of measurements does not imply any requirements regarding the intervals of measurements. This means that observations are not required to be measured, for example, every year or every month, and instead any timepoint per measurement might be suitable.

[43] The notation of this chapter will be following the notation of M. Wang (2014).

[44] For example, if $Y_{i,j}$ is a continuous variable, then $v(\mu_{i,j})$ is equal to one and ϕ, which represents the error variance, will be estimated. In case $Y_{i,j}$ is a count variable, then $v(\mu_{i,j}) = \mu_{i,j}$ and ϕ is set to one (M. Wang, 2014).

within subject *i.* The working correlation matrix is of size $T \times T$ and depends on a vector of association parameters described by α. The iterative algorithm for calculating the estimates $\hat{\alpha}$ for α is based on the Pearson residuals,[45] derived from the current estimated value $\hat{\beta}$ for β. Table 9 provides an overview of frequently used working correlation structures and corresponding estimates for α.[46]

Name	**Correlation structure**	**Sample matrix for $R_I(\alpha)$ (3×3)**	**Estimator $\hat{\alpha}$ for α**
Independent	$Corr(Y_{i,j}, Y_{i,k}) = \begin{cases} 1 & j = k \\ 0 & j \neq k \end{cases}$	$\begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$	N/A
Exchangeable	$Corr(Y_{i,j}, Y_{i,k}) = \begin{cases} 1 & j = k \\ \alpha & j \neq k \end{cases}$	$\begin{pmatrix} 1 & \alpha & \alpha \\ \alpha & 1 & \alpha \\ \alpha & \alpha & 1 \end{pmatrix}$	$\hat{\alpha} = \frac{1}{(N'-p)\phi}\sum_{i=1}^{N}\sum_{j\neq k} e_{i,j}e_{j,k}$ $N' = \sum_{i=1}^{N} n_i(n_i-1)$
k-dependent	$Corr(Y_{i,j}, Y_{i,k}) = \begin{cases} 1 & m = 0 \\ \alpha_m & m = 1, \ldots, k \\ 0 & m > k \end{cases}$	$\begin{pmatrix} 1 & \alpha_1 & 0 \\ \alpha_1 & 1 & \alpha_1 \\ 0 & \alpha_1 & 1 \end{pmatrix}$	$\widehat{\alpha_m} = \frac{1}{(K_m-p)\phi}\sum_{i=1}^{N}\sum_{j\leq n_i-m} e_{i,j}e_{j,j+m}$ $K_m = \sum_{i=1}^{N}(n_i-m)$
Autoregres-sive AR(1)	$Corr(Y_{i,j}, Y_{i,j+m}) = \alpha^m \quad m = 0, 1, \ldots, n_i-j$	$\begin{pmatrix} 1 & \alpha & \alpha^2 \\ \alpha & 1 & \alpha \\ \alpha^2 & \alpha & 1 \end{pmatrix}$	$\hat{\alpha} = \frac{1}{(K_1-p)\phi}\sum_{i=1}^{N}\sum_{j\leq n_i-1} e_{i,j}e_{j,j+1}$ $K_1 = \sum_{i=1}^{N}(n_i-1)$
Unstructured	$Corr(Y_{i,j}, Y_{i,k}) = \begin{cases} 1 & j = k \\ \alpha_{j,k} & j \neq k \end{cases}$	$\begin{pmatrix} 1 & \alpha_{1,2} & \alpha_{1,3} \\ \alpha_{2,1} & 1 & \alpha_{2,3} \\ \alpha_{3,1} & \alpha_{3,2} & 1 \end{pmatrix}$	$\widehat{\alpha_{j,k}} = \frac{1}{(N-p)\phi}\sum_{i=1}^{N} e_{i,j}e_{j,k}$
…	…	…	…

Table 9: Overview Working Correlation Structures for GEE models[47]
Source: Adapted from M. Wang (2014)*.*

[45] The Pearson residual is defined as $e_{i,j} = \frac{(Y_{i,j}-\mu_{i,j})}{\sqrt{v(\mu_{i,j})}}$. See also Cordeiro and Simas (2009).

[46] Note that Table 9 is not comprehensive. For example, the Toeplitz working correlation structure is not included (M. Wang, 2014). See also Hardin (2005).

[47] In the case of this thesis, $n_i = T$ (for i = 1, …, N).

Further, the estimator $\hat{\phi}$ for the scale parameter ϕ,[48] if required to be estimated, can be obtained by solving

$$\hat{\phi} = \frac{1}{NT\text{-}p} \sum_{i=1}^{N} \sum_{j=1}^{T} e_{i,j}^2 \ . \tag{4}$$

Now the vector of regression coefficients β can be estimated as $\hat{\beta}$ by solving the estimating equation

$$U(\beta) = \sum_{i=1}^{N} D_i' V_i^{-1} (Y_i - \mu_i) = 0 \ , \tag{5}$$

with the partial derivative $D_i' = \partial \mu_i / \partial \beta_i$. According to Zeger and Liang (1986), based on GEE including a sandwich estimator (also known as robust covariance estimator[49]) for the covariance matrix V_i, the resulting estimator $\hat{\beta}$ and corresponding standard errors are asymptotically consistent, even when the working correlation structure $R_i(\alpha)$ is misspecified.[50]

The choice for a suitable link function g, which models the relationship between the expectation of the response variable and the covariates as an additive model (Ballinger, 2004; McCullagh & Nelder, 1989), is dependent on the selected correlation structure of the dependent variable. While the simplest link function is the identity function for Gaussian dependent variables, which means no transformation of $\mu_{i,j}$, more complex link functions for non-Gaussian response variables include, for example, the power link, reciprocal link, probit link or logit link function (Ballinger, 2004).[51]

Further, the operationalization of a GEE model involves the specification of a working correlation structure $R_i(\alpha)$ as defined as before, which allows an estimation

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[48] Note that in the general case with an individual amount of measurements n_i per subject i, the estimator $\hat{\phi}$ for the scale parameter ϕ would have a different fraction in front of the sums, i.e., $\frac{1}{K\text{-}p}$ with $K = \sum_{i=1}^{N} n_i$ and the second sum would range until n_i instead of T.

[49] For further details on the sandwich estimator (such as its form) and its assumptions and implications for other included parameters, see, for example, Liang and Zeger (1986), M. Wang (2014) or Lu et al. (2007).

[50] Note that when the working correlation structure is misspecified, some cases might lead to situations when the estimator for α does not exist or the resulting estimator for β is not optimal (Crowder, 1995). A possible solution to this problem is given by Qu et al. (2000) by using quadratic inference functions (which was not necessary to be applied in this thesis).

[51] For an overview of potential link functions depending on the dependent variable's distribution, see page 148 of Ballinger (2004).

considering the response variable's correlation within each subject (Liang & Zeger, 1986). Although GEE models are an extension of GLM models, which utilize maximum likelihood theory (McCullagh & Nelder, 1989), GEE models are based on quasi-likelihood theory (Wedderburn, 1974). This implies that model selection characteristics, which have been developed assuming maximum likelihood theory, are not applicable when studying GEE models (Cui & Qian, 2007). Therefore, commonly used criteria like Akaike's information criterion (AIC) (Akaike, 1974) or Bayesian information criterion (Schwarz, 1978) are not directly utilizable (Cui & Qian, 2007; M. Wang, 2014).[52] Thus, Pan (2001) proposed a modified version of AIC as a method for model selection in the GEE context, called the quasi-likelihood under the independence model criterion (QIC),[53] which can be used for selecting the best working correlation structure. It is interesting to note that when assuming a linear model with a normally distributed dependent variable and when applying an identity link function, the GEE model collapses to a standard OLS equation (Litman et al., 2011).

Finally, in order to derive consistent estimates even when the working correlation structure is not correctly specified, the GEE model requires one additional assumption to hold true regarding the data structure. In case of missing data within the longitudinal data set, lacking data points need to be missing completely at random or there is only a diminishing amount of missing data (Rubin, 1976; Zeger & Liang, 1986). In case the probability of missing data depends on past values of the dependent variable, parameter estimates might be compromised, i.e., the GEE model is not robust to misspecified working correlation structures (C. J. W. Zorn, 2001).

Next, the discussed methodology of GEE models will be applied in the context of studying CDO presence within companies.

[52] The Bayesian information criterion is also known as the Schwarz information criterion.
[53] For details on QIC, which is based on adjustments of AIC, see Pan (2001) or Cui and Qian (2007).

4.4 Application of a Generalized Estimating Equations Model for Investigation of Chief Digital Officer Presence

As described in previous sections and when deriving all hypotheses, the main objective is to model the likelihood of having a CDO within a company given a CEO's perceptions influenced by certain characteristics, and organizational and environmental company factors. In addition, several control variables were also considered as important when discussing the propensity of CDO presence within a company. By definition of the dependent variable *CDO existence*, which assumes either the values one or zero, i.e., when a company employed a CDO for a given year or not, it is obvious that this variable does not follow a normal distribution (as already pointed out before). Instead, the variable of interest is binomially distributed (Ballinger, 2004).[54] In order to convert a linear combination of covariates with any range to a probability scale, i.e., between values from zero to one, scholars frequently exploited a logit (e.g., Dalton & Kesner, 1985; Eccles et al., 2014; Firk et al., 2019; Hambrick & Cannella, 2004; Hong, 2020; Kunisch et al., 2020; Lauterbach & Weisberg, 1994; MacKenzie et al., 2018) or probit modeling approach (e.g., Arnold & Javorcik, 2009; Cui, 2007; Harris & Helfat, 1997; Razzaghi, 2013; Weng & Lin, 2014; Wooldridge, 2002; M. L. Zorn et al., 2017) in order to investigate similar (binary) subjects. As both approaches are commonly used by researchers and theoretical justification for preferring one approach over the other in binary settings seems to be absent (Razzaghi, 2013), both types of link function will be considered.[55] The logit link function is of the general form as follows

$$logit\left(\theta\right) = ln\left(\frac{\theta}{1-\theta}\right), \tag{6}$$

where θ is the probability of interest (MacKenzie et al., 2018).

[54] In this case, the variable can also be described as Bernoulli or binary variable (King & Zeng, 2001; Zeger & Liang, 1986). This is a special case of the binomial distribution with one draw only.
[55] Due to its definition, the probit link function is more complicated to compute by hand compared to the logit link function. Yet, modern statistical software packages provide support for both probit and logit link function. Overall, both link functions follow a sigmoid-shaped curve and oftentimes yield similar results (Razzaghi, 2013).

Regarding the probit link function, the general form can be displayed as follows

$$probit\ (\theta) = \Phi^{-1}(\theta), \tag{7}$$

where θ is again the probability of interest, and Φ^{-1} is the inverse of the cumulative distribution function of a standard normally distributed random variable with

$$\Phi(z) = \int_{-\infty}^{z} \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}t^2} dt. \tag{8}$$

When applying a logit and probit link function in the context of fitting a population average GEE model, the marginal probability of CDO presence within a company, i.e., $\mu_{i,j}$, is assumed to satisfy the equations as follows[56]

$$logit\ (\mu_{i,j}) = ln\left(\frac{\mu_{i,j}}{1-\mu_{i,j}}\right) = X'_{i,j-1}\beta, \tag{9}$$

and

$$probit\ (\mu_{i,j}) = \Phi^{-1}\left(\mu_{i,j}\right) = X'_{i,j-1}\beta, \tag{10}$$

where $\mu_{i,j} = P[Y_{i,j} = 1 \mid X_{i,j-1}] = P[CDO\ existence_{i,j} = 1 \mid X_{i,j-1}]$ and P denoting the probability of an event, i.e., that a CDO is present at time j within company i (Gardiner et al., 2009). Plugging in independent and control variables yields the desired (full) model for estimating β by the GEE approach, i.e.,[57]

$$\begin{aligned} logit\ (\mu_{i,j}) = {} & \beta_0 + \beta_1\ CEO\ company\ outsider_{i,j-1} + \beta_2\ CEO\ tenure_{i,j-1} \\ & + \beta_3\ CEO\ STEM\ background_{i,j-1} + \beta_4\ company\ size_{i,j-1} \\ & + \beta_5\ industry\ revenue\ growth_{i,j-1} + \beta_6\ CIO\ presence_{i,j-1} \\ & + \beta_7\ controls_{i,j-1} + \beta_8\ year_{i,j-1} + \beta_9\ GICS_i, \end{aligned} \tag{11}$$

with all variables as defined as before and the two-digit *GICS* as dummy variables per industry in order to control for before described industry effects. The probit model can be defined analogously.

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[56] Recall that independent and control variables are lagged by one year. The reasoning for this approach, i.e., endogeneity, will be discussed below in section 4.5.2.

[57] In order to test all effects of hypothesized independent variables, varying sub-models of the full model in equation (11) will be analyzed. See section 4.5.3.

For applying the GEE approach, the working correlation structure is left to be defined as explained above. Therefore, the QIC was investigated for different working correlation structures for both logit and probit link functions (Pan, 2001). Similar to AIC, the aim is to choose a working correlation structure for the GEE model with the smallest QIC value (Pan, 2001). An overview of resulting QIC values given a logit and probit link function and different working correlation structures can be found in Table 10.[58]

Working correlation structure[59]	**QIC (logit)**	**QIC (probit)**
Independent	2707.35 *(not preferred)*	2700.61 *(not preferred)*
Exchangeable	2762.76 *(not preferred)*	2779.80 *(not preferred)*
Autoregressive AR(1)	2702.55 *(not preferred)*	**2692.97** *(preferred)*
Unstructured	*Estimates diverging (missing predictions)*	$1.89*10^{23}$ *(not preferred)*
Stationary-1	*Estimates diverging (missing predictions)*	2711.01 *(not preferred)*
Nonstationary-1	2717.52 *(not preferred)*	6893.82 *(not preferred)*

Table 10: QIC Assessment for Different Working Correlation Structures (Logit Link and Probit Link Functions)
Source: Own illustration.

From Table 10, one can observe that the working correlation structure of choice is an autoregressive AR(1) structure.[60] Interestingly, the QIC value for an independent working correlation is closest to the AR(1) structure, yet higher. As the data is time-varying panel data, an AR(1) structure is also more appropriate from a theoretical point of view (Ballinger, 2004).[61] Further, the model based on a probit link function provides

[58] Note that higher order autoregressive working correlation structures would yield even lower QIC values (the lowest observed QIC was 2687.36 and 2680.90 for a probit link function and an AR(3) working correlation structure for ROA and Tobin's Q respectively). As some companies do not have more than two observations, higher order autoregressive working correlation structures were not applied, such that the full potential data set was considered. Still, assessing the GEE model with AR(2) or AR(3) working correlation structures yielded both quantitively and qualitatively similar results. This is at least partially due to applying robust variance estimates (see below).
[59] Displayed QIC values are based on the model with *ROA* performance measures (both for the company and the industry; based on the full model 9 of Table 14). Assessing QIC values based on the model including *Tobin's Q* instead of *ROA* yields similar results leading to the same conclusions.
[60] As all analyses were conducted by using Stata (version 16.1), all working correlation structures, which were available within Stata, were tested (as displayed in Table 10).
[61] Note that when applying an independent working correlation structure, i.e., the identity matrix, estimates are equivalent to a GLM or simple pooled models (depending on the link function and distributional assumptions) (C. J. W. Zorn, 2001). Thus, the before described advantage of GEE models vanishes, namely allowing to consider within subject correlation structures.

better QIC values compared to the model based on a logit link function. Thus, the final model based on Equation (11) will be estimated using an autoregressive AR(1) working correlation structure and a probit link function.[62]

4.5 Results of Investigating Chief Digital Officer Presence with a Generalized Estimating Equations Model

Before assessing results from the GEE model as defined in the previous section, general characteristics of the data set will be described. Further, suitability of the data for conducting the selected GEE modeling approach will be assessed such that correct results and interpretations can be ensured.

4.5.1 Data Inspection

Recalling from section 4.2, S&P 500 companies were analyzed regarding the existence of a CDO for the time period 2007 to 2019. Especially, companies were considered to employ a CDO when not only a dedicated "Chief Digital Officer" position was identified, but also when alternative positions similar to the terms "(Vice) President Digital" and "Head of Digital" were uncovered.[63] As illustrated in Figure 14, a total of 459 company-year observations (out of 5,988 total company-year observations) are characterized by having a CDO employed. Ca. 55% (or 252) of these 459 CDO company-year observations are for companies in which a "Chief Digital Officer" position was identified. The opposite, i.e., 45% or 207 out of 459 CDO company-year observations are the result of identifying positions with similar titles. Further, from Figure 14 it can be observed that the growth rate of CDO positions within S&P 500 companies followed

[62] The models based on a probit link function and logit link function provide both quantitatively and qualitatively similar results. Thus, results will only be displayed for models based on the probit link function.
[63] See section 4.2.2 for further details regarding this approach.

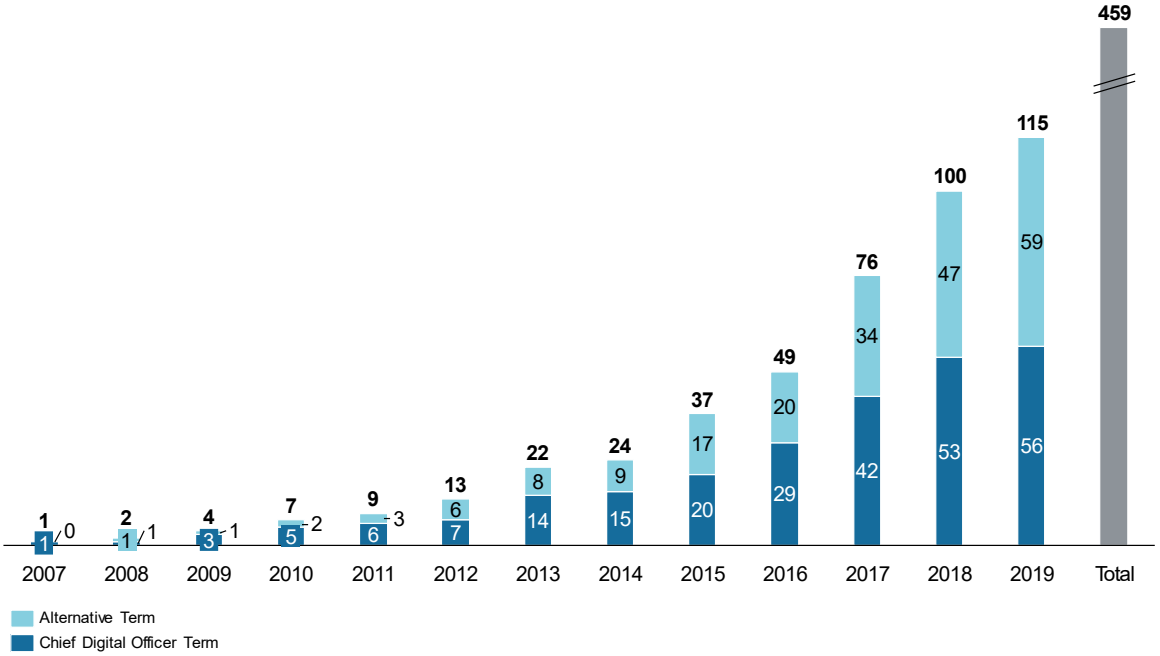

Figure 14: Overview CDO Positions within S&P 500 Companies, 2007-2019
Source: Own illustration.

an exponentially-like growth. More than 60% (i.e., 291) of all CDO positions (for explicit and alternative CDO titles) were created in the last three years of the observation period, i.e., between the years 2017 and 2019. This development is also in line with the results of Friedrich and Péladeau (2015), and Péladeau and Acker (2019), which indicate a strong growth of CDO positions in the years 2015 to 2018 as well (see Figure 1).

Within the collected data sample, companies are allocated to 11 different industries according to the two-digit *GICS* categorization. An overview of CDO adoption rates among all investigated industries can be found in Table 11. While the left part of the table provides a summary for all 5,988 company-year observations by industry, the right part of the table shows an overview on company level providing insights on companies, which employed a CDO at least once during the observed period for each industry.

Industry	Number of company-year observations	Of which are with CDO existence = 1	In %	Number of companies	Of which are with CDO existence = 1 at least once	In %
Information Technology	845	39	5%	71	12	17%
Industrials	844	60	7%	71	19	27%
Financials	806	87	11%	64	26	41%
Consumer Discretionary	780	94	12%	63	27	43%
Health Care	748	71	9%	60	22	37%
Consumer Staples	400	40	10%	33	14	42%
Real Estate	398	10	3%	31	4	13%
Utilities	336	10	3%	26	6	23%
Energy	308	8	3%	27	3	11%
Materials	282	13	5%	24	5	21%
Communication Services	241	27	11%	21	9	43%
Total	5,988	459		491	147	

Table 11: Overview CDO Positions within S&P 500 Companies by Industry
Source: Own illustration.

From the results of the systematic literature review in section 2.4.2, it was unveiled that a focus on customer experience defines one of the most important fields of responsibility for a CDO (e.g., Singh & Hess, 2017; Tumbas et al., 2017, 2018). Following this insight, one might assume that especially companies of customer-centric industries tend to hire a CDO. According to Haffke et al. (2016), for companies with a digital transformation focus on external areas, the need for a CDO might be higher compared to companies, which aim to digitally transform internal areas. Similarly, Friedrich & Péladeau (2015) derive that especially companies of consumer-oriented industries tend to employ a CDO. Based on the database of this thesis, this trend can be observed as well. Both the share of CDO company-years with a CDO (including all time periods) as well as the share of companies, which had a CDO at least once, are higher for consumer-centric industries like Communication Services, Consumer Discretionary, Consumer Staples or Financials compared to less customer-centric industries like Energy or Utilities. Thus, when analyzing the conditions, which increase the likelihood of CDO existence within a company, it is important to control for industry factors in order to capture the pure effect of studied variables and consequently to

reduce the risk of endogeneity.[64] In order to control for industry factors, two-digits *GICS* were included as dummy variables within the GEE model.

Finally, Table 12 provides an overview of basic summary statistics of all variables, which are used (not simultaneously) in the GEE model for assessing the impact of hypothesized factors on the likelihood of CDO presence within companies based on the dataset as described as before.

Variable	Obser-vations	Mean	Standard deviation	1st percentile	99th percentile
(1) CDO existence	5,988	0.077	0.266	0.000	1.000
(2) CEO company outsider	5,988	0.197	0.397	0.000	1.000
(3) CEO tenure	5,988	6.593	7.017	0.000	34.000
(4) CEO STEM background	5,988	0.341	0.474	0.000	1.000
(5) CIO presence	5,988	0.218	0.413	0.000	1.000
(6) Company age	5,988	68.496	48.851	4.000	207.000
(7) Risk	5,988	0.297	0.161	0.116	0.931
(8) Segments	5,988	3.829	2.665	1.000	13.000
(9) Previous ROA	5,988	0.062	0.077	-0.176	0.267
(10) Previous Tobin's Q	5,988	1.851	1.595	0.140	8.109
(11) Company size	5,988	9.598	1.502	6.300	13.723
(12) Revenue growth	5,988	0.102	0.670	-0.394	0.886
(13) Leverage	5,988	0.615	0.218	0.120	1.150
(14) CEO age	5,988	56.628	6.608	41.000	76.000
(15) CEO gender	5,988	1.034	0.181	1.000	2.000
(16) Previous industry ROA	5,988	0.058	0.028	0.010	0.097
(17) Previous industry Tobin's Q	5,988	1.490	0.624	0.290	2.620
(18) Industry revenue growth	5,988	0.060	0.065	-0.169	0.246
(19) Year	5,988	2,012.181	3.728	2,006.000	2,018.000

All variables (except CDO existence, previous (industry) ROA, previous (industry) Tobin's Q) are lagged by one year.

Table 12: Summary Statistics of Variables Included in the GEE Model
Source: Own illustration.

It can be observed that of all company-year observations, ca. 7.7% (or 459) can be characterized by having a CDO, which is in line with the results from before. Further, of all CEOs within the dataset, ca. 19.7% joined the company from outside before assuming the CEO position. The average tenure of a CEO over all company-year observation is 6.6 years, with the longest tenure of 55 years. Regarding the educational

[64] For a discussion on endogeneity, see section 4.5.2 below.

background of a CEO, for ca. 34.1% of all observed company-years the CEO possesses a background in STEM. Further, it can be observed that of all company-year observations ca. 21.8% are characterized by employing a CIO.

Before assessing the results of the GEE model, data suitability will be discussed in the following.

4.5.2 Suitability of Data

When analyzing classical OLS regression models, researchers should address certain assumptions on the underlying data and how the regression model satisfies such assumptions. For example, it should be ensured that the disturbance is uncorrelated with independent variables, satisfies homoscedasticity and non-autocorrelation, and follows are normal distribution (e.g., Greene, 2003; Studenmund, 2014). Further, scholars should consider the influence of missing observation, influential observations and potential multicollinearity among independent variables (e.g., Greene, 2003; Studenmund, 2014). In the case of GEE models, which are based on quasi-likelihood methodology, traditional approaches for model and data diagnostics of OLS regression or GLM models are not always applicable (Oh et al., 2008; C. J. W. Zorn, 2001). Thus, adapted diagnostic procedures will be considered in the following, where necessary.

Outliers and missing data

As for analyzing repeated measures with multivariate OLS regression models, outliers within the data set should also be considered when applying GEE models (Oh et al., 2008). Thus, the data set has been inspected for outliers, i.e., observations that lie far outside of the range of all observations or which are not meaningful due to measurement errors (Studenmund, 2014). Incorrect values had been corrected accordingly. As the pure existence of an outlier is no valid reason for simply dropping observations, correctly measured values, which are not close to the range of all observation, were not excluded from the data set (Studenmund, 2014). Still, an analysis of defined GEE model with a probit link function as displayed in equation (11) was performed based on a winsorized data set.[65] Winsorization was conducted in the

[65] For all continuous variables.

sense of transforming observations, which lie above the 95th percentile, to be set at the 95th percentile, as well as re-setting observations below the 5th percentile to the 5th percentile (Gottfredson & Joo, 2013). Analogously, the 1st and 99th percentiles were considered as well. Both approaches for analyzing the GEE model including either *ROA* or *Tobin's Q* yielded quantitatively and qualitatively very similar results.[66]

Further, removing observations was also not considered due to the issue of missing data within the panel. As GEE models should be assessed on complete data, or in case of missing data, such data should be missing completely at random, removing outliers would cause violations of assumptions and thus leading to suspect or unreliable results (Hardin, 2005). Since the sample size and the number of observations is relatively large, the effect of outliers can be expected to be less severe as corresponding problems are more relevant for small sample sizes (Kennedy et al., 1992). As mentioned before, the data set is unbalanced in the sense of different numbers of observations per company. Yet, the sequence of observations for each company is not interrupted by missing values, which is no issue when applying GEE models as highlighted before (M. Wang, 2014).[67]

Normal distribution of disturbance

In the case of classical OLS regression models, one of the underlying assumptions is that the disturbance is normally distributed (Greene, 2003). For assessing this assumption, one typically investigates residuals as result of the fitted values derived from the estimated model. In the case of modeling a binary dependent variable, which follows a binomial distribution as described before, estimated residuals will have a

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[66] Note that another approach to identifying influential observations is given by the measure DFBETA, which, in simple terms, is a comparison of regression coefficients based on the normal model and a model estimated by excluding single observations (Belsley et al., 1980). This approach is repeated for each observation. As DFBETA is not supported by Stata's GEE commands, DFBETAs were calculated based on a standard logit model (which in general results in very comparable results), due to the availability of DFBETA calculation. The threshold of 2 for absolute DFBETA values, as suggest by Belsley et al. (1980), was not exceeded. Thus, issues regarding outliers cannot be observed.

[67] Although Stata's command for GEE models handles unbalanced data well, an alternative modeling approach was investigated as well. The GEE-based method called quasi-least squares, which considers a Kronecker product working correlation structure for both balanced and unbalanced data sets and which can account for multiple sources of correlation, was used to further assess the GEE model's robustness. The alternative approach yields very similar results. For further details on quasi-least squares, see, for example, Kim and Shults (2014) or Shults et al. (2007).

similar discrete nature (Kasza, 2015). Thus, Landwehr et al. (1984) suggested to examine observed and fitted data based on partitioning in multiple non-overlapping groups. This approach, also called binned or smoothed residuals plots, allows for assessing the fit of models for binary dependent variables (Gelman et al., 2000; Gelman & Hill, 2007; Kasza, 2015). The underlying idea is to partition all observation based on ordered fitted values and plot the average residual against the average fitted value for each bin (Gelman et al., 2000). Further, for each bin an approximate 95% confidence interval will be plotted as well (Kasza, 2015). Only the choice of an appropriate bin size remains somewhat arbitrary as each bin should contain at least enough observations such that averaged residuals remain free of too much noise, but also enough bins in order to identify any pattern (Gelman & Hill, 2007).[68] Following Kasza (2015), Figure 15 and Figure 16 show the binned residual plots for 50, 77 and 100 bins for both models based on *ROA* and *Tobin's Q* respectively.[69]

[68] One recommendation to selecting an appropriate bin size is to use the square root of number of observations (Kasza, 2015). In the case of the underlying data set with 5,988 observations, a recommended number of bins would be roughly 77.
[69] Binned residual plots were calculated based on the full model 9 of Table 14 and the full model 9 of Table B1 in the appendix B for *ROA* and *Tobin's Q* respectively.

For a binned residual plot with an approximate 95% confidence interval, the model is expected to be correct, if ca. 95% of the points lie within the confidence interval (Kasza, 2015). From both Figure 15 and Figure 16, one can observed that depending on the chosen bin size, more or less of the data points lie within the confidence interval. Especially for low average predicted values of CDO presence likelihood, the values are close to the confidence intervals boundaries. Overall, it can be captured that most points are within or close the confidence interval, leading to conclude that the models and the underlying data is appropriate.

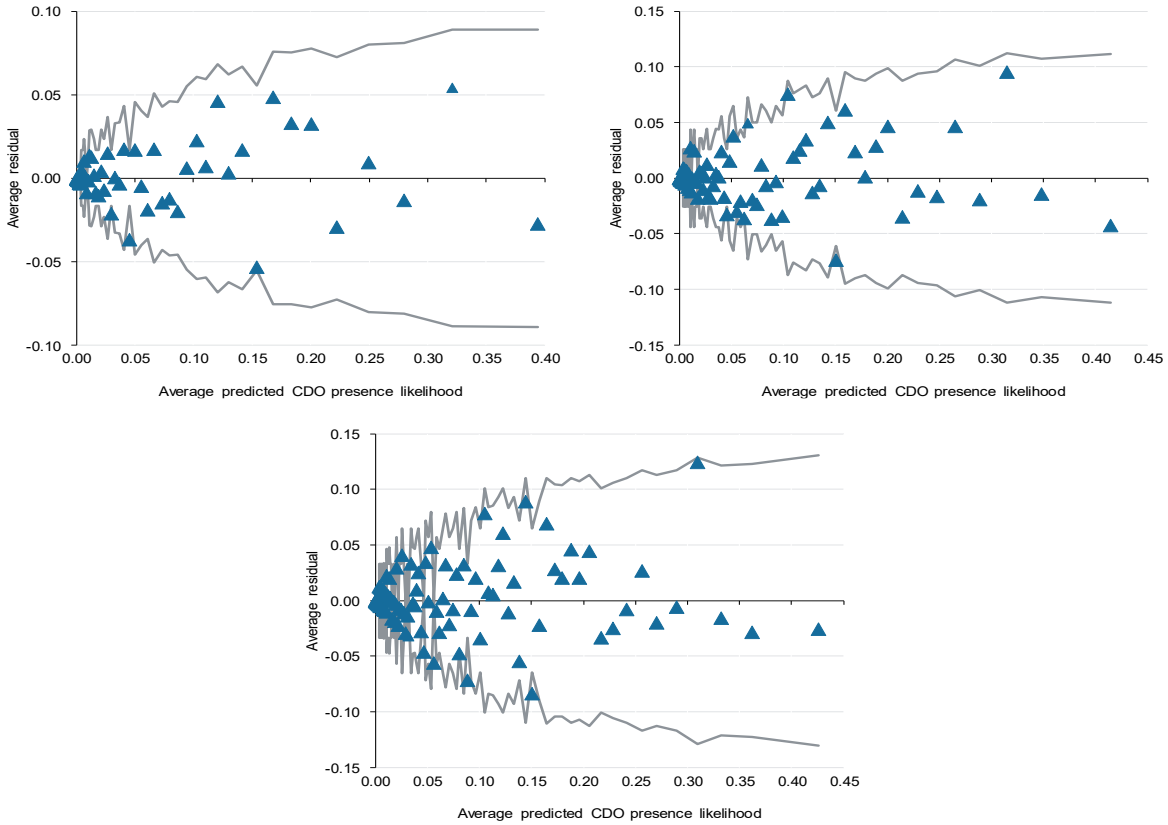

Figure 15: Binned Residual Plots for GEE Model (*ROA*) for 50 bins (top left), 77 bins (top right) and 100 bins (bottom)
Source: Own illustration.

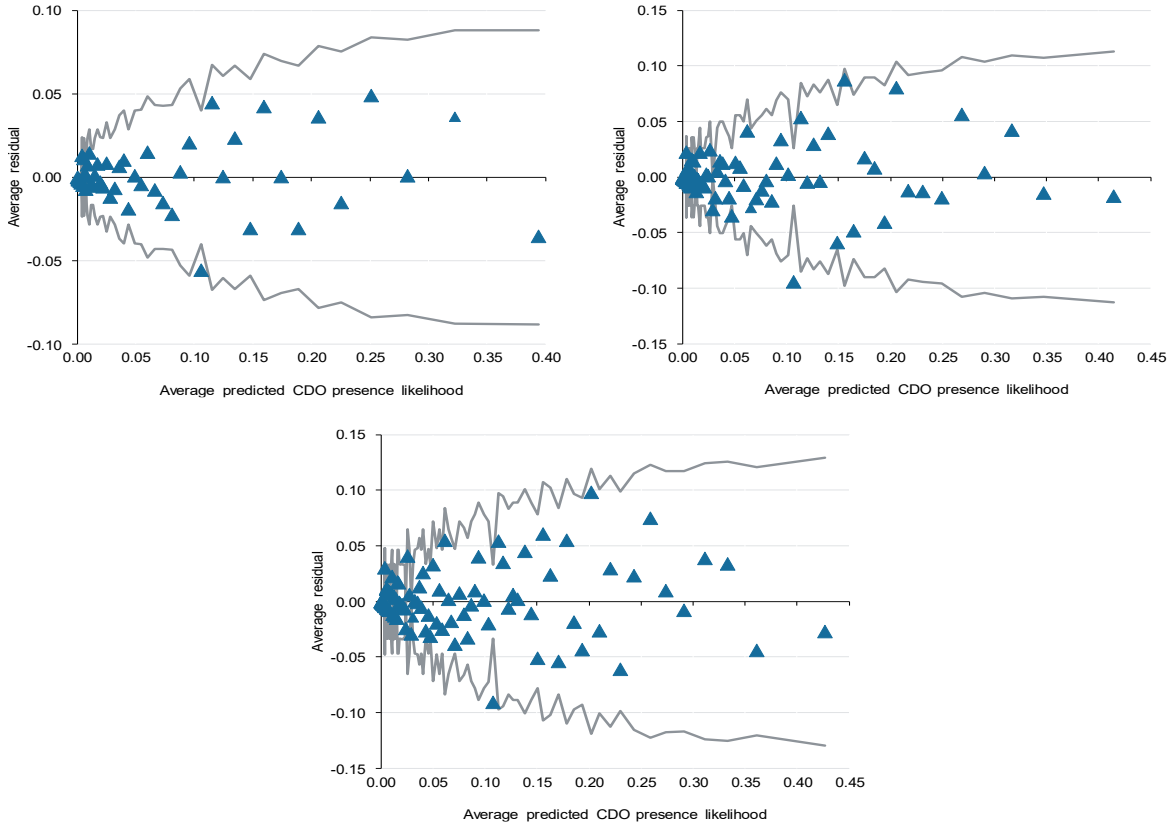

Figure 16: Binned Residual Plots for GEE Model (*Tobin's Q*) for 50 bins (top left), 77 bins (top right) and 100 bins (bottom)
Source: Own illustration.

Homoscedasticity and non-autocorrelation of disturbance

For classical OLS regression models, one of the assumptions is that disturbances are not heteroscedastic and not autocorrelated (Greene, 2003). Homoscedasticity implies that each disturbance (or residual) has the same finite variance, whereas heteroscedastic disturbances are characterized by a non-constant variance (Greene, 2003). Further, autocorrelation means that disturbances are correlated over time (Greene, 2003). Both heteroscedasticity and autocorrelation of disturbances are to be avoided as they would contradict some of the underlying assumptions and therefore resulting estimates would not be best (minimum variance) linear unbiased estimates (Studenmund, 2014).

Although such assumptions are not given in the context of GEE models, applying a GEE model still implies the definition of a working correlation matrix for deriving the variance estimator (Liang & Zeger, 1986). As mentioned before, misspecification of

such working correlation structures might lead to inefficient estimates (Ballinger, 2004). In order to assure robustness against misspecified working correlation structures, a robust covariance estimator (or sandwich estimator) can be included (Zeger & Liang, 1986). Thus, the following analysis will be based on robust variance estimates and therefore implicitly account for potential heteroskedasticity and autocorrelation of disturbances (even though autocorrelation is at least partially addressed by choosing an AR(1) working correlation structure).

Linear independence and endogeneity of independent variables

Similar to OLS regression models, multicollinearity or perfect collinearity among predictor variables (independent and control variables) is also to be avoided when applying a GEE modeling approach, as an extension of GLMs (Hill & Adkins, 2003). Although linear independence of all predictors variables is desired, applied researchers are oftentimes not able to specify models based on perfectly uncorrelated variables, as some correlation is quite common (Greene, 2003; Studenmund, 2014). In order to detect severe multicollinearity, simple pairwise correlation coefficients between the predictors variables is assessed (Studenmund, 2014). Table 13 provides all pairwise correlations for all variables including the dependent variable as described as before.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) CDO existence	1.000									
(2) CEO company outsider	-0.013	1.000								
(3) CEO tenure	-0.036*	-0.087*	1.000							
(4) CEO STEM background	-0.053*	0.046*	-0.092*	1.000						
(5) CIO presence	0.069*	-0.001	-0.062*	-0.035*	1.000					
(6) Company age	0.050*	-0.092*	-0.189*	-0.028*	0.163*	1.000				
(7) Risk	-0.072*	0.037*	0.026*	0.005	-0.078*	-0.112*	1.000			
(8) Segments	0.007	-0.074*	-0.012	-0.010	-0.026*	0.222*	0.048*	1.000		
(9) Previous ROA	-0.014	-0.028*	0.035*	0.000	0.018	-0.043*	-0.191*	-0.130*	1.000	
(10) Previous Tobin's Q	-0.012	0.057*	0.099*	0.054*	-0.037*	-0.252*	-0.057*	-0.283*	0.425*	1.000
(11) Company size	0.138*	-0.114*	-0.078*	-0.035*	0.109*	0.382*	-0.123*	0.331*	-0.209*	-0.494*
(12) Revenue growth	-0.008	0.024*	0.037*	0.000	-0.021*	-0.070*	0.023*	-0.065*	-0.025*	0.121*
(13) Leverage	0.118*	-0.012	-0.062*	-0.109*	0.130*	0.268*	-0.020	0.149*	-0.267*	-0.277*
(14) CEO age	0.032*	-0.006	0.397*	-0.008	0.079*	0.112*	-0.101*	0.090*	0.014	-0.087*
(15) CEO gender	0.029*	0.060*	-0.075*	0.030*	-0.021*	-0.005	-0.045*	0.037*	-0.004	-0.010
(16) Industry ROA	0.008	0.048*	-0.062*	0.074*	-0.032*	-0.156*	-0.066*	-0.208*	0.320*	0.319*
(17) Industry Tobin's Q	0.037*	0.085*	-0.052*	0.098*	-0.056*	-0.250*	-0.167*	-0.230*	0.236*	0.404*
(18) Industry revenue growth	-0.007	0.045*	0.040*	0.004	-0.030*	-0.117*	-0.102*	-0.226*	0.121*	0.083*
(19) Year	0.265*	-0.004	0.004	0.020	0.105*	0.050*	-0.333*	-0.067*	0.018	0.089*

* shows significance at the 10% level. All variables (except CDO existence, previous ROA, previous Tobin's Q) are lagged by one year.

Table 13: Pairwise Correlations of all Variables used in the GEE Model
Source: Own illustration.

Variables	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
(11) Company size	1.000								
(12) Revenue growth	-0.081*	1.000							
(13) Leverage	0.383*	-0.027*	1.000						
(14) CEO age	0.162*	-0.023*	0.125*	1.000					
(15) CEO gender	0.059*	-0.011	0.054*	-0.022*	1.000				
(16) Industry ROA	-0.365*	0.033*	-0.261*	-0.064*	0.033*	1.000			
(17) Industry Tobin's Q	-0.387*	0.028*	-0.289*	-0.091*	0.051*	0.796*	1.000		
(18) Industry revenue growth	-0.093*	0.124*	-0.101*	-0.050*	-0.011	0.294*	0.163*	1.000	
(19) Year	0.180*	-0.038*	0.113*	0.128*	0.066*	-0.019	0.144*	-0.096*	1.000

* shows significance at the 10% level. All variables (except CDO existence, previous ROA, previous Tobin's Q) are lagged by one year.

Table 13 (continued): Pairwise Correlations of all Variables used in the GEE Model
Source: Own illustration.

It can be observed that for all relevant variables, no absolute pairwise correlation coefficient exceeds 0.500. The only exemption is the correlation coefficient of *industry ROA* and *industry Tobin's Q* with a correlation of 0.796. Yet, as both coefficients are not included in the same GEE model simultaneously, this is not an issue. As some researchers accept pairwise correlation of up to 0.800, issues regarding multicollinearity cannot be identified (Studenmund, 2014).

In order to further assure that multicollinearity is not an issue, scholars also rely on other influential-data diagnostics such that unusual observations can be identified (Hill & Adkins, 2003). One common approach is to exploit the concept of variance inflation factors (VIF) for detecting strong multicollinearity for each variable of the model (Studenmund, 2014). Due to the design of VIFs, this approach is not applicable in the GEE context. Thus, scholars often investigate variance decomposition and the condition index of Belsley et al. (1980) for diagnosing collinearity (Hill & Adkins, 2003). Analyzing before defined models for both *ROA* and *Tobin's Q* unveils that both condition indices are below 30. According to Belsley et al. (1980), moderate to strong collinearity should be considered for indices ranging between 30 to 100. Combined with the previous results of analyzing pairwise correlations, no multicollinearity issues can be identified.

Finally, in the context of endogeneity of predictor variables, three common types of endogeneity typically arise in econometrics. An endogenous variable is defined as a variable, which is correlated with the residual of the estimated equation (Wooldridge, 2002). The first source of endogeneity stems from one or more omitted variables, which are correlated with the dependent variable, and which oftentimes appear in cases of data unavailability or unobservability (Wooldridge, 2002). A second cause for endogeneity follows from simultaneity meaning that the dependent variable is simultaneously determined along at least one of the predictor variables (Wooldridge, 2002). Thirdly, endogeneity might follow as a results of measurement error in the predictors variables (Wooldridge, 2002). Thus, addressing endogeneity is important to ensure valid results and interpretations (Clougherty et al., 2015). As the field of CDO research is still fairly new, results regarding factors promoting CDO existence are limited. By drawing from theory, research on CDOs and research in the field of other

individual top management team members, like COO (Hambrick & Cannella, 2004), CFO (D. M. Zorn, 2004) or CMO (Nath & Mahajan, 2008), a comprehensive set of influencing factors is considered in the analysis of investigating likelihood of CDO presence within companies. Further, all identified variables were collected without issues of unobservability as well as with high care from renowned sources like Capital IQ or annually filed reports. Regarding sample selection bias, i.e., the issues of non-representability of the sample, assessing S&P 500 companies over a 12-year time period was chosen in order to follow a common approach of sample selection, especially within similar matters (e.g., Kale et al., 2002; Kanashiro & Rivera, 2019; Menz & Scheef, 2014; Shi et al., 2018). From results of section 2.4.2 and from Table 11 one can observe that companies of certain industries might be more likely to employ CDOs due to industry-specific conditions or due to being more concerned about actions of competitors within their industry. In order to ensure that potential industry-factors are also considered in the estimating model and omitted variable bias is avoided, industry dummies were added to the GEE model (Sharp et al., 2013). Thus, endogeneity induced by omitted variables or measurement error can be expected to be neglectable. Further, by following the common approach of lagging all variables included in the GEE model by one year, potential endogeneity bias from simultaneous and reverse causation will be addressed and mitigated (e.g., Buch et al., 2012; Gorter et al., 2016; Green et al., 2005; Hong, 2020; Nath & Mahajan, 2008; Weng & Lin, 2014).

After assuring that the underlying data and approach for modeling the likelihood of CDO presence within companies satisfies all relevant requirements, the following section will display all results derived from applying the GEE model.

4.5.3 Generalized Estimating Equations Model Results

In order to assess the hypothesized relationship between the likelihood of having a CDO within the company and each derived factor as in chapter 3, several different models were estimated including only selected or all variables while following the overall approach of a GEE model with a binomial distribution, probit link function and an AR(1) working correlation structure. The results for testing hypothesis one, i.e., the influence of relevant CEO characteristics on the likelihood of CDO presence in

companies, are presented in Table 14 below. Thereafter, results regarding hypothesis two, i.e., the influence of contingency related factors on the likelihood of CDO presence in companies, will be presented. Note that in order to conserve space, all models based on *Tobin's Q* instead of *ROA* as performance measure are displayed in the appendix as no crucial differences for hypothesis testing were identified.[70]

In Table 14, Model 1 shows the results when only control variables and none of the hypothesized independent variables are included as a kind of baseline model. Models 2, 3 and 4 each include one of the CEO characteristics separately to the baseline model. In Model 5, all three CEO characteristics are included in the baseline model at once. Finally, models 6, 7, 8 and 9 are similar to models 2, 3, 4 and 5 and in addition also include all three contingency-related independent variables from hypothesis two. The reason for also considering these three variables when assessing hypothesis one is simply that variables like a company's size, its industry's revenue growth or presence of other relevant top management team executives like CIOs are commonly used as control variables in the top management team literature (e.g., Hambrick & Cannella, 2004; Nath & Mahajan, 2008; Shi et al., 2018).

[70] See Table B1 and Table B2 in the appendix B for *Tobin's Q* based GEE models for hypothesis one and two respectively. The *Tobin's Q* based GEE models yield both quantitively and qualitatively similar results, except that the coefficient of *Tobin's Q (t-1)* is not significance and the coefficient of *industry Tobin's Q (t-1)* has an opposite sign (but is still significant). A discussion of both effects will follow below.

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
CEO company outsider (t-1) *H1a*		0.016 (0.881)			-0.003 (0.977)	0.033 (0.751)			0.015 (0.883)
CEO tenure (t-1) *H1b*			-0.013** (0.029)		-0.013** (0.031)		-0.012* (0.050)		-0.012* (0.053)
CEO STEM background (t-1) *H1c*				0.023 (0.787)	0.009 (0.913)			0.013 (0.879)	0.000 (0.998)
Company size (t-1)						0.101** (0.021)	0.093** (0.032)	0.100** (0.022)	0.094** (0.031)
Industry revenue growth (t-2 to t-1)						0.296 (0.403)	0.319 (0.366)	0.299 (0.399)	0.317 (0.368)
CIO presence (t-1)						-0.020 (0.790)	-0.026 (0.731)	-0.020 (0.793)	-0.026 (0.732)
Company age (t-1)	0.001 (0.207)	0.001 (0.209)	0.001 (0.378)	0.001 (0.212)	0.001 (0.393)	0.001 (0.524)	0.000 (0.733)	0.001 (0.544)	0.000 (0.725)
Risk (t-1)	-0.019 (0.933)	-0.020 (0.929)	-0.010 (0.962)	-0.020 (0.929)	-0.010 (0.961)	0.032 (0.882)	0.042 (0.839)	0.033 (0.875)	0.040 (0.843)
Segments (t-1)	0.013 (0.334)	0.013 (0.329)	0.013 (0.308)	0.013 (0.339)	0.013 (0.309)	0.009 (0.522)	0.010 (0.481)	0.009 (0.529)	0.010 (0.479)
ROA (t-1)	-0.548* (0.062)	-0.547* (0.062)	-0.545* (0.057)	-0.544* (0.065)	-0.544* (0.059)	-0.473 (0.156)	-0.483 (0.133)	-0.475 (0.155)	-0.481 (0.136)
Revenue growth (t-2 to t-1)	0.001 (0.881)	0.001 (0.886)	0.004 (0.685)	0.001 (0.888)	0.004 (0.686)	-0.019 (0.661)	-0.014 (0.687)	-0.018 (0.666)	-0.014 (0.682)
Leverage (t-1)	0.438*** (0.003)	0.439*** (0.003)	0.446*** (0.002)	0.439*** (0.003)	0.446*** (0.002)	0.428*** (0.008)	0.434*** (0.006)	0.428*** (0.009)	0.434*** (0.006)
Industry ROA (t-1)	-3.465** (0.017)	-3.471** (0.017)	-3.347** (0.021)	-3.466** (0.017)	-3.346** (0.021)	-4.338** (0.040)	-4.290** (0.043)	-4.332** (0.041)	-4.292** (0.043)
CEO age (t-1)	-0.005 (0.450)	-0.005 (0.438)	0.003 (0.648)	-0.005 (0.451)	0.003 (0.641)	-0.005 (0.390)	0.002 (0.778)	-0.005 (0.414)	0.002 (0.789)

***, ** and * indicate significance at the 1%, 5%, and 10% level, respectively.
P-values are provided in parentheses. Standard errors are clustered by company.

Table 14: GEE Model. Dependent Variable: CDO Existence (t) (for ROA Based Model) – Hypothesis 1
Source: Own illustration.

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
CEO gender (t-1)	0.205	0.205	0.194	0.204	0.194	0.199	0.189	0.199	0.189
	(0.249)	(0.250)	(0.266)	(0.252)	(0.268)	(0.269)	(0.282)	(0.267)	(0.284)
Year (t-1)	0.182***	0.182***	0.182***	0.182***	0.181***	0.178***	0.177***	0.178***	0.177***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Intercept	-369.630***	-369.613***	-368.071***	-369.317***	-367.941***	-361.421***	-360.714***	-361.366***	-360.651***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Wald chi^2	154.4***	156.7***	171.3***	155.7***	172.8***	162.6***	172.0***	157.8***	174.2***
Industry effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Marginal R^2	0.115	0.115	0.118	0.115	0.118	0.123	0.126	0.123	0.125
N	5,988	5,988	5,988	5,988	5,988	5,988	5,988	5,988	5,988

***, ** and * indicate significance at the 1%, 5%, and 10% level, respectively.
P-values are provided in parentheses. Standard errors are clustered by company.

Table 14 (continued): GEE Model. Dependent Variable: CDO Existence (t) (for ROA Based Model) – Hypothesis 1
Source: Own illustration.

All models show a significant Wald chi^2 statistic, implying a rejection of the null hypothesis that all coefficients of all variables for each model are zero. Further, the value of marginal R^2 is increased by including all independent variables in the model.[71] As marginal R^2 is not comparable with the classical R^2 in the OLS regression context, most authors do not report such values. Still, comparing, for example, with results of Kanashiro and Rivera (2019) in a similar context regarding CSuOs shows that the derived marginal R^2 of around 0.12 based on this study's sample and GEE modeling approach is reasonable.[72]

Based on all models in Table 14, hypothesis H1b can be confirmed, which stated that early tenure CEOs are more likely to perceive the necessity for a CDO. For example, model 9 shows that with increasing tenure the likelihood of CDO presence within a company significantly decreases with a coefficient of -0.012 (with p-value 0.053). Yet, as the underlying estimating model is non-linear and instead based on a probit link function, the interpretation of the coefficient is not intuitively easy. Therefore, Figure 17 provides an overview of the marginal effect of a CEO's tenure on the likelihood of CDO existence combined with a 95% confidence interval while keeping all other variables at their respective means and varying tenures.[73] As hypothesized, it can be observed that especially for early tenure CEOs, the likelihood of having a CDO in their company is significantly higher and decreases with increasing tenure up to a tenure of ca. 42 years. The effect ranges from ca. 4.0% at a CEO tenure of zero years to ca. 1.4% at a tenure of 37 years. For tenures larger than 37 years, the impact on propensity of CDO existence within the company is not significant anymore. Overall, these results provide

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[71] See, for example, Hardin and Hilbe (2003) regarding marginal R^2. As the dependent variable is of binary nature and the estimated probabilities are continuous, marginal R^2 cannot be interpreted the same way as R^2 from OLS regressions. Still, marginal R^2 is reported for the sake of completeness and as it provides an indication of model improvements by including more variables.

[72] Note that another approach to measuring a GEE (or other binary) model's goodness of fit would be percent correctly predicted (see Wooldridge (2002)). For calculating percent correctly predicted, an arbitrary cutoff point is required, commonly set to 0.5, in order to assign a predicted value from the calculated predicted probabilities (e.g., observations with predicted probabilities larger than 0.5 are assigned the value 1, and 0 otherwise). As the cutoff point can be chosen arbitrarily, this measure is not reported here in detail. Still, choosing cutoff points as 0.5 as well as the average of CDO existence (ca. 0.077) resulted in percent correctly predicted of ca. 70% to ca. 90%.

[73] Based on the estimated coefficients of model 9 in Table 14.

evidence for confirming hypothesis H1b. Note that the maximum *CEO tenure* (lagged) within the sample of this study is 55 years.

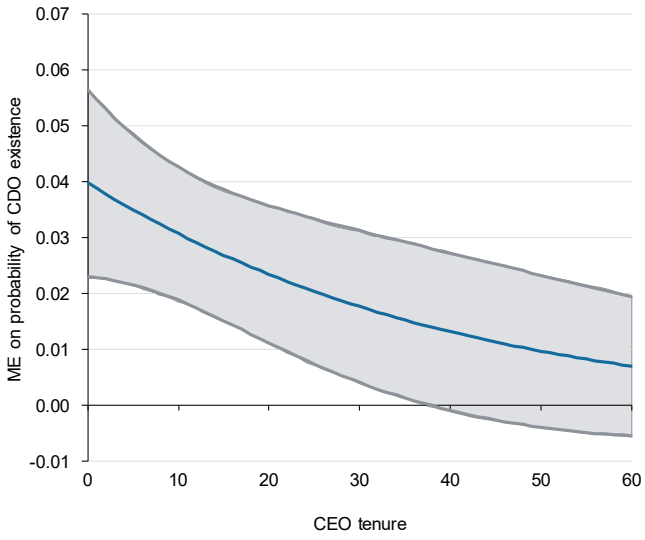

Figure 17: Marginal Effect (ME) of CEO Tenure on Likelihood of CDO Existence
Source: Own illustration.

Both other hypothesized CEO characteristics of hypothesis one, i.e., CEOs, who joined the company from outside (H1a) and CEOs, who obtained an educational background outside of STEM (H1c), have no significant impact on the likelihood of CDO presence within the company. Therefore, hypotheses H1a and H1c have to be rejected.

In order to investigate hypothesis two regarding the influence of contingency-related factors on the likelihood of CDO presence within companies, additional GEE models were estimated. Similar to varying models for testing hypothesis one as display in Table 14, models 1 to 7 in Table 15 provide results for adding each hypothesized variable to the model with and without considering independent variables of hypothesis one, i.e., CEO characteristics, as control variables. The baseline model and the full model are not displayed due to avoiding repetition of the same results.[74] Similar to before, Wald chi^2 statistic are significant and values of marginal R^2 are ranging around 0.12.

[74] See models 1 and 9 of Table 14.

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
CEO company outsider (t-1)					0.013	0.000	-0.003
					(0.904)	(0.997)	(0.979)
CEO tenure (t-1)					-0.012*	-0.013**	-0.013**
					(0.052)	(0.034)	(0.030)
CEO STEM background (t-1)					0.002	0.008	0.008
					(0.978)	(0.920)	(0.920)
Company size (t-1) *H2a*	0.101**			0.100**	0.094**		
	(0.021)			(0.022)	(0.029)		
Industry revenue growth (t-2 to t-1) *H2b*		0.302		0.299		0.325	
		(0.385)		(0.399)		(0.348)	
CIO presence (t-1) *H2c*			-0.014	-0.020			-0.021
			(0.850)	(0.790)			(0.783)
Company age (t-1)	0.001	0.001	0.001	0.001	0.000	0.001	0.001
	(0.558)	(0.206)	(0.203)	(0.539)	(0.755)	(0.388)	(0.381)
Risk (t-1)	0.010	0.008	-0.019	0.034	0.015	0.018	-0.011
	(0.961)	(0.972)	(0.933)	(0.873)	(0.941)	(0.934)	(0.960)
Segments (t-1)	0.007	0.015	0.013	0.009	0.008	0.015	0.013
	(0.605)	(0.281)	(0.336)	(0.527)	(0.558)	(0.254)	(0.312)
ROA (t-1)	-0.467	-0.559*	-0.547*	-0.477	-0.471	-0.555*	-0.543*
	(0.157)	(0.060)	(0.062)	(0.153)	(0.138)	(0.057)	(0.059)
Revenue growth (t-2 to t-1)	-0.013	-0.002	0.002	-0.018	-0.008	0.001	0.004
	(0.724)	(0.887)	(0.868)	(0.669)	(0.768)	(0.957)	(0.667)
Leverage (t-1)	0.429***	0.437***	0.438***	0.428***	0.436***	0.444***	0.446***
	(0.008)	(0.003)	(0.003)	(0.009)	(0.006)	(0.002)	(0.002)
Industry ROA (t-1)	-3.531**	-4.256**	-3.482**	-4.334**	-3.428**	-4.203**	-3.368**
	(0.016)	(0.042)	(0.016)	(0.041)	(0.019)	(0.045)	(0.020)
CEO age (t-1)	-0.005	-0.005	-0.005	-0.005	0.001	0.003	0.003
	(0.396)	(0.459)	(0.455)	(0.413)	(0.814)	(0.640)	(0.628)

***, ** and * indicate significance at the 1%, 5%, and 10% level, respectively.
P-values are provided in parentheses. Standard errors are clustered by company.

Table 15: GEE Model. Dependent Variable: CDO Existence (t) (for ROA Based Model) – Hypothesis 2
Source: Own illustration.

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
CEO gender (t-1)	0.198	0.206	0.206	0.200	0.187	0.195	0.195
	(0.269)	(0.246)	(0.247)	(0.265)	(0.289)	(0.264)	(0.265)
Year (t-1)	0.178***	0.182***	0.183***	0.178***	0.177***	0.181***	0.182***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Intercept	-361.280***	-368.877***	-370.170***	-361.525***	-360.138***	-367.224***	-368.729***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Wald chi^2	152.6***	158.5***	155.7***	157.5***	168.8***	177.0***	174.7***
Industry effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Marginal R^2	0.124	0.115	0.115	0.123	0.126	0.118	0.117
N	5,988	5,988	5,988	5,988	5,988	5,988	5,988

***, ** and * indicate significance at the 1%, 5%, and 10% level, respectively.
P-values are provided in parentheses. Standard errors are clustered by company.

Table 15 (continued): GEE Model. Dependent Variable: CDO Existence (t) (for ROA Based Model) – Hypothesis 2
Source: Own illustration.

The models displayed in Table 15 (and also Table 14) provide evidence for the positive and significant impact of a company's size on the likelihood of CDO existence within companies (H2a). Based on the full model (model 9 in Table 14), the average effect of a company's size is characterized by the estimated coefficient of 0.094 (with p-value 0.031). Again, due to the underlying probit modeling approach, the marginal effect of the variable *company size* on likelihood of CDO existence is not linear with the estimated coefficient. Thus, Figure 18 displays the marginal effect of a company's size on the propensity of CDO presence for increasing *company size* values and all other variables fixed at their respective means.[75] As hypothesized, it can be observed that the effects ranges from ca. 8.9% at a (lagged) *company size* of ca. 14.8 to ca. 1.4% at a size of ca. 5.7.[76] For sizes below 5.7, the marginal effect becomes insignificant. In total, these results lead to confirming hypothesis H2a.

The remaining contingency-related hypotheses, namely the impact of high dynamic

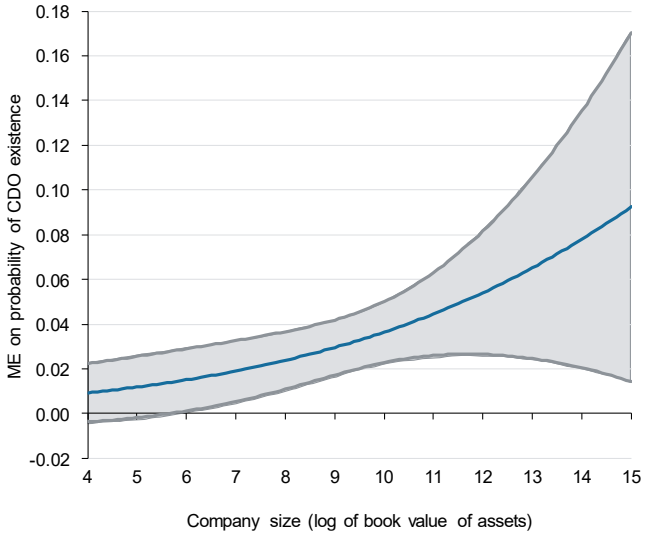

Figure 18: Marginal Effect (ME) of Company Size on Likelihood of CDO Existence
Source: Own illustration.

industries (H2b) and the absence of a CIO within the company (H2c), are not confirmed by the models. Both underlying variables, *industry revenue growth* and *CIO presence*,

[75] Based on the estimated coefficients of model 9 in Table 14.
[76] Note that *company size* is measured as log of the book value of assets. The maximum observed value for *company size* is ca. 14.8.

show no significant impact on the likelihood of CDO existence within companies. Thus, hypotheses H2b and H2c are rejected.

Besides the two (out of six) hypothesized variables, several control variables appear to significantly influence CDO presence within companies. These variables include *leverage*, *industry performance* (yet with different signs for *ROA* and *Tobin's Q*[77]) and *year*. Company performance (for *ROA*) appears to be slightly significant, but only for certain combinations of variables, yet not for the full model.

4.5.4 Concluding Remarks

In total, only two out of six hypothesized influencing factors for CDO presence within companies could be verified by the GEE model to significantly impact CDO presence. A comparison with results of scholars, who investigated how factors similar to the hypothesized factors of this study influence the presence of other top management team members, shows that there is no clear overarching answer for which factors promote presence of individual C-level executives. While the implications of being a company outsider CEO appear to be not relevant for CDO presence and COO presence (Hambrick & Cannella, 2004), CMO presence is more likely when CEOs joined the company from outside (Nath & Mahajan, 2008). Further, the results of the GEE models indicate a positive and significant impact of early tenure CEOs on CDO presence. Yet, CEOs, who are early in their tenure, seem to negatively impact COO presence (Hambrick & Cannella, 2004), similar to CFO presence and CSO presence (Menz & Scheef, 2014; D. M. Zorn, 2004), and to not significantly influence CMO existence in companies at all (Nath & Mahajan, 2008). A CEO's lacking educational background in STEM appears to be non-influential for CDO existence or in finance regarding CFO presence (D. M. Zorn, 2004), but lacking operational education of CEOs increases the likelihood of COO presence in companies (Hambrick & Cannella, 2004). In terms of contingency-related factors, *company size* not only affects CDO presence, but also COO and Chief Diversity Officer existence (Hambrick & Cannella,

[77] See Table B1 and Table B2 in the appendix B. This result also indicates that the contingency-related influence of higher dynamic industries, measures by *industry revenue growth*, is not in line with the hypothesis.

2004; Shi et al., 2018). In their studies regarding CDO presence, Firk et al. (2019) and Kunisch et al. (2020) also came to the same conclusions. Yet, the size of the company seems to not influence CMO, CSO, CSuO or CFO presence (Menz & Scheef, 2014; Nath & Mahajan, 2008; Roh et al., 2016; D. M. Zorn, 2004). In line with research on COO and CFO, *industry revenue growth* is not significantly affecting presence of individual C-level positions (Hambrick & Cannella, 2004; D. M. Zorn, 2004). Regarding studies on CDOs, Kunisch et al. (2020) also found no significant impact of *industry revenue growth* while Firk et al. (2019) provided support for this hypothesis. Finally, the presence of a competing or overlapping C-level position, like CIO for CDOs, is also not significant for CMO presence (Nath & Mahajan, 2008). Opposing to this study and to the hypothesized effect, Kunisch et al. (2020) derived that companies, which employ a CIO, are more likely to appoint a CDO. While the presence of a competing C-level position negatively affects existence of CSCO and CSO (Menz & Scheef, 2014; Roh et al., 2016), the likelihood of CFO presence appears to be positively affected by such a position (D. M. Zorn, 2004). As each of the positions are certainly different regarding their activities and responsibilities, a comparison as described before might only be reasonably to some extent. Still, it clearly shows that for each (C-level) position, a differentiate view and approach to clarifying such answers is required. Further, such a comparison also highlights that disperse and disconnected insights require to be (re-) connected and integrated for drawing more fine-grained conclusions (Menz, 2012).

Still, several control variables were identified to affect CDO existence as well. As for example argued by Roh et al. (2016), who derived similar results regarding *leverage* and CSCO presence, highly leveraged firms are required to generate sufficient amounts of returns in order to serve the high amounts of debt. Thus, such companies might also be pressured to be more productive and efficient (Roh et al., 2016), which is also scope of a CDO's efforts in digitally transforming the company (Vial, 2019; Walchshofer & Riedl, 2017). Firk et al. (2019) also showed that highly leveraged companies are more likely to employ a CDO, yet this effect appears to be not significant based on their analyses. Regarding industry performance and in line with results of this study, Hambrick and Cannella (2004) also derived that while industry performance measured by *ROA* has a negative and significant impact on COO presence in

companies, industry performance based on a value linked to the market (similar to *Tobin's Q*) has a positive and significant impact on COO presence.[78] Kunisch et al. (2020) derived that industry performance, both *ROA* and a market-based measure, has a positive but non-significant effect on CDO presence. When comparing the effect of *year* on CDO presence with similar studies, the results are mixed. For example, Menz and Scheef (2014) find support that *year* positively impacts CSO presence, whereas Nath and Mahajan (2008) derive that there is a negative, yet non-significant relationship between *year* and CMO presence. With respect to CDO presence, a positive effect seems to be plausible as especially in recent years many companies decided to hire CDOs (see also Figure 14). This result is also derived by Firk et al. (2019) and Kunisch et al. (2020). In line with several authors, who investigate influencing factors for presence of individual top management team members, performance of a company has no significant impact on existence of such within companies (Hambrick & Cannella, 2004; Kanashiro & Rivera, 2019; Menz & Scheef, 2014; Nath & Mahajan, 2008; Roh et al., 2016; Shi et al., 2018). Opposing to that, both Firk et al. (2019) and Kunisch et al. (2020) provided evidence for a positive but non-significant effect of previous company performance on CDO presence. Overall, derived results of control factors as in the baseline GEE model appear to be reasonable.

To conclude, in terms of the investigated CDO presence in companies, additional factors, which were not in scope for this analysis, should be considered by future scholars. After a more holistic overview of this study's results in chapter 6, a discussion of future research potential will follow as well. The following chapter will now discuss performance implications of CDOs as explained before.

[78] When including both *ROA* and *Tobin's Q* based *industry performance* in the full model 9 of Table 14, the results do not change.

5. Research Question Three: Performance Implications of the Chief Digital Officer Position[79]

5.1 Objective

After addressing research questions one and two, the following chapter aims to answer the remaining research question three. As derived before, the objective is to clarify how CDOs impact company performance and whether certain characteristics of them are preferable over others in the light of superior company performance. In addition, several combinations of such CDO characteristics with varying structures of CEO and CIO will be assessed regarding the implications for a company's performance. In addition, before described contingency factors will be investigated in terms of their relationship with a CDO's impact on company performance as well. The overarching research question for this chapter is as follows:

(3) What is the impact of a CDO on company performance? Especially, are different CDO characteristics, various company contingencies (organizational and environmental) and varying C-level structures of CDO, CEO and CIO favorable over others?[80]

For answering this research question, hypotheses were developed based on three major theoretical pillars consisting of human capital theory, resource-based view and contingency theory. As the underlying data base will be in line with chapter 4 and thus of longitudinal structure, taking advantage of the panel form helps strengthening derived results by addressing potential omitted variable bias to obtain consistent estimates (Wooldridge, 2002). Commonly used estimation approaches in panel data

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[79] Several parts of this chapter were used word by word (potentially with the exception of a few words) or with rearrangements (in order to match style and format of this thesis) for the preparation of a scientific paper. Affected paragraphs have been marked with an asterisk (*) at the end. In addition, some marked paragraphs were further enriched by explanations, which had not been used for the described paper. For further information regarding publication outlets and corresponding status, see the Foreword on page II.
Further, selected results of this chapter (incl. their discussion and visualization) were used for the preparation of the scientific paper as well. As no paragraphs considering these results were used word-by-word or with rearrangements as explained above, dedicated markings with an asterisk were not inserted. Related tables and figures were not marked as well.

[80] In terms of CDO implications on company performance.

research are fixed effects and random effects estimator (e.g., Gardiner et al., 2009; Georgakakis et al., 2017; Hong, 2020; Kanashiro & Rivera, 2019; Nielsen, 2010; Roh et al., 2016; Weng & Lin, 2014), which allow for correction of unobserved effects (also known as unobserved heterogeneity) and differ depending on the type of the unobserved effect (Wooldridge, 2002).[81] For the case of including time invariant variables in the regression model, random effects estimation is more suitable than a fixed effect estimation (Greene, 2003). As the analysis for this study is not considering time invariant effects, and instead aims to rule out company-specific time invariant effects such that the influence of hypothesized factors can be isolated, a fixed effects estimating approach will be conducted. The following sections will supplement information from section 4.2 on incorporated data and measures, introduce the fixed effects estimator and present derived results.

5.2 Sample Selection and Data Description

5.2.1 Data Gathering Process

The data base for investigating research question three, i.e., the implications of CDOs on company performance while also considering contingency and human capital related impacts, is equivalent to the data base of the previous chapter's analyses.[82]

5.2.2 Description of Measures

While the majority of relevant measures was already described in section 4.2.2, additional measures will be explained in the following.[83] For analyzing the impact of CDOs on company performance depending on varying human capital characteristics, a set of categorical variables with similar rationales to the specification of variables for

[81] For a detailed discussion on the differences between varying types of the unobserved effect and accordingly both fixed and random effects estimators, see, for example, Wooldridge (2002). To summarize, the random effects estimator assumes that the unobserved effect is orthogonal to all explanatory variables, considers the unobserved effect as part of the error term and accounts for implied serial correlation in the composite error term (Wooldridge, 2002).
[82] For a description of the data gathering process, see section 4.2.1.
[83] See Table 8 for an overview of included variables.

a CEO's attributes was specified.[84] Thus, for measuring the impact of a CDO's previous company affiliation a categorical variable was defined, which takes on the value of one, when a CDO existed, who was hired from outside of the company (i.e., *CDO existence – Company outsider*), takes on the value of two, when a CDO existed, but who was already employed within the company before becoming CDO (i.e., *CDO existence – Company insider*), and zero otherwise. Following the same logic, a categorical variable for a CDO's industry affiliation was established using the first four digits of the *GICS* drawn from S&P Capital IQ.[85] For a CDO, who's previous company was not within the same industry, the factorial variable was set to one (i.e., *CDO existence – Industry outsider*), for a CDO, who's previous company was within the same industry, the variable is set to two (i.e., *CDO existence – Industry insider*), and zero otherwise. Finally, for addressing a CDO's educational background, a factorial variable was specified, which takes on the value one, when a CDO's educational background lies within STEM for at least one degree (i.e., *CDO existence – STEM background*), or which was set to two for a CDO without a background in STEM (i.e., *CDO existence – Other background*), and zero otherwise. All analyses including the CDO's educational background were based on 26 company-years less due to missing information on some CDO's educational background.*

Due to the chosen approach of fixed effects estimation models, a different measure for previous company performance is required.[86] An alternative commonly used in literature is return on equity (*ROE*), measured as net income over total equity (Eccles

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[84] This approach to variable specification was chosen over moderation of *CDO existence* and a dummy variable for one of the characteristics (e.g., a CDO's educational background), due to strong collinearity of such variables. Most companies only had one CDO during the observed period, thus resulting in strong collinearity within each company between *CDO existence* and one of their characteristics (as investigated characteristics are time-invariant).*

[85] Note that four digits of the GICS were used (instead of two digits) in order to distinguish between different industries of CDOs for classifying CDO outsiders and insiders, because otherwise too different types of companies would have been compared when it comes to relevant CDO skills and knowledge for operating in this industry (e.g., software and service companies would in the same category as technology, hardware and equipment companies for a two-digit GICS categorization).

[86] The inclusion of lagged dependent variables in a fixed effects model might cause a violation of the strict exogeneity assumption. See footnote 88 or Wooldridge (2002). An alternative approach to designing fixed effects models with lagged dependent variables might be the Arellano and Bond estimator for dynamic panel analysis (Arellano & Bond, 1991; M. L. Zorn et al., 2017), which was not further considered here.

et al., 2014; M. Li & Roberts, 2018). Thus, a company's previous performance, i.e., *previous ROE*, was included as the lagged value of *ROE*. Similarly, *previous industry ROE* was operationalized as median value of lagged *ROE* for each industry and year. Therefore, both control variables replace *ROA* and *Tobin's Q* based company and industry performance measures.

5.3 An Introduction to Fixed Effects Estimation Models

Starting with studies by Mundlak (1961) or Balestra and Nerlove (1966), exploiting panel data gained increasing importance in econometrics (Nerlove, 2005). One of the main advantages of panel data regression lies within the possibility to account for endogeneity induced by unobserved variables of individuals (Greene, 2003; Wooldridge, 2002). Thus, consistent estimates can be derived even when omitted variables are present (Wooldridge, 2002). Especially in the case of studying performance implications of CDOs, individual yet time invariant company-specific factors might be present and unobservable as such companies could be systematically different from companies without a CDO. By following, for example, Roh et al. (2016), exploiting fixed effects estimation helps avoiding such endogeneity issues.

For introducing the fixed effects estimator, suppose again that $Y_{i,j}$ represents the j-th response (for $j = 1, \ldots, T$), i.e., the dependent variable, and $X_{i,j}$ denotes a $p \times 1$ vector of covariates, in line with the definition of chapter 4. Then, following the definition of Wooldridge (2002), the linear unobserved effects model of interest for T time periods can be written as

$$Y_{i,j} = X_{i,j}^{'} \beta + C_i + U_{i,j} \, . \qquad (12)$$

The term $U_{i,j}$ represents the idiosyncratic errors or disturbances as they might change across individual i and time period j (Wooldridge, 2002). Further, the model contains the unobserved effect C_i (among others also known as unobserved heterogeneity, individual effect or individual heterogeneity), which will be addressed by the fixed effects estimation approach (Wooldridge, 2002). It would be possible to estimate the unobserved effects model from equation (12) by normal pooled OLS, which assumes the composite error consisting of C_i and $U_{i,j}$ and which might provide consistent

estimates, if the composite error is not correlated with the explanatory variables for each time period (Wooldridge, 2002). While pooled OLS and also the random effects estimator consider the unobserved effect C_i as error term (including assumptions on implied correlations), the fixed effects estimator allows for an arbitrary correlation of the unobserved effect with all explanatory variables (Wooldridge, 2002).[87] Thus, fixed effects estimations are also more robust than random effects models (Wooldridge, 2002). As equation (12) represents an estimating equation, the interpretation of β results from the conditional expectation $E(Y_{i,j} | X_{i,j} , C_i) = X_{i,j}^{'} \beta + C_i$ (Wooldridge, 2002).

Assuming strict exogeneity of the explanatory variables conditional on C_i ,[88] the fixed effects estimators can be derived from transforming equation (12) such that the unobserved effect C_i will be eliminated (Wooldridge, 2002). The fixed effects transformation (also known as within transformation) can be obtained by firstly averaging equation (12) over $j = 1, \ldots, T$ as follows

$$\bar{Y}_i = \bar{X}_i^{'} \beta + \bar{C}_i + \bar{U}_i , \tag{13}$$

with $\bar{Y}_i = \frac{1}{T}\sum_{j=1}^{T} Y_{i,j}$, $\bar{X}_i = \frac{1}{T}\sum_{j=1}^{T} X_{i,j}$, $\bar{U}_i = \frac{1}{T}\sum_{j=1}^{T} U_{i,j}$ and $\bar{C}_i = \frac{1}{T}\sum_{j=1}^{T} C_i = C_i$, which reduces equation (13) to

$$\bar{Y}_i = \bar{X}_i^{'} \beta + C_i + \bar{U}_i . \tag{14}$$

When subtracting equation (14) from equation (12) for each j, the fixed effects transformed equation follows

$$Y_{i,j} - \bar{Y}_i = (X_{i,j} - \bar{X}_i)^{'} \beta + U_{i,j} - \bar{U}_i , \tag{15}$$

which is commonly written as

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[87] This assumption implies that for C_i , i.e., the unobserved time invariant effect, $E(C_i | X_{i,j})$ can be any function of $X_{i,j}$ (Wooldridge, 2002).

[88] Strict exogeneity of the explanatory variables conditional on C_i is characterized by $E(U_{i,j} | X_{i,j} , C_i) = 0$, for all for $j = 1, \ldots, T$ (Wooldridge, 2002). Note that this also implies that the explanatory variables are not correlated with idiosyncratic disturbances in each time period, i.e., $E(X_{i,s}^{'} U_{i,j}) = 0$, for all for $s, j = 1, \ldots, T$ (Wooldridge, 2002). By definition, strict exogeneity is violated in case lagged dependent variables are included as explanatory variables, which might lead to inconsistent estimates (Wooldridge, 2002).

$$\ddot{Y}_{i,j} = \ddot{X}'_{i,j}\,\beta + \ddot{U}_{i,j}\,, \qquad (16)$$

with $\ddot{Y}_{i,j} = Y_{i,j} - \overline{Y}_i$, $\ddot{X}_{i,j} = X_{i,j} - \overline{X}_i$ and $\ddot{U}_{i,j} = U_{i,j} - \overline{U}_i$ respectively. Thus, time demeaning of the original equation removed the unobserved time invariant effect C_i from the equation. In order to assure asymptotical well behavior of the fixed effects estimator, all explanatory variables $X_{i,j}$ must not include variables, which do not vary over time for any i (Wooldridge, 2002).[89] Finally, in order to ensure efficiency of the fixed effects estimator (and similar to normal OLS), each variance and each covariance of elements, which involve residuals, are required to be constant conditionally on all $X_{i,j}$ as well as the idiosyncratic error terms $U_{i,j}$ are not serially correlated and are characterized by constant variance across time (Wooldridge, 2002).[90] Without the unobserved effect C_i , estimating equation (12) can also be considered as a normal pooled OLS regression (Wooldridge, 2002).

An application of the discussed fixed effects estimator will be presented in the following section.

5.4 Application of a Fixed Effects Estimation Model for Assessing Performance Implications of the Chief Digital Officer

Like it was stated before, the aim of this analysis is to investigate how a CDO impacts company performance. While different CDO characteristics as well as contingency related factors were hypothesized to be more beneficial than others in terms of company performance implications of the CDO position, it was also derived from the resource-based view that complementary human capital in form of CDO, CIO and CEO also positively affect the performance results of companies. In order to rule out unobserved company time fixed effects and thereby reduce omitted variables bias, a fixed effects estimating approach was selected (Wooldridge, 2002). The full model for estimating implications of CDOs on company performance measured by *ROA* can be displayed as

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[89] This condition is also called standard rank condition on the time-demeaned explanatory variables. For more information, see Wooldridge (2002).
[90] Further technical details are provided, for example, by Wooldridge (2002).

$$
\begin{aligned}
ROA_{i,j} \;=\; & \beta_0 + \beta_1\, CDO\ existence_{i,j} + \beta_2\, CEO\ company\ outsider_{i,j} \\
& + \beta_3\, CEO\ tenure_{i,j} + \beta_4\, CEO\ STEM\ background_{i,j} \\
& + \beta_5\, company\ size_{i,j} + \beta_6\, industry\ revenue\ growth_{i,j} \\
& + \beta_7\, CIO\ presence_{i,j} + \beta_8\, H_{i,j} \times M_{i,j} + \beta_9\, controls_{i,j} \\
& + \beta_{10}\, year_j + \beta_{11}\, company_i\,, \qquad (17)
\end{aligned}
$$

where $year_j$ represents unobserved year fixed effects and $company_i$ are unobserved time invariant effects on company level.[91] For testing the combined effects of hypothesized factors form hypotheses four and five, the interaction term $H_{i,j} \times M_{i,j}$ is included in equation (17). $H_{i,j}$ represents the hypothesized CDO characteristic and $M_{i,j}$ describes the hypothesized CEO characteristic or contingency factor, depending on the hypothesis. The fixed effects model for assessing *Tobin's Q* is defined accordingly. Besides unobserved time fixed effects specific to individual companies, scholars also argue for the influence of economic cycles on company performance (Dess et al., 1990). Thus, following the approach of similar studies, year dummies $year_j$ were included in order to account for unobserved year fixed effects (e.g., A. A. Cannella et al., 2008; Chari et al., 2012; Eccles et al., 2014; Kanashiro & Rivera, 2019). As argued in the previous chapter, industry specific effects might be relevant in the context of company performance as well. Yet, as industry is a time-invariant company characteristic, the fixed effects estimator already accounts for this effect (Roh et al., 2016).

In order to assure that the assumption of the fixed effects estimator on the unobserved effects and the explanatory variables is correct (as described before), i.e., $X_{i,j}$ and $U_{i,j}$ are correlated, and therefore a fixed effects estimation model is in fact more appropriate than a random effects estimation model, a robust Hausman test was conducted (Schaffer & Stillman, 2006; Wooldridge, 2002).[92] The results of the

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[91] Note that different to the GEE model approach, where $year_{i,j\text{-}1}$ was included as continuous variable, here $year_j$ is included as dummy variable in order to account for unobserved year fixed effects.

[92] The Hausman test is a test of overidentifying restriction in the case of the random effects estimator. In addition to the fixed effects estimator assumption of no correlation between explanatory variables and the idiosyncratic error term, the random effects estimator assumes no correlation between

Hausman test confirm that for assessing *ROA* and *Tobin's Q* based on equation (17), a fixed effects estimator is the right choice.[93] Similarly, a test for choosing between the fixed effects estimator and the standard pooled OLS estimator yielded that fixed effects estimation should be preferred over a pooled OLS estimator.[94]

In order to investigate hypothesis three regarding the influence of varying CDO human capital on company performance, the variable *CDO existence* was alternately exchanged with the categorical variables, for example, like *CDO existence – Company outsider* and *CDO existence – Company insider*, defined as in section 5.2.2. Further, for assessing hypotheses four and five regarding the impact of complementing human capital of CEO, CIO and CDO as well as contingency related factors on company performance, the variable *CDO existence* or the categorical variables from section 5.2.2 were interacted with the respective hypothesized variables (represented by $H_{i,j} \times M_{i,j}$ in equation (17)) depending on the analyzed hypothesis. For example, the interaction between *CDO existence* ($H_{i,j}$) and *company size* ($M_{i,j}$) was included in order to assess hypothesis H5a.

Before investigating the results of the fixed effects estimator model, a discussion of self-selection-based endogeneity of strategic actions, such as employing a CDO, is required and a solution to address this issue will be presented (Clougherty et al., 2015; Shaver, 1998). Based on the derived solution, an assessment of data suitability will follow afterwards.

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explanatory variables and the unobserved effect. For further technicalities of the Hausman test, see Wooldridge (2002).

[93] For both the matched and unmatched samples. See section 5.5.

[94] For investigating whether a pooled OLS estimator should be preferred over a fixed effects estimation model, a Least Squares Dummy Variable (LSDV) regression including company specific dummy variables was conducted. Based on this regression, a F test was performed for assessing, if additional coefficients for each company, i.e., the unobserved effects, are jointly equal to zero or not. See also Wooldridge (2002).

5.5 Propensity Score Matching in the Presence of Self-Selection-Based Endogeneity

5.5.1 Issues of Self-Selection-Based Endogeneity

In the context of management research, scholars typically aim to identify the relationship of organizational decisions and organizational outcome (Shaver, 1998). An underlying issue of this relationship is the idea that such organizational decisions are selected while already keeping outcome and performance implications in mind (Clougherty et al., 2015). In other words, such managerial decision are not random and instead endogenous in terms of the expected performance impact (Bascle, 2008). This so-called self-selection-based endogeneity issue, which represents a subdimension of omitted variable bias, should be addressed in order to avoid inconsistent and uninterpretable estimates (Clougherty et al., 2015; Hamilton & Nickerson, 2003). Especially strategic actions of companies, such as hiring a CDO, are subject to endogeneity induced by self-selection due to a company's decision-making based on its attributes and industry conditions with regards to expected outcome (Clougherty et al., 2015; Shaver, 1998). Thus, when investigating the performance effects of the strategic decision of hiring a CDO, it is important to address the induced endogeneity of such a decision (Clougherty et al., 2015; Shaver, 1998).

Several approaches for solving self-selection-based endogeneity have been developed and are commonly referred to as Heckman two stage selection or Heckman correction models (Bascle, 2008; J. Heckman, 1974; J. J. Heckman, 1979; J. J. Heckman & Todd, 2009; L.-F. Lee, 1978). One crucial aspect of such models is that exclusion restrictions are required, which are variables explaining the decision to self-select, but are not correlated with the investigated organizational outcome (Bascle, 2008; J. J. Heckman, 1979).[95] Unfortunately, in many cases it is difficult to identify valid exclusion restrictions (Hamilton & Nickerson, 2003; J. Heckman, 1974). An alternative approach to correcting for self-selection bias in the absence of valid exclusion restrictions is the application of propensity score matching (PSM) (Hamilton &

[95] Note that such variables are sometimes also referred to as instrumental variables. Although similar characteristics are desirable for both instruments and exclusion restrictions, the approaches are still different. For more information on instrumental variables and applications, see, for example, Wooldridge (2002).

Nickerson, 2003; J. J. Heckman & Todd, 2009; Kanashiro & Rivera, 2019; Rosenbaum & Rubin, 1983).

5.5.2 An Overview of Propensity Score Matching

The underlying concept of propensity score matching and matching in general is to derive valid estimates of treatment effects when observational nonrandomized data is exploited (Rosenbaum & Rubin, 1983; Rubin, 1974, 1977). The effects of interest on some outcome are characterized by the effect a certain (binary) treatment causes on a (treatment) group compared to a (control) group, which did not receive the treatment (Abadie & Imbens, 2006; Rosenbaum & Rubin, 1983). Ideally, one would investigate the effect of treatment compared to non-treatment for the same individual at the same time, which is obviously not possible (Caliendo & Kopeinig, 2008). By using a matching approach, it is possible to pair individuals or companies, which received a treatment, with individuals from a large non-treatment group, which are similar in all other characteristics, and thus to correctly attribute the effect on outcome to the treatment itself (Caliendo & Kopeinig, 2008). The underlying assumptions for achieving valid matches and consequently valid estimates is known as strongly ignorable treatment assignment, i.e., unconfoundedness and common overlap (Rosenbaum & Rubin, 1983).[96] While normal matching is aimed at pairing treatment and non-treatment by (potentially many) different covariates with exact or nearest-neighbor matching, PSM utilizes propensity scores, i.e., the probability to receive the treatment given observed covariates, as single matching criteria (Caliendo & Kopeinig, 2008; Rosenbaum & Rubin, 1983). This propensity score is commonly modeled, for example, by logit or

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[96] Following the notation of Rosenbaum and Rubin (1983), strongly ignorable treatment assignment, given an observed vector of covariates X, is given if (i) $(r_0,r_1) \perp Z \mid X$ and (ii) $0 < P(Z = 1 \mid X) < 1$, where (r_0,r_1) describe the outcome for treatment $Z = 1$ and $Z = 0$ respectively and P denotes the standard probability of an event. Assumption (i) is known as unconfoundedness, selection on observables or conditional independence and assumption (ii) as common overlap. For further technical information on PSM, see Rosenbaum and Rubin (1983). Selection on observable can be interpreted as, given/conditionally on an appropriate set of observables X, the distribution of the (counterfactual) outcome of the treatment group is the same distribution as the (observed) outcome of the matched control group, which can be achieved by proper matching and propensity score modeling (Blundell et al., 2005). Note that this assumption is also required for the following fixed effects (OLS) regression (Blundell et al., 2005), thus this requirement is also assumed for the PSM approach. In order to verify proper matching, the matching quality will be assessed below.

probit models (Caliendo & Kopeinig, 2008; Rosenbaum & Rubin, 1983; Sasidharan & Donnell, 2013). The advantage of PSM over normal matching is that PSM is able to consider a multidimensional set of covariates combined within one propensity score while under normal matching, conditioning on all relevant covariates is limited when being dependent on a high dimensionality of covariates (Caliendo & Kopeinig, 2008).[97]

Further, PSM allows for model-based adjustments on matched samples (Negi & Wooldridge, 2020; Rubin & Thomas, 2000), potentially leading to more robust estimates than under random sampling (Rosenbaum & Rubin, 1983). Negi and Wooldridge (2020) called the application of regression (e.g., by exploiting the fixed effects estimator) on the matched sample a pooled regression adjustment.[98] In addition, by generating matched pairs of treatment individuals and control individuals, PSM provides the opportunity to assess difference-in-difference analyses (for mean and median) (Rosenbaum & Rubin, 1983).

5.5.3 Application of Propensity Score Matching

In the context of this study, the treatment of interested is the strategic choice of companies to hire a CDO, while control companies are characterized by not hiring a CDO. By matching CDO companies with non-CDO companies based on propensity score matching calculated and a large sample of observable (relevant) characteristics, the self-selection induced endogeneity can be avoided or at least reduced (Rosenbaum & Rubin, 1983; Rubin & Thomas, 2000; Sasidharan & Donnell, 2013). In simple words, the matching approach allows for comparison of CDO companies with non-CDO companies, which are otherwise very similar. In chapter 4, models for calculating propensity scores were already derived and assessed. As especially model 9 in Table 14 combines all covariates and yields the highest marginal R^2, propensity scores of this model, except one adjustment, have been used to generate matched samples of CDO and non-CDO companies for the first year a CDO was hired within

[97] This problem is also known as curse of dimensionality (Caliendo & Kopeinig, 2008; Ho et al., 2007).
[98] Note that by exploiting the fixed effects estimators on matched samples, unobserved fixed effects are controlled for as well next to self-selection-based endogeneity.

each company.[99] In order to avoid bias from matching on propensity scores calculated from covariates including *ROA* or *Tobin's Q*, model 9 in Table 14 was estimated based on *ROE* for both company and industry level and propensity scores were derived accordingly.[100]

Following the approach of Chang and Shim (2015), matching of CDO companies with non-CDO companies was conducted based on before described propensity score and while only allowing to match companies within the same year and industry according to the first two GICS digits to further increase similarity, with a caliper of 0.05 and nearest-neighbor matching. Some observations without a CDO were matched multiple times, in line with similar studies, such as, the study of Kanashiro and Rivera (2019). As the matching accuracy is crucial for the quality of results, balancing tests on individual covariate level and overall model level have been conducted for all covariates, which are included in the matching, by assessing standardized bias (or differences) and running a Hotelling T^2 test respectively (Rosenbaum & Rubin, 1985; Smith & Todd, 2005).[101] Figure 19 displays standardized bias in percent before and after matching according to before described baseline matching with exact match on year and industry, with a caliper of 0.05 and nearest-neighbor matching. As it can be seen standardized biases were improved significantly for the matched sample compared to the entire unmatched sample. According to Rosenbaum and Rubin (1985), standardized biases are too large if they exceed values of (absolute) 20%. As it can be seen in Figure 19, all biases comply with this requirement after matching. The Hotelling T^2 test, which assess whether a set of means is equal between two groups, indicated with a p-value of 0.975 that all covariates have equal means after matching. Overall, it can be concluded that the matching accuracy is good, and the matched sample is well balanced such that difference-in-difference analyses and model-based

[99] By using lagged observable covariates in the GEE model and finding matched pairs only for the first year of having a CDO, no assumptions for PSM are violated.

[100] The adjusted model 9 of Table 14 based on *ROE* yields the same results and satisfies all criteria as assessed in section 4.5.2 regarding suitability of data. With a marginal R^2 0.126, the model fit is even better than the original model 9 of Table 14. Thus, the model is well suitable as basis for the PSM approach.

[101] Standardized bias "…in percent is the mean difference as a percentage of the average standard deviation" (Rosenbaum & Rubin, 1985, p. 34). See, for example, Rosenbaum and Rubin (1985) or Chari et al. (2012) for a technical definition of standardized bias.

adjustments can be conducted. Further, of all 147 companies, which hired a CDO at least once (see Table 11), 144 companies were on support of the matching procedure, meaning that a suitable non-CDO company was identified from the control group.[102]

As highlighted by Wooldridge (2002), several options for assessing treatment effects have been suggested in the literature. For performing mentioned difference-in-difference analyses, the average treatment effect on treated (*ATT*) in line with the

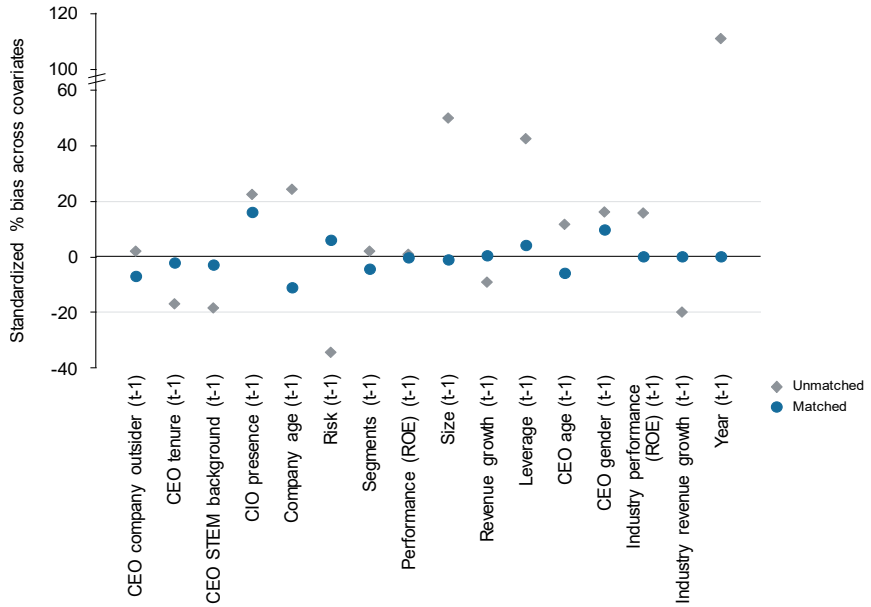

Figure 19: Standardized Percent Bias Across Covariates Included in Baseline Matching Before and After Matching
Source: Own illustration.

definition of Arnold and Javorcik (2009) will be considered in this study. Following the same logic of ATT, the median treatment effect on treated (*MTT*) will be assessed. For observing the impact of CDOs on company performance, the change of performance in the year before the CDO joined the company to the year when the CDO joined the company (as well as one year and two years after joining the company[103]) were

[102] Note that company-year observations of CDO companies in the years before hiring the CDO were treated as non-CDO companies in order to ensure a larger control group. This approach resulted in two CDO-companies to be included in the sample as they were matched in previous years as part of the control group.
[103] Note that as many companies hired a CDO at the end of the study's sampling period, the number of matched pairs decreases with increases assessment period of a CDO company's performance compared to a non-CDO company. For more than two years, the number of matched pairs decreases to such an extent that a difference-in-difference analysis based on a t test would not be meaningful.

analyzed compared to the same change of performance in a non-CDO company. Thus, for k = 0, 1 and 2, we define both *ATT* and *MTT* as

$$ATT_k = \frac{1}{n}\sum_{1}^{n}\left(ROA_{t+k}^{CDO} - ROA_{t-1}^{CDO}\right) - \frac{1}{n}\sum_{1}^{n}\left(ROA_{t+k}^{Non\text{-}CDO} - ROA_{t-1}^{Non\text{-}CDO}\right)$$

$$= \bar{\Delta}CDO_{t-1}^{t+k} - \bar{\Delta}Non\text{-}CDO_{t-1}^{t+k}, \qquad (18)$$

and similarly,

$$MTT_k = Median\left(ROA_{t+k}^{CDO} - ROA_{t-1}^{CDO}\right) - Median\left(ROA_{t+k}^{Non\text{-}CDO} - ROA_{t-1}^{Non\text{-}CDO}\right)$$

$$= \tilde{\Delta}CDO_{t-1}^{t+k} - \tilde{\Delta}Non\text{-}CDO_{t-1}^{t+k}. \qquad (19)$$

Following the same logic, *ATT* and *MTT* are defined for *Tobin's Q*. For assessing the significance of defined differences, a t test was applied (Chang & Shim, 2015). By investigating *ATT* and *MTT* on a medium-time horizon of two years for companies, which employ a CDO, compared to non-CDO companies, these analyses provide insights for the first part of hypothesis three. Recalling from section 3.4.1, hypothesis H3a states that CDOs have a positive impact on a company's performance. Table 16 and Table 17 provide an overview of derived results for *ATT* and *MTT* based on equations (18) and (19) respectively.

Variables		ROA[a]			Tobin's Q[a]		
Period		*t*	*t*+1	*t*+2	*t*	*t*+1	*t*+2
$\bar{\Delta}CDO_{t-1}^{t+k}$	*(CDO company)*	0.742	0.749	-0.097	-1.648	0.188	-1.120
$\bar{\Delta}Non\text{-}CDO_{t-1}^{t+k}$	*(Non-CDO company)*	-0.250	0.385	0.605	12.485	13.125	19.942
ATT_k		0.993*	0.364	-0.702	-14.132	-12.937	-21.062
		(0.064)	(0.621)	(0.496)	(0.156)	(0.314)	(0.260)
# matches (N)		144	118	90	144	118	90

***, ** and * indicate significance at the 1%, 5%, and 10% level, respectively.
P-values are provided in parentheses.

Table 16: PSM analysis. Average Treatment Effect on Treated (*ATT*) for *ROA* and *Tobin's Q* – Hypothesis 3a
Source: Own illustration.
[a] Performance measures are displayed as percentage points.

Variables		ROA[a]			Tobin's Q[a]		
Period		*t*	*t*+1	*t*+2	*t*	*t*+1	*t*+2
$\tilde{\Delta}CDO_{t-1}^{t+k}$	*(CDO company)*	0.195	0.536	0.350	4.164	5.320	1.336
$\tilde{\Delta}Non\text{-}CDO_{t-1}^{t+k}$	*(Non-CDO company)*	0.121	0.356	0.451	3.787	2.895	4.339
MTT_k		0.074**	0.180	-0.101	0.377	2.425	-3.003
		(0.014)	(0.390)	(0.927)	(0.327)	(0.720)	(0.740)
# matches (N)		144	118	90	144	118	90

***, ** and * indicate significance at the 1%, 5%, and 10% level, respectively.
P-values are provided in parentheses.

Table 17: PSM analysis. Median Treatment Effect on Treated (*MTT*) for *ROA* and *Tobin's Q* – Hypothesis 3a
Source: Own illustration.
[a] Performance measures are displayed as percentage points.

From both Table 16 and Table 17 it can be observed that companies, which employed a CDO, are able to significantly achieve 0.993% higher *ROA* (with p-value 0.064) regarding *ATT* (mean) compared to non-CDO companies in the year of hiring a CDO. Similarly, regarding *MTT* (median), CDO companies achieved significant higher results in terms of *ROA* by 0.074% (with p-value 0.014) compared to non-CDO companies in the year of employing a CDO. Yet, for the year and the second year after employing a CDO, this performance advantage vanishes. Both *ATT* and *MTT* for *ROA* become insignificant for t+1 and t+2. Regarding *Tobin's Q,* the results provide no evidence for any performance advantage of CDO companies compared to non-CDO companies, regardless of *ATT* and *MTT* for the same year, the year after and two years after hiring a CDO. Overall, these results provide only weak evidence for hypothesis H3a as it

appears that only at the beginning of a CDO's tenure, company performance is significantly better compared to non-CDO companies (in terms of *ROA*).

In order to further ensure the robustness of these results, alternative matching procedures have been considered. Thus, matching was also conducted based on 5-nearest-neighbor matching, matching without exact industry match, matching without replacement, matching with caliper 0.01, and 5-nearest-neighbor matching with caliper 0.01. In sum, all different matching procedures lead to the same results, which further validates and strengthens the analyses' robustness.[104]

In order to investigate the long-term impact of a CDO on company performance, model-based adjustments on matched samples, in the sense of estimating the fixed effects estimator model on the matched sample, will follow in the next section.

5.6 Results of Assessing Performance Implications of Chief Digital Officers with a Fixed Effects Estimation Model

Analogously to section 4.5, general characteristics of the data set will be assessed, followed by a discussion regarding the suitability of the data for conducting a fixed effects modeling approach. Finally, results from the fixed effects model will be investigated.

5.6.1 Data Inspection

In section 4.5.1, CDO adoption rates over time as well as across industries were already discussed. While Figure 14 showed a clear trend in increasing numbers of companies, which employee a CDO, in the last years, Table 11 showed a tendency of CDO employment in customer-centric industries. Opposing to variables used in the GEE model, i.e., lagged variables, the analyses of this chapter do not include lagged variables. Therefore, Table 18 displays basic summary statistics of the matched data

[104] For 5-nearest-nearest neighbor matching, *ATT* for *ROA* in the year of employing a CDO was only significant when conducting a one-sided t test. Matching without the exact industry conditions lead to a loss of significance regarding *ATT* for *ROA* in the year of employing a CDO. All other approaches to matching lead to the same results, but with even higher levels of significance.

base for all variables,[105] which are used (not simultaneously) in the fixed effects model for investigating the impact of CDO presence on company performance. As the GEE model contained lagged versions of each variable as displayed in Table 12, descriptive statistics in Table 18 are quite similar and therefore not further discussed. Only descriptive statistics of newly added CDO characteristics will be addressed in the following.

[105] See section 5.5 for a discussion on why all fixed effects estimations were based on a reduced (matched) sample. Summary statistics of the full sample are provided in the appendix C in Table C1 for the sake of completeness and comparability with the data used in the GEE model.

Variable	Obser-vations	Mean	Standard deviation	1st percentile	99th percentile
(1) ROA	2,933	0.059	0.068	-0.134	0.250
(2) Tobin's Q	2,933	1.680	1.516	0.103	7.355
(3) CDO existence	2,933	0.156	0.363	0.000	1.000
(4) CDO company outsider[106]	458	0.659	0.474	0.000	1.000
(5) CDO industry outsider[106]	458	0.550	0.498	0.000	1.000
(6) CDO STEM background[106]	432	0.493	0.501	0.000	1.000
(7) CEO company outsider	2,933	0.196	0.397	0.000	1.000
(8) CEO tenure	2,933	5.826	6.194	0.000	30.000
(9) CEO STEM background	2,933	0.283	0.451	0.000	1.000
(10) CIO presence	2,933	0.255	0.436	0.000	1.000
(11) Company age	2,933	79.302	51.063	8.000	220.000
(12) Risk	2,933	0.291	0.170	0.120	1.045
(13) Segments	2,933	4.056	2.565	1.000	14.000
(14) Previous ROE	2,933	0.203	2.689	-1.144	2.401
(15) Company size	2,933	10.017	1.536	6.350	14.466
(16) Revenue growth	2,933	0.082	0.388	-0.348	0.893
(17) Leverage	2,933	0.664	0.198	0.204	1.102
(18) CEO age	2,933	57.114	6.516	42.000	76.000
(19) CEO gender	2,933	1.045	0.208	1.000	2.000
(20) Previous industry ROE	2,933	0.149	0.048	0.043	0.235
(21) Industry revenue growth	2,933	0.054	0.052	-0.120	0.162
(22) Year	2,933	2013.179	3.720	2,007.000	2,019.000

Table 18: Summary Statistics of Variables Included in the Fixed Effects Model (Matched Sample)
Source: Own illustration.

First of all, Table 18 shows that the PSM approach as described before lead to a total of 2,933 company-year observations as for each CDO company and its matched non-CDO company, all company-year observations are considered in the sample for the fixed effects estimation. Further, it can be observed that of all 458 CDO company-year

[106] Note that by creating categorical variables as described in section 5.2.2, the number of observations for the categorical variable is in line with other variables, i.e., 2,933 company-year observations. As displaying summary statistics of categorical variables is not meaningful, summary statistics of CDO characteristics are only displayed for observations of CDO-companies. Further, as explained before, the variable for describing a CDO's educational background consists of 26 company-year observations (for nine companies) less due to their unobservable educations. By excluding these nine CDO-companies (all company-year observations with and without CDO) as well as their matched control non-CDO companies results in a matched sample of 2,761.

observations,[107] ca. 65.9% are characterized by CDOs, who joined the company from outside when assuming the CDO position. Yet, Table 18 displays that only ca. 55.0% joined the company from another industry. Finally, ca. 49.3% of all 432 CDO company-year observation can be described by a CDO, who possesses an educational background in STEM.[108]

Before assessing the results of the fixed effects estimator model, data suitability will be discussed hereinafter.

5.6.2 Suitability of Data

Following the same logic and cause of section 4.5.2, necessary assumptions for conducting fixed effects regression models will be assessed based on the underlying data set.

Outliers and missing data

The underlying data set for investigating performance implications of a CDO is equivalent to the data base for all analyses of chapter 4 in the context of the GEE modeling approach regarding CDO existence within companies. Therefore, outliers and missing data was handled analogously meaning that wrong values have been corrected and missing data has been added where appropriate. Similar to before, additional analyses had been conducted based on a winsorized data set for the 5th and 95th percentiles as well as 1st and 99th percentiles as simple exclusion of observations might not be meaningful (Gottfredson & Joo, 2013; Studenmund, 2014). Both approaches for winsorization when assessing implications on *ROA* or *Tobin's Q* yielded quantitively and qualitatively mostly similar results.[109] Again, the underlying

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[107] Note that the approach as described in footnote 102 lead to one CDO company-year observation less in the matched sample compared to the full sample (and 12 non-CDO company-year observations less), when comparing Table 18 with Table C1 from appendix C.

[108] See footnote 106 regarding the fewer amount of CDO company-year observations for the educational background of CDOs.

[109] Results for hypothesis H3c and H5a were deviating for the winsorized data sets compared to the non-winsorized data set. More information in this regard can be found as part of the corresponding discussion of results in section 5.6.3. Similar to section 4.5.2, DFBETAs were calculated for the full model (*ROA* and *Tobin's Q*) on the matched sample as described by equation (17) without the interaction term. Yet, due to the limitation of Stata's fixed effects estimation command, the models were estimated based on least squares dummy variable regression (which provides similar results)

data set is unbalanced, yet for each company the sequence of observations is uninterrupted, which can be addressed accordingly by the fixed effects estimator.[110]

Normal distribution of disturbance

As explained in chapter 4, OLS regression models assume that the disturbance is normally distributed (Greene, 2003). In order to assess the validity of this assumption, Figure 20 provides histograms of residuals derived from the full model for *ROA* (left) and *Tobin's Q* (right) on the matched sample as described by equation (17) without the interaction term. Both visualization appear to follow the density curve of a normal distribution.[111]

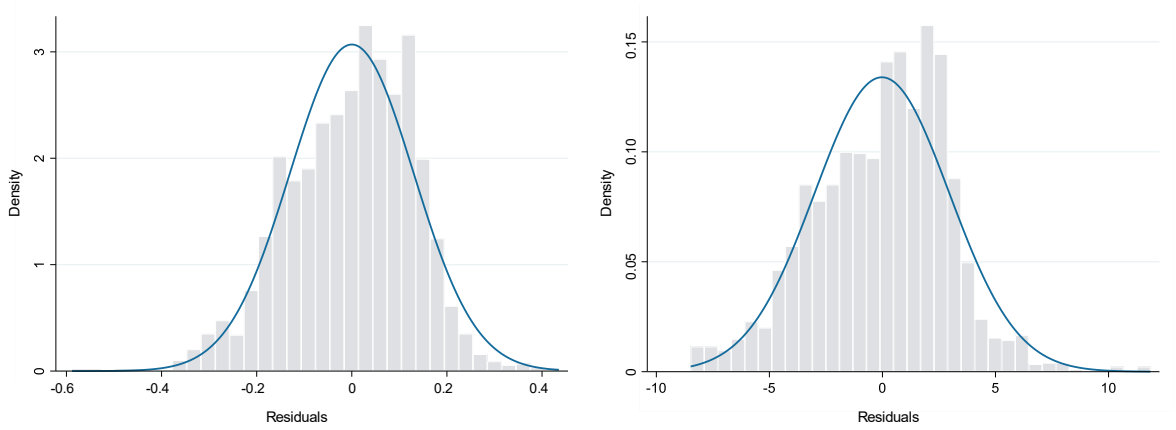

Figure 20: Histograms of Residuals for Fixed Effects Regression Models on the Matched Sample for *ROA* (left) and *Tobin's Q* (right)
Source: Own illustration.

(Wooldridge, 2002). For one company, absolute DFBETAs larger than 2 were identified. Therefore, results as described below were also validated by estimating each model on a same data set, which excludes all company observations of the influential company observation. All results remain both quantitatively and qualitatively similar.

[110] As mentioned before, all analyses were conducted based on Stata (version 16.1). Stata's fixed effects estimator is well applicable for both balanced and unbalanced data sets. In the unbalanced case, Stata weighs the unobserved effect C_i by the number of observations. For more information on the technical implementation, see Stata's website: https://www.stata.com/.

[111] Note that the histogram for residuals of the fixed effects estimation model for *Tobin's Q* is cut on the right for visualization purposes as there were few residuals ranging at ca. 15 and as the winsorization method yields the same results for the overall analysis.

Homoscedasticity and non-autocorrelation of disturbance

Recalling from section 4.5.2, OLS regression models assume that disturbances are not heteroscedastic and not autocorrelated in order to derive the best (minimum variance) linear unbiased estimates (Greene, 2003; Studenmund, 2014). Following Greene (2003), a test for heteroskedasticity in the disturbance of the fixed effect estimation model was conducted for both matched and unmatched samples based on equation (17) for assessing *ROA* and *Tobin's Q* respectively.[112] All tests indicate that heteroskedasticity might be an issue. Therefore, heteroskedasticity-robust standard errors clustered on company level are used for all fixed effects estimation models in order to ensure valid interpretations (Wooldridge, 2002). Similarly, for both models including *ROA* and *Tobin's Q* as well as matched and unmatched samples, a test for serial correlation in the idiosyncratic error terms is conducted.[113] All tests yield that serial correlation might be an issue. Yet, as standard errors are clustered on company level, serial correlation is addressed accordingly ensuring valid results (Drukker, 2003; Wooldridge, 2002).

Linear independence and endogeneity of independent variables

As linear independence of all predictors variables is desired, simple pairwise correlation coefficients between the predictors variables are assessed for detecting potential multicollinearity issues (Greene, 2003; Studenmund, 2014). Table 19 displays all pairwise correlations for variables included in the fixed effects estimation models as described before for the matched sample. For the unmatched sample, no noticeable correlations were identified and the interpretation is in line with results as reported as in Table 19.

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[112] For testing groupwise heteroskedasticity in disturbances of a fixed effect estimation model, a modified Wald statistic is calculated. Based on that the null hypothesis of homoskedasticity can be tested. For more details, see Greene (2003).

[113] The test assumes that residuals derived from the fixed effects estimation model of the first-differenced variables should have an autocorrelation of -0.5. A Wald test is performed to test the implication that the coefficient on the lagged disturbances when regressing lagged residuals on the current residuals should be -0.5 as well. For more details, see Wooldridge (2002) and Drukker (Drukker, 2003).

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) ROA	1.000									
(2) Tobin's Q	0.497*	1.000								
(3) CDO existence	0.004	0.033*	1.000							
(4) CEO company outsider	0.037*	0.000	0.065*	1.000						
(5) CEO tenure	-0.040*	0.048*	-0.021	-0.021	1.000					
(6) CEO STEM background	0.050*	0.076*	0.003	-0.073*	-0.070*	1.000				
(7) CIO presence	0.003	-0.007	-0.018	-0.028	0.042*	-0.111*	1.000			
(8) Company age	-0.090*	-0.241*	-0.010	0.104*	-0.080*	-0.217*	0.031*	1.000		
(9) Risk	-0.232*	-0.125*	-0.089*	-0.053*	0.063*	0.022	-0.041*	-0.079*	1.000	
(10) Segments	-0.158*	-0.270*	-0.020	-0.072*	-0.129*	-0.046*	0.052*	0.202*	0.083*	1.000
(11) Previous ROE	0.014	0.018	-0.001	0.020	-0.037*	-0.007	-0.024	0.001	-0.029	-0.012
(12) Company size	-0.293*	-0.512*	0.106*	0.097*	-0.138*	-0.069*	0.071*	0.363*	-0.034*	0.283*
(13) Revenue growth	0.001	0.086*	0.006	-0.013	0.074*	0.038*	0.015	-0.059*	0.020	-0.069*
(14) Leverage	-0.391*	-0.305*	0.081*	0.089*	0.005	-0.087*	-0.046*	0.268*	0.069*	0.110*
(15) CEO age	0.033*	-0.033*	0.033*	0.032*	0.009	0.402*	0.013	0.091*	-0.076*	0.055*
(16) CEO gender	0.047*	0.033*	0.015	-0.007	-0.009	-0.092*	0.038*	0.020	-0.043*	0.025
(17) Industry ROE	0.288*	0.247*	0.067*	0.011	-0.015	-0.056*	-0.042*	-0.024	-0.087*	-0.158*
(18) Industry revenue growth	0.095*	0.066*	0.022	-0.010	0.026	0.032*	0.020	-0.123*	-0.143*	-0.227*

* shows significance at the 10% level.

Table 19: Pairwise Correlations of all Variables used in the Fixed Effects Estimator Model (Matched Sample)

Source: Own illustration.

Variables	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
(11) Previous ROE	1.000							
(12) Company size	-0.006	1.000						
(13) Revenue growth	0.006	-0.059*	1.000					
(14) Leverage	0.020	0.411*	-0.011	1.000				
(15) CEO age	0.009	0.101*	0.004	0.112*	1.000			
(16) CEO gender	-0.010	0.014	-0.018	0.055*	-0.037*	1.000		
(17) Industry ROE	0.045*	-0.311*	-0.031*	-0.142*	0.024	0.074*	1.000	
(18) Industry revenue growth	0.013	-0.048*	0.169*	-0.116*	-0.035*	-0.003	-0.083*	1.000
* shows significance at the 10% level.								

Table 19 (continued): Pairwise Correlations of all Variables used in the Fixed Effects Estimator Model (Matched Sample)
Source: Own illustration.

It can be observed that except for *company size* and *Tobin's Q*, all variables show pairwise correlations below 0.500. As already pointed out before, some scholars accept pairwise correlation of up to 0.800, issues regarding multicollinearity cannot be identified (Studenmund, 2014).

As already described in section 4.5.2, scholars commonly also apply other influential-data diagnostics such as VIFs for investigating whether multicollinearity is a problematic issue (Hill & Adkins, 2003; Studenmund, 2014). Thus, VIFs were calculated for all variables, which were included in the full fixed effects estimator model using OLS regression, for both the matched and unmatched samples (Schmid & Dauth, 2014; M. L. Zorn et al., 2017). For all variables, VIFs are close to or below three and therefore far below the universal threshold value of ten (Hair et al., 2006). Overall, both VIFs and pairwise correlations lead to concluding that multicollinearity is not an issue.

Recalling from before, three common types of endogeneity of predictor variables are discussed in econometrics (Wooldridge, 2002). Regarding measurement error and omitted variables bias, the same argumentation as in section 4.5.2 holds. In addition, in section 5.5 self-selection-based endogeneity issues as subdimension of omitted variable bias was addressed by applying the fixed effects estimator on the matched sample resulting from PSM. To further validate derived results, the before mentioned common approach of two stage Heckman correction models was applied (J. Heckman, 1974; J. J. Heckman, 1979). By calculating an inverse Mill's ratio based on a probit model for estimating the selection of CDO employment, all models are estimated on the full sample including the inverse Mill's ratio as independent variable.[114] This alternative approach to PSM leads to very similar results regarding the assessment of before described hypotheses.[115] In addition, unobserved company specific effects are

[114] For further technicalities on this approach, see for example Wooldridge (2002). The probit model for calculating the inverse Mill's ratio is based on the adjusted GEE model 9 in Table 13 (considering *ROE*) as explained in section 5.5.3 with an additional instrument calculated as average CDO adoption rate by year and industry (based on the two-digit GICS categorization). The results remained mostly similar when applying a simple probit model only including the instrument. In order to adjust the variance accordingly, bootstrapped standard errors were exploited (e.g., Petrin & Train, 2010).
[115] The two stage Heckman correction model approach even leads to stronger results for hypothesis H4d as the expected effect could also be verified for *Tobin's Q*. For some hypotheses, even a partial

eliminated by the chosen fixed effects estimation approach. Overall, bias induced by omitted variables or measurement error can be expected to be minor or not relevant. Different to the GEE models from the previous chapter, the fixed effects estimation model in equation (17) is not based on lagged explanatory variables. Thus, for addressing the concern of simultaneity and other sources of endogeneity induced bias, all models were also estimated based on an instrumental variable approach for *CDO existence* (Wooldridge, 2002) as well as based on lagged explanatory variables similar to the GEE models (e.g., Kanashiro & Rivera, 2019).[116] Combining the results of both approaches yields very similar results compared to results presented in the next section and concerns regarding non-addressed bias appear to be limited.[117]

Overall, the chosen approach and data basis are suitable for investigating the implications of CDOs (and in combination with hypothesized factors derived from contingency theory and resource-based view). In the following section, results from the fixed effects estimation models will be presented.

5.6.3 Fixed Effects Estimation Model Results

Following the explanations of section 5.4, several variations of the full model displayed in equation (17) will be assessed in order to investigate hypotheses three, four and five, which are derived in chapter 3. The results for investigating the impact of CDOs on company performance in general and depending on different CDO characteristics,

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significant effect opposing to the hypothesized expectation can be observed, which will not be further discussed, as the overall results and their interpretations are based on the PSM approach (as displayed in section 5.6.3) are not compromised by these results. Instead, these tendencies provide grounds for future scholars to assess the same hypotheses based on alternative methods.

[116] Note that due to limitations of appropriate instruments, models including interactions of categorical variables with other hypothesized variables (e.g., regarding hypotheses H4a, H4b, H4d and H4e) could not be estimated based on this approach. Further, the instrumental variable approach was conducted on the full sample due to the methodological nature of the approach and without including an inverse Mill's ratio as the instruments would not satisfy relevant criteria. Especially, the instruments satisfied the underidentification test (Kleibergen & Paap, 2006), the weak identification test given the rule of thumb for test statistics in this setting (Staiger & Stock, 1997; Stock & Yogo, 2005), and the overidentification test (L. P. Hansen, 1982; Sargan, 1988) under robust standard errors (Baum et al., 2007; Schaffer, 2005). The underlying instrument is again calculated as average CDO adoption rate by year and industry (based on the two-digit GICS categorization).

[117] Combining both approaches, hypotheses H3c and H4d can be verified, but no further evidence is provided for hypothesis H4e. Yet, all other approaches for eliminating endogeneity verify hypothesis H4e. In total, the results as presented in section 5.6.3 are used for further argumentation and interpretation.

i.e., hypothesis three, are displayed in Table 20 and Table 21 for *ROA* and *Tobin's Q* respectively. Following that, derived results regarding hypothesis four concerning the impact of varying human capital combinations of CDO, CIO and CEO are presented. Thereafter, a CDO's impact on company performance depending on different contingency related factors, i.e., hypothesis five, is shown. As explained before, all models including the educational background of CDOs as variable are based on a reduced sample consisting of 2,761 company-year observations instead of 2,933 due to unobservable educational background of some CDOs.

Following the same line of argumentation as before, all three hypothesized contingency-related variables from hypothesis two are considered as baseline control variables when assessing hypothesis three as these are commonly considered in the performance related top management team literature (models 1 to 4) (e.g., Hambrick & Cannella, 2004; Nath & Mahajan, 2008; Shi et al., 2018). In addition, all three hypothesized CEO characteristics from hypothesis one are added as additional control variables in a second step (models 5-8), in order to exploit the full model from equation (17). Models 1 in both Table 20 and Table 21 each shows the full model excluding the interaction term and without the three hypothesized CEO characteristics. Models 5 additionally include all CEO characteristics as further controlling mechanism. Models 2,3 and 4 as well as models 6, 7 and 8 present the full model excluding the interaction term for each hypothesized CDO characteristic based on the categorical variables as defined before, with and without hypothesized CEO characteristics respectively.

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
CDO existence (t) *H3a*	-0.004				-0.004			
	(0.278)				(0.340)			
CDO existence – Company outsider (t) *H3b*		-0.009*				-0.008		
		(0.075)				(0.113)		
CDO existence – Company insider (t) *H3b*		0.003				0.003		
		(0.573)				(0.594)		
CDO existence – Industry outsider (t) *H3c*			-0.010*				-0.009*	
			(0.064)				(0.088)	
CDO existence – Industry insider (t) *H3c*			0.002				0.002	
			(0.735)				(0.704)	
CDO existence – STEM background (t) *H3d*				-0.008				-0.007
				(0.229)				(0.251)
CDO existence – Other background (t) *H3d*				-0.001				0.000
				(0.819)				(0.999)
CEO company outsider (t)					-0.002	-0.002	-0.002	-0.001
					(0.763)	(0.790)	(0.788)	(0.848)
CEO tenure (t)					0.001	0.001	0.001	0.001
					(0.227)	(0.234)	(0.226)	(0.215)
CEO STEM background (t)					-0.007	-0.007	-0.007	-0.008
					(0.187)	(0.204)	(0.200)	(0.167)
Company size (t)	-0.030***	-0.029***	-0.029***	-0.031***	-0.029***	-0.029***	-0.029***	-0.031***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Industry revenue growth (t-1 to t)	0.098***	0.097***	0.097***	0.101***	0.098***	0.097***	0.096***	0.100***
	(0.001)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
CIO presence (t)	0.006	0.005	0.006	0.005	0.005	0.005	0.005	0.005
	(0.178)	(0.194)	(0.177)	(0.202)	(0.218)	(0.233)	(0.216)	(0.240)

***, ** and * indicate significance at the 1%, 5%, and 10% level, respectively.
P-values are provided in parentheses. Standard errors are clustered by company.

Table 20: Fixed Effects Estimation Model. Dependent Variable: ROA (t) – Hypothesis 3
Source: Own illustration.

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Company age (t)	0.003***	0.003***	0.003***	0.003***	0.003***	0.003***	0.003***	0.003***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Risk (t)	-0.038**	-0.038**	-0.037**	-0.049***	-0.037**	-0.037**	-0.036**	-0.048***
	(0.019)	(0.017)	(0.020)	(0.005)	(0.023)	(0.022)	(0.025)	(0.006)
Segments (t)	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
	(0.527)	(0.525)	(0.541)	(0.356)	(0.471)	(0.472)	(0.486)	(0.318)
ROE (t-1)	-0.000**	-0.000**	-0.000***	-0.000***	-0.000***	-0.000***	-0.000***	-0.000***
	(0.013)	(0.010)	(0.009)	(0.007)	(0.006)	(0.005)	(0.004)	(0.003)
Revenue growth (t-1 to t)	0.011***	0.011***	0.011***	0.011***	0.012***	0.012***	0.012***	0.011***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Leverage (t)	-0.146***	-0.148***	-0.148***	-0.149***	-0.144***	-0.146***	-0.146***	-0.148***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)	(0.002)	(0.003)
CEO age (t)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(0.281)	(0.278)	(0.277)	(0.316)	(0.684)	(0.680)	(0.686)	(0.749)
CEO gender (t)	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
	(0.230)	(0.269)	(0.271)	(0.242)	(0.213)	(0.249)	(0.253)	(0.235)
Industry ROE (t-1)	0.208**	0.206**	0.208**	0.211**	0.208***	0.207**	0.208**	0.212**
	(0.011)	(0.013)	(0.012)	(0.013)	(0.009)	(0.010)	(0.010)	(0.010)
Intercept	0.188***	0.189***	0.187***	0.193***	0.203***	0.203***	0.202***	0.209***
	(0.001)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
F statistic	7.84***	7.62***	7.61***	7.25***	7.58***	7.45***	7.36***	7.05***
Company & year effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R^2 (within)	0.168	0.169	0.170	0.174	0.172	0.173	0.173	0.178
N	2,933	2,933	2,933	2,761	2,933	2,933	2,933	2,761

***, ** and * indicate significance at the 1%, 5%, and 10% level, respectively.
P-values are provided in parentheses. Standard errors are clustered by company.

Table 20 (continued): Fixed Effects Estimation Model. Dependent Variable: ROA (t) – Hypothesis 3
Source: Own illustration.

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
CDO existence (t) *H3a*	-0.095				-0.085			
	(0.284)				(0.333)			
CDO existence – Company outsider (t) *H3b*		-0.114				-0.097		
		(0.361)				(0.435)		
CDO existence – Company insider (t) *H3b*		-0.060				-0.064		
		(0.530)				(0.505)		
CDO existence – Industry outsider (t) *H3c*			-0.157				-0.142	
			(0.248)				(0.295)	
CDO existence – Industry insider (t) *H3c*			-0.029				-0.025	
			(0.766)				(0.793)	
CDO existence – STEM background (t) *H3d*				-0.156				-0.149
				(0.285)				(0.309)
CDO existence – Other background (t) *H3d*				-0.031				-0.008
				(0.723)				(0.926)
CEO company outsider (t)					-0.117	-0.116	-0.114	-0.125
					(0.147)	(0.148)	(0.151)	(0.144)
CEO tenure (t)					0.010	0.010	0.010	0.011
					(0.187)	(0.188)	(0.186)	(0.165)
CEO STEM background (t)					-0.134	-0.133	-0.132	-0.161*
					(0.133)	(0.135)	(0.137)	(0.098)
Company size (t)	-0.586***	-0.585***	-0.583***	-0.613***	-0.583***	-0.583***	-0.580***	-0.610***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Industry revenue growth (t-1 to t)	0.389	0.384	0.373	0.415	0.382	0.379	0.367	0.405
	(0.143)	(0.145)	(0.157)	(0.112)	(0.153)	(0.153)	(0.166)	(0.124)
CIO presence (t)	0.093	0.092	0.093	0.097	0.082	0.081	0.082	0.085
	(0.157)	(0.157)	(0.156)	(0.144)	(0.210)	(0.209)	(0.209)	(0.192)

***, ** and * indicate significance at the 1%, 5%, and 10% level, respectively.
P-values are provided in parentheses. Standard errors are clustered by company.

Table 21: Fixed Effects Estimation Model. Dependent Variable: Tobin's Q (t) – Hypothesis 3
Source: Own illustration.

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Company age (t)	0.055***	0.055***	0.055***	0.061***	0.054***	0.054***	0.054***	0.060***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Risk (t)	0.284	0.283	0.291	0.172	0.305	0.305	0.311	0.194
	(0.292)	(0.292)	(0.282)	(0.557)	(0.250)	(0.250)	(0.243)	(0.502)
Segments (t)	-0.023	-0.023	-0.023	-0.027	-0.025	-0.025	-0.025	-0.029
	(0.161)	(0.161)	(0.163)	(0.127)	(0.127)	(0.128)	(0.129)	(0.100)
ROE (t-1)	-0.004**	-0.004**	-0.005**	-0.005**	-0.006***	-0.006***	-0.006***	-0.006***
	(0.021)	(0.022)	(0.018)	(0.013)	(0.007)	(0.008)	(0.007)	(0.004)
Revenue growth (t-1 to t)	-0.108	-0.108	-0.108	-0.125	-0.105	-0.105	-0.105	-0.122*
	(0.209)	(0.210)	(0.209)	(0.100)	(0.215)	(0.215)	(0.215)	(0.098)
Leverage (t)	-0.465	-0.473	-0.489	-0.467	-0.425	-0.430	-0.448	-0.423
	(0.354)	(0.352)	(0.331)	(0.372)	(0.383)	(0.383)	(0.359)	(0.403)
CEO age (t)	0.008	0.008	0.008	0.008	0.005	0.005	0.005	0.005
	(0.290)	(0.290)	(0.288)	(0.346)	(0.394)	(0.392)	(0.393)	(0.500)
CEO gender (t)	0.096	0.094	0.091	0.108	0.087	0.086	0.083	0.093
	(0.493)	(0.503)	(0.519)	(0.463)	(0.526)	(0.533)	(0.552)	(0.524)
Industry ROE (t-1)	0.223	0.215	0.218	0.273	0.187	0.182	0.183	0.252
	(0.772)	(0.781)	(0.779)	(0.733)	(0.803)	(0.808)	(0.808)	(0.743)
Intercept	3.080**	3.084**	3.074**	2.985**	3.335***	3.336***	3.328***	3.272***
	(0.014)	(0.014)	(0.014)	(0.022)	(0.006)	(0.006)	(0.006)	(0.009)
F statistic	12.79***	12.3***	12.31***	12.29***	12.21***	11.8***	11.78***	12.4***
Company & year effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R^2 (within)	0.143	0.144	0.144	0.150	0.148	0.148	0.149	0.156
N	2,933	2,933	2,933	2,761	2,933	2,933	2,933	2,761

***, ** and * indicate significance at the 1%, 5%, and 10% level, respectively.
P-values are provided in parentheses. Standard errors are clustered by company.

Table 21 (continued): Fixed Effects Estimation Model. Dependent Variable: Tobin's Q (t) – Hypothesis 3
Source: Own illustration.

It can be observed that all models feature a significant F statistic implying a rejection of the null hypothesis that all coefficients of all variables for each model are equal to zero. Also, by including all three additional CEO characteristics into the models, the adjusted within R^2 keeps increasing, yet only slightly. As all three additional CEO characteristics (regarding tenure, company entry from outside and educational background) have no significant coefficients, including them in the models does not greatly improve the overall models' fit. Overall, all models for predicting *ROA* show adjusted within R^2 of ca. 0.170, while for *Tobin's Q* the adjusted within R^2 ranges around 0.145. Due to the nature of the fixed effects estimator, i.e., the (demeaning) within transformation, and the exploited statistical software, explanatory power of predictor variables is reduced. A comparison with similar fixed effects analyses considering the same and other performance measures, for example, in the studies of Roh et al. (2016), Firk et al. (2019) or Jensen and Zajac (2004), the models' (adjusted within) R^2 were ranging between 0.120 and 0.230. Thus, combined with the significant F statistics, the models displayed in Table 20 and Table 21 provide reasonable grounds for interpretation of derived results.[118]

Unlike derived results implying week evidence for the medium-term performance impact of CDOs regarding *ROA* in section 5.5.3, models 1 and 5 in both Table 20 and Table 21 do not provide further strengthening support for these results (hypothesis H3a). Instead, it can be observed that CDO existence is not leading to significantly better company performance for either *ROA* or *Tobin's Q*. Estimated coefficients are even negative for *CDO existence* meaning that company performance is lower for CDO companies, yet these coefficients provide no statistically significant grounds for interpretation. Overall, hypothesis H3a cannot be further confirmed.

Model 2 in Table 20 shows that company outsider CDOs have a significantly negative impact on company performance in terms of *ROA*. Still, model 6 provides no further

[118] Note that when running the same models based on pooled OLS regression including dummy variables for company and year fixed effects, resulting adjusted R^2 range around 0.600 and 0.750 for models assessing implications on *ROA* and *Tobin's Q* respectively. Authors of similar studies, for example, Hambrick and Cannella (2004), Kanashiro and Rivera (2019) or Nath and Mahajan (2008), derive comparable or lower (adjusted) R^2 when assessing performance implications based on pooled OLS regressions.

evidence for this negative relationship implying that in general neither company outsider CDOs or company insider CDOs are preferable in terms of a company's *ROA*. Similarly, models 2 and 6 in Table 21 show that there is no preference with regards to a CDO's company entry before assuming the CDO position and performance implications in terms of *Tobin's Q*. Overall, hypothesis H3b is not supported. Instead, it appears that company insider CDOs should be considered in terms of advantageous *ROA* implications, but fully significant support cannot be stated. In total, hypothesis H3b has to be rejected.

Models 3 and 7 in Table 20 both provide evidence for hypothesis H3c, i.e., that industry outsider CDOs have a significantly negative effect on company performance compared to non-CDO companies. In other words, this implies that industry insider CDOs affect company performance (*ROA*) less negative and should be thus preferred. According to model 7, industry outsider CDOs reduce a company's *ROA* by -0.009 on average (with p-value 0.088) compared to a non-CDO company. Since industry insider CDOs do not significantly impact company performance (*ROA*) compared to non-CDO companies, they should be preferred over industry outsider CDOs when hiring a CDO. When assessing hypothesis H3c based on the winsorized data set as described as in section 5.6.2, this effect becomes insignificant. As it can be seen in Table 21, this effect cannot be verified when investigating *Tobin's Q*. Overall, partial evidence was identified for hypothesis H3c related to *ROA*,[119] but not for *Tobin's Q*.

Finally, models 4 and 8 in both Table 20 and Table 21 provide no support for hypothesis H3d, i.e., that CDOs with an educational background in STEM significantly improve company performance. Thus, hypothesis H3d must be rejected. Generally speaking, hypothesized effects of CDO characteristics are not significantly affecting *Tobin's Q*.

For assessing hypothesis four, which theorized about the joint implications of CDO, CIO and CEO depending on combined characteristics, interactions of the full model as displayed in equation (17) were exploited in order to test hypotheses H4a to H4e. Like

[119] As the winsorized data base lead to a loss of significance.

before, contingency related factors are considered as control variables.[120] Table 22 and Table 23 display the results for *ROA* and *Tobin's Q* respectively.

[120] Since hypothesis four considered *CIO presence* from a resource-based view perspective, only *company size* and *industry revenue growth* are included as baseline controlling factors from a contingency theory point of view. As it can be observed in Table 20 and Table 21, all three hypothesized CEO characteristics and *CIO presence* are not significant and thus not considered as baseline control factors in the following analysis. Still, all estimations in Table 22 and Table 23 have been conducted including each described excluded control variable. All results remain unchanged.

Variables	Model 1	Model 2	Model 3	Model 4	Model 5
CDO existence (t)	-0.009*				
	(0.080)				
CDO existence – Company outsider (t)		-0.008			
		(0.188)			
CDO existence – Company insider (t)		-0.002			
		(0.732)			
CDO existence – Industry outsider (t)			-0.009		
			(0.170)		
CDO existence – Industry insider (t)			-0.002		
			(0.659)		
CDO existence – STEM background (t)				-0.006	-0.005
				(0.485)	(0.499)
CDO existence – Other background (t)				0.000	0.003
				(0.953)	(0.609)
CEO tenure (t)	0.001				
	(0.298)				
CEO company outsider (t)		-0.004	-0.004		
		(0.564)	(0.579)		
CEO STEM background (t)				-0.008	
				(0.186)	
CIO presence (t)					0.007
					(0.105)
CDO existence (t) x CEO tenure (t) *H4c*	0.001**				
	(0.025)				
CDO existence – Company outsider (t) x CEO company outsider (t) *H4d*		-0.008			
		(0.477)			
CDO existence – Company insider (t) x CEO company outsider (t) *H4d*		0.041***			
		(0.002)			
CDO existence – Industry outsider (t) x CEO company outsider (t) *H4e*			-0.009		
			(0.484)		
CDO existence – Industry insider (t) x CEO company outsider (t) *H4e*			0.023*		
			(0.061)		
CDO existence – STEM background (t) x CEO STEM background (t) *H4b*				-0.009	
				(0.443)	
CDO existence – Other background (t) x CEO STEM background (t) *H4b*				0.000	
				(0.966)	
CDO existence – STEM background (t) x CIO presence (t) *H4a*					-0.010
					(0.253)
CDO existence – Other background (t) x CIO presence (t) *H4a*					-0.012*
					(0.066)

***, ** and * indicate significance at the 1%, 5%, and 10% level, respectively.
P-values are provided in parentheses. Standard errors are clustered by company.

Table 22: Fixed Effects Estimation Model. Dependent Variable: ROA (t) – Hypothesis 4
Source: Own illustration.

Variables	Model 1	Model 2	Model 3	Model 4	Model 5
Company size (t)	-0.030***	-0.030***	-0.029***	-0.031***	-0.031***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Industry revenue growth (t-1 to t)	0.098***	0.098***	0.096***	0.102***	0.100***
	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)
Company age (t)	0.003***	0.003***	0.003***	0.003***	0.003***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Risk (t)	-0.037**	-0.038**	-0.037**	-0.049***	-0.050***
	(0.023)	(0.017)	(0.020)	(0.005)	(0.004)
Segments (t)	-0.001	-0.001	-0.001	-0.001	-0.001
	(0.508)	(0.504)	(0.502)	(0.337)	(0.381)
ROE (t-1)	-0.000**	-0.000**	-0.000**	-0.000***	-0.000***
	(0.013)	(0.012)	(0.011)	(0.005)	(0.006)
Revenue growth (t-1 to t)	0.011***	0.011***	0.011***	0.011***	0.011***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Leverage (t)	-0.145***	-0.147***	-0.148***	-0.148***	-0.150***
	(0.003)	(0.003)	(0.003)	(0.002)	(0.003)
CEO age (t)	0.000	0.000	0.000	0.000	0.000
	(0.852)	(0.275)	(0.264)	(0.287)	(0.330)
CEO gender (t)	0.007	0.007	0.007	0.008	0.009
	(0.273)	(0.344)	(0.348)	(0.236)	(0.230)
Industry ROE (t-1)	0.210**	0.201**	0.205**	0.208**	0.212**
	(0.010)	(0.015)	(0.013)	(0.013)	(0.012)
Intercept	0.203***	0.190***	0.186***	0.193***	0.194***
	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)
F statistic	8.30***	7.75***	7.35***	6.73***	6.86***
Company & year effects	Yes	Yes	Yes	Yes	Yes
Adjusted R^2 (within)	0.170	0.172	0.170	0.175	0.175
N	2,933	2,933	2,933	2,761	2,761

***, ** and * indicate significance at the 1%, 5%, and 10% level, respectively.
P-values are provided in parentheses. Standard errors are clustered by company.

Table 22 (continued): Fixed Effects Estimation Model. Dependent Variable: ROA (t) – Hypothesis 4
Source: Own illustration.

Variables	Model 1	Model 2	Model 3	Model 4	Model 5
CDO existence (t)	-0.123 (0.247)				
CDO existence – Company outsider (t)		-0.099 (0.481)			
CDO existence – Company insider (t)		-0.090 (0.397)			
CDO existence – Industry outsider (t)			-0.149 (0.324)		
CDO existence – Industry insider (t)			-0.041 (0.699)		
CDO existence – STEM background (t)				-0.261 (0.142)	-0.131 (0.426)
CDO existence – Other background (t)				0.038 (0.701)	-0.008 (0.943)
CEO tenure (t)	0.011 (0.183)				
CEO company outsider (t)		-0.133 (0.123)	-0.130 (0.130)		
CEO STEM background (t)				-0.195* (0.068)	
CIO presence (t)					0.111 (0.122)
CDO existence (t) x CEO tenure (t) *H4c*	0.005 (0.615)				
CDO existence – Company outsider (t) x CEO company outsider (t) *H4d*		-0.083 (0.730)			
CDO existence – Company insider (t) x CEO company outsider (t) *H4d*		0.221 (0.184)			
CDO existence – Industry outsider (t) x CEO company outsider (t) *H4e*			-0.048 (0.872)		
CDO existence – Industry insider (t) x CEO company outsider (t) *H4e*			0.058 (0.710)		
CDO existence – STEM background (t) x CEO STEM background (t) *H4b*				0.324 (0.256)	
CDO existence – Other background (t) x CEO STEM background (t) *H4b*				-0.229 (0.166)	
CDO existence – STEM background (t) x CIO presence (t) *H4a*					-0.086 (0.610)
CDO existence – Other background (t) x CIO presence (t) *H4a*					-0.073 (0.598)

***, ** and * indicate significance at the 1%, 5%, and 10% level, respectively.
P-values are provided in parentheses. Standard errors are clustered by company.

Table 23: Fixed Effects Estimation Model. Dependent Variable: Tobin's Q (t) – Hypothesis 4
Source: Own illustration.

Variables	Model 1	Model 2	Model 3	Model 4	Model 5
Company size (t)	-0.590***	-0.586***	-0.583***	-0.607***	-0.613***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Industry revenue growth (t-1 to t)	0.379	0.395	0.375	0.425	0.411
	(0.158)	(0.140)	(0.155)	(0.102)	(0.117)
Company age (t)	0.057***	0.055***	0.055***	0.061***	0.061***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Risk (t)	0.294	0.293	0.299	0.143	0.169
	(0.272)	(0.274)	(0.266)	(0.623)	(0.564)
Segments (t)	-0.023	-0.024	-0.024	-0.026	-0.026
	(0.157)	(0.147)	(0.145)	(0.127)	(0.129)
ROE (t-1)	-0.004**	-0.005**	-0.005**	-0.006***	-0.005**
	(0.033)	(0.012)	(0.010)	(0.007)	(0.011)
Revenue growth (t-1 to t)	-0.107	-0.108	-0.108	-0.120	-0.125
	(0.216)	(0.211)	(0.213)	(0.101)	(0.102)
Leverage (t)	-0.455	-0.460	-0.476	-0.443	-0.470
	(0.364)	(0.371)	(0.349)	(0.378)	(0.367)
CEO age (t)	0.003	0.010	0.010	0.008	0.008
	(0.660)	(0.238)	(0.232)	(0.356)	(0.351)
CEO gender (t)	0.085	0.065	0.063	0.101	0.109
	(0.535)	(0.639)	(0.652)	(0.482)	(0.455)
Industry ROE (t-1)	0.240	0.119	0.150	0.310	0.284
	(0.755)	(0.875)	(0.845)	(0.700)	(0.723)
Intercept	3.290***	3.108**	3.081**	3.006**	2.989**
	(0.006)	(0.014)	(0.014)	(0.020)	(0.022)
F statistic	12.57***	11.82***	11.73***	11.91***	11.40***
Company & year effects	Yes	Yes	Yes	Yes	Yes
Adjusted R^2 (within)	0.144	0.144	0.144	0.155	0.151
N	2,933	2,933	2,933	2,761	2,761

***, ** and * indicate significance at the 1%, 5%, and 10% level, respectively.
P-values are provided in parentheses. Standard errors are clustered by company.

Table 23 (continued): Fixed Effects Estimation Model. Dependent Variable: Tobin's Q (t) – Hypothesis 4
Source: Own illustration.

Similar to before, it can be noticed from Table 22 and Table 23 that all models' F statistics indicate that all coefficients of all variables are jointly not equal to zero. Also, the adjusted within R^2 lies in similar ranges to the results of the previous fixed effects estimation models. Further, it can be observed in Table 23 that, analogously to the previous models, hypothesized effects for hypothesis four do not significantly influence *Tobin's Q*. Still, based on the results displayed in Table 22, some of the hypothesized effects significantly influence a company's performance measured by *ROA*. Yet, not all significant factors affect *ROA* as expected, but in the opposite direction. To further guide interpretation of significant interaction effects for models in Table 22, interactions are plotted and displayed below.

Model 5 in Table 22 shows that opposing to the hypothesis, CDOs, who's educational background lies outside of STEM and which are complemented by a CIO, negatively affect company performance (*ROA*) by ca. -0.012 on average at a 10% significance level compared to a non-CDO company (with p-value 0.066). However, the effect of STEM background CDOs complemented by CIOs is not significant. Therefore, when a company aims at employing a CDO and a CIO is already part of the top management team, a STEM background CDO should be preferred. Figure 21 illustrates the interaction effect of CDO absence, CDOs with a STEM background and CDOs with another educational background on *ROA* when a CIO is employed within the company and when no CIO is present (keeping all other variables of the model at their respective means[121]). From the figure it can be seen that when a CIO is already within the company, the decrease in *ROA* is lower in cases when a non-STEM background CDO is hired and stronger in case of employing a STEM background CDO. Overall, this leads to rejecting hypothesis H4a since the effect is reversed compare to the initial hypothesis.

[121] Note that Figure 22, Figure 23 and Figure 24 are also plotted based on keeping all non-displayed variables of the respective model at their means (like the plot for Figure 21).

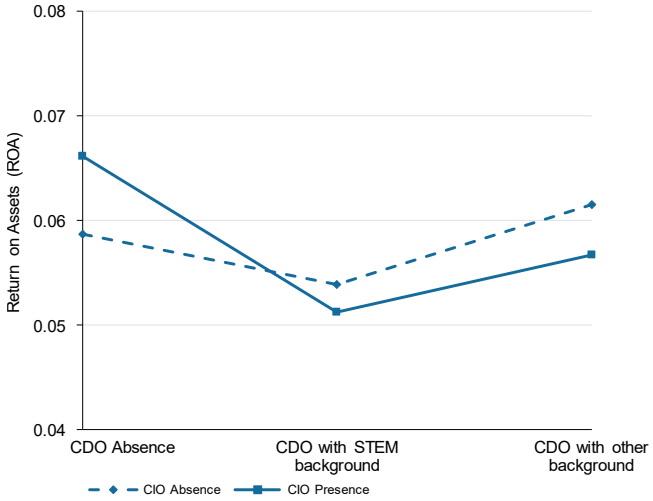

Figure 21: Interaction Effect Between CDO Educational Background and CIO Presence on Company Performance (ROA)
Source: Own illustration.

As it can be seen in model 4 within Table 22, there is no significant benefit or harm from employing either a STEM background or non-STEM background CDO, when the CEO is already educated in STEM. This leads to rejecting hypothesis H4b.

Similarly, model 1 as displayed in Table 22 provides no evidence for hypothesis H4c, but instead an effect was identified, which is opposite to the hypothesized influence of a CDO combined with an early tenure CEO. Based on the analysis, CDOs have a more positive impact on company performance when being complemented by a CEO, who is late in their tenure. For every additional year of a CEO's tenure, company performance assessed by *ROA* increases by ca. 0.001 at a 5% significance level for companies, which hired a CDO (with p-value 0.025). Model 1 is the only scenario in which inclusion of the interaction between *CDO presence* and *CEO tenure* resulted in a negative significant effect of CDOs on company performance. In Figure 22, this interaction effect becomes visible for a CDO's effect on company performance when the CEO is early in the tenure (5^{th} percentile) as well as when the CEO is late in the tenure (95^{th} percentile). Opposing to the hypothesis, the effect on *ROA* is more beneficial in the case of a late tenure CEO and causing an increase in company performance. As the effect is significantly and opposing to the hypothesized expectation, hypothesis H4c has to be rejected.

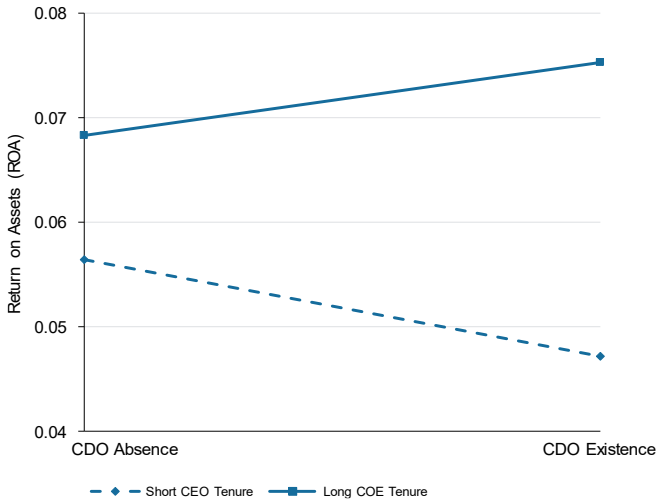

Figure 22: Interaction Effect Between CDO Presence and CEO Tenure on Company Performance (ROA)
Source: Own illustration.

The results presented by models 2 and 3 in Table 22 provide evidence for both hypothesis H4d and H4e, i.e., the beneficial complementation of a company insider CDO with a company outsider CEO as well as of an industry insider CDO with a company outsider CEO. According to the estimation in model 2, a company outsider CEO, who employs a CDO from insider the company, provides grounds for a performance increase of 0.041 on average in terms of *ROA* compared to a non-CDO company at a significance level of 1% (with p-value 0.002). The other way around, if both CDO and CEO joined the company from outside, this beneficial effect on *ROA* compared to non-CDO companies turns to be negative but is not significant anymore. As the effect is not apparent for *Tobin's Q*, evidence can only be provided for hypothesis H4d related to *ROA*. Similarly, model 3 shows that company outsider CEOs, who employ an industry insider CDO, enable the company to increase *ROA* by 0.023 on average at a 10% significance level compare to non-CDO companies (with p-value 0.061). Again, this significant effect vanishes for company outsider CEOs, who decide for an industry outsider CDO, and even turns negative. As described before, this effect cannot be observed for *Tobin's Q*. Further, the results imply that based on the effects magnitude, company outsider CEOs and company insider CDOs perform better than company outsider CEOs and industry insider CDOs, meaning that a company insider CDO should be preferred over an industry insider CDO when the CEO

was hired from outside of the company.[122] Overall, evidence is found for hypothesis H4e in terms of *ROA*, but not for *Tobin's Q*. Both hypothesized interaction effects of hypotheses H4d and H4e are also shown in Figure 23 and Figure 24. In both figures it can be seen that the increase in *ROA* is higher in cases when a company outsider CEO employs a CDO when the CDO assumes their position from within the company, or at least from the same industry. Especially, both effects cause an actual increase in company performance, while some of other before described significant effects solely result in less negative implications for company performance.

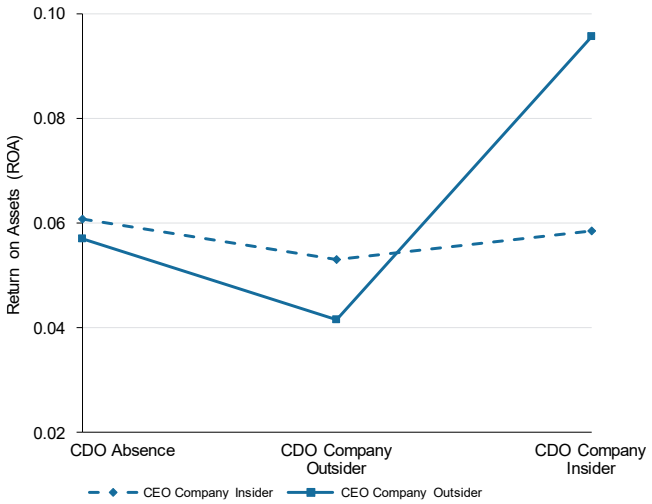

Figure 23: Interaction Effect Between CDO Company Entry and CEO Company Entry on Company Performance (ROA)
Source: Own illustration.

[122] Note that a company insider CDO is obviously also an industry insider CDO.

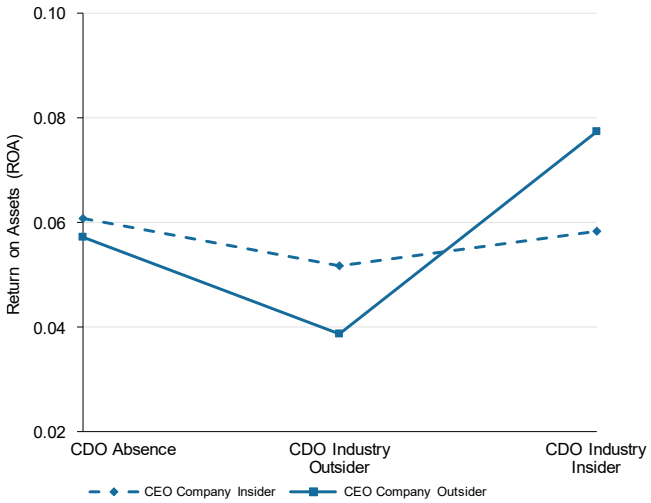

Figure 24: Interaction Effect Between CDO Industry Entry and CEO Company Entry on Company Performance (ROA)
Source: Own illustration.

Finally, Table 24 provides estimation results regarding hypothesis five. Recalling from section 3.4.3, hypothesis five theorized about the implications of a CDO on company performance given different contingency related factors, i.e., *company size* and *industry revenue growth*. Similar to before, both variables are considered as controlling factors and only the interaction terms are included separately.[123]

[123] See footnote 120 on why CEO characteristics and CIO presence are not further considered as controlling factors. Still, all estimations in Table 24 have been conducted including each described excluded control variable. All results remain unchanged.

Variables	Model 1a	Model 2a	Model 1b	Model 2b
	ROA (t)		Tobin's Q (t)	
CDO existence (t)	0.044	-0.003	0.841	-0.116
	(0.177)	(0.578)	(0.256)	(0.253)
Company size (t)	-0.030***	-0.029***	-0.591***	-0.585***
	(0.000)	(0.000)	(0.000)	(0.000)
Industry revenue growth (t-1 to t)	0.099***	0.101***	0.408	0.371
	(0.001)	(0.001)	(0.122)	(0.170)
CDO existence x Company size (t) *H5a*	-0.005		-0.090	
	(0.111)		(0.166)	
CDO existence x Industry revenue growth (t-1 to t) (t) *H5b*		-0.030		0.325
		(0.568)		(0.731)
Company age (t)	0.003***	0.003***	0.057***	0.056***
	(0.000)	(0.000)	(0.000)	(0.000)
Risk (t)	-0.040**	-0.038**	0.243	0.280
	(0.013)	(0.018)	(0.376)	(0.298)
Segments (t)	-0.001	-0.001	-0.021	-0.023
	(0.590)	(0.537)	(0.196)	(0.167)
ROE (t-1)	-0.000**	-0.000**	-0.004**	-0.004**
	(0.013)	(0.017)	(0.022)	(0.030)
Revenue growth (t-1 to t)	0.011***	0.011***	-0.107	-0.108
	(0.000)	(0.000)	(0.216)	(0.210)
Leverage (t)	-0.146***	-0.146***	-0.470	-0.468
	(0.003)	(0.003)	(0.340)	(0.351)
CEO age (t)	0.000	0.000	0.008	0.008
	(0.274)	(0.280)	(0.285)	(0.291)
CEO gender (t)	0.007	0.008	0.084	0.086
	(0.260)	(0.258)	(0.533)	(0.527)
Industry ROE (t-1)	0.207**	0.207**	0.203	0.221
	(0.012)	(0.012)	(0.793)	(0.776)
Intercept	0.186***	0.186***	3.055**	3.035**
	(0.001)	(0.001)	(0.014)	(0.015)
F statistic	8.19***	7.57***	13.36***	12.66***
Company & year effects	Yes	Yes	Yes	Yes
Adjusted R^2 (within)	0.168	0.167	0.145	0.142
N	2,933	2,933	2,933	2,933

***, ** and * indicate significance at the 1%, 5%, and 10% level, respectively.
P-values are provided in parentheses. Standard errors are clustered by company.

Table 24: Fixed Effects Estimation Model. Dependent Variable: ROA (t) and Tobin's Q (t) – Hypothesis 5
Source: Own illustration.

Similar to previous models regarding hypotheses three and four, all models shown in Table 24 for assessing hypothesis five are characterized by comparable adjusted within R^2 and significant F statistics. From models 1a (*ROA*) and 1b (*Tobin's Q*) in Table 24 it can be observed that the hypothesized effect of CDOs on company performance, given a more complex working environment of large scale companies, is not verified by the underlying fixed effects estimation model. Similarly, models 2a (*ROA*) and 2b (*Tobin's Q*) provide no evidence for higher company performance stemming from CDOs working in a high dynamic industry environment in terms of rapid industry revenue growth. If even, the both effects appear to be opposite to the hypotheses (except from the effects of CDOs in dynamic industries regarding *Tobin's Q*), but estimated coefficients are not statistically significant. However, basing the fixed effects estimation models on the winsorized data sets results in a significant negative effect (again opposing to the hypothesis) of CDOs in large companies on both *ROA* and *Tobin's Q*.[124] Overall, hypotheses H5a and H5b are not proven by the models and thus, have to be rejected.

Across all models presented in this section for assessing all three hypotheses three, four and five, several control variables were identified to significantly affect company performance. These variables include *company size*, *previous ROE*, *leverage* and *risk*, which negatively affect company performance (*leverage* and *risk* are only significant for *ROA*). While *company age* positively shapes *ROA* and *Tobin's Q*, *industry revenue growth*, *revenue growth* and *previous industry ROE* positively affect *ROA* only.

5.6.4 Concluding Remarks

Summing up the results from the previous section, only three out of eleven hypothesized effects were verified by the fixed effects models to significantly influence company performance as expected. Yet, these effects are just significant in terms of their relationship with *ROA*, but not *Tobin's Q*. The models are able to verify that

[124] In the case of winsorization on the 5th and 95th percentile, the effect is significant for *Tobin's Q* but not for *ROA*. Further, all other approaches to eliminating endogeneity (i.e., considering lagged variables, instrumental variables and the inverse Mill's ratios) yield the same result. Therefore, future scholars should especially further investigate the relationship of *CDO presence* and *company size* in the light of performance implications.

industry insider CDOs are favorable over industry outsider CDOs and with partial evidence, opposing to the hypothesis, company insider CDOs are to be favored over company outsiders as well. Especially when pairing industry or company insider CDOs with company outsider CDOs, company performance benefits significantly. Next to the already mentioned effect of company insider CDOs, which is different than expected, two other effects are also opposing to the hypothesized effect. In companies with CEOs, who are late in their tenure, employing a CDO can significantly increase company performance. Also, it appears to be more beneficial for companies, which already hired a CIO, to consider CDOs with an educational background in STEM. The remaining five hypotheses could not be verified. While this study found no evidence for a significant (isolated) effect of a CDO's educational background on company performance, Drechsler et al. (2019) derived that an educational background in STEM is perceived negatively by investors leading to negative stock market returns.

Most sobering of all is the finding that CDOs do not positively impact company performance as hypothesized and instead, although not significant, companies perform worse when a CDO is employed. Looking to similar studies in the top management team literature unveils that this outcome is not limited to the CDO. For example, Roh et al. (2016) identified that presence of the CSCO has no significant effect on company performance. Similar to this study, under some interacted contingency related conditions, the effect of CSCO presence even turns significantly negative. Yet, these contingencies are so strong such that at high levels of such, overall CSCO presence leads to significantly higher company performance. In the light of this study, at high levels of CEO tenure and CDO presence as well as for CEO company outsiders and CDO industry or company insiders, the (partially) non-significant effects without interaction turn significantly positive in terms of company performance implications. Still, some interactions within this study showed that certain conditions should be preferred over others in terms of less harmed *ROA*, but the overall performance effect cannot be expected to be positive. Nevertheless, the results allow to decide which characteristic for CDOs to choose when employing a CDO is required. Analogously, Nath and Mahajan (2008) unveiled that CMO presence does not result in significant performance implications. Menz and Scheef (2014) concluded the same

for CSOs. As another example, Hambrick and Cannella (2004) derived that CEOs, which decide to hire COOs, even deliver significantly lower company performance. Similarly, Kanashiro and Rivera (2019) showed that companies, which employ a CSuO, have a worse environmental performance compared to companies without a CSuO. Opposing to these results, Firk et al. (2019) found evidence for a positive effect of CDO presence of *Tobin's Q*. Also Drechsler et al. (2019) concluded that CDO appointments increase cumulative abnormal stock market returns. Although all these studies on C-level executives investigated different (interactive) factors compared to this study, derived partially mixed results and were based on varying methodologies and data bases, it becomes clear that research on individual C-level executives is required to identify these differences and conditions under which positive performance implications can be expected.

Further, several control variables were identified to significantly impact company performance as well. As described throughout this section, both hypothesized contingency factors from hypothesis five were also included as control variables for analyses regarding hypotheses three and four. It can be observed that *company size* significantly affects both *ROA* and *Tobin's Q*, yet with negative sign. Larger companies have lower performance compared to smaller companies based on this study's analyses. However, industry revenue growth appears to positively impact *ROA*, but not *Tobin's Q*. Further, older companies measured by the variable *company age* appear to generate higher performance in both *ROA* and *Tobin's Q*. A high-risk profile of companies is negative influencing *ROA*, whereas *Tobin's Q* is positively affected (but not significantly). In terms of previous performance measured by *ROE*, high performance in the last period appears to decrease both *ROA* and *Tobin's Q*. A company's *revenue growth* positively interferes with *ROA*, but negatively with *Tobin's Q* (but not significantly). Highly leverage companies also have lower performance measured by *ROA*. Finally, strong industry performance (*ROE*) in the previous period results in higher company performance in the current period in terms of *ROA*. Looking at similar or other performance related studies in the top management team literature, scholars came to both similar and different conclusions regarding the influence of described control variables (e.g., Georgakakis et al., 2017; Hambrick & Cannella,

2004; M. Li & Roberts, 2018; Marcel, 2009; Nath & Mahajan, 2008; Roh et al., 2016). Differences can certainly be explained due to different settings of each study (such as time period, sample or methodology). Overall, the results regarding control variables appear to be in line with studies in the field.

In the following chapter, all derived results will be summarized and discussed, followed by an overview of this study's contributions to praxis, limitations and identified future research potential.

6. Concluding Discussion

6.1 Summary of Results and Implications

In this study, three fundamental research questions centered around the CDO position are addressed. First, by systematically reviewing existing literature in the field, the CDO position is explained in full depth regarding tasks, responsibilities, skills and competencies, and unexplored research areas in CDO research are identified. Second, CEO characteristics and contingency related factors are analyzed regarding their influence on CDO presence within companies by exploring a large-scale data base of S&P 500 companies. Third, performance implications of CDOs are assessed in the light of pure CDO presence, different CDO characteristics, varying company contingencies as well as different C-level structures of CDO, CEO and CIO, based on the same sample. As the scholarly discussion in the field of the CDO position is still relatively new and rather under-researched (see chapter 2), the results of this study contribute to further developing the understanding of this position, top management team research and as grounds for decision makers. In the following section, results and implications of this study will be summarized and mutually discussed regarding content, conceptualization and methodology. While detailed insights regarding derived content can be found in the previous chapters, the mutual discussion in this chapter focuses on the combined results across all three research questions.

6.1.1 Content

As derived in chapter 2, tasks and responsibilities of CDOs and required skills, competencies, education and training for successfully accomplishing digital transformation are manifold. While each company's situation, environment and requirements require a focus on certain skills and fields of responsibility for the CDO position (Haffke et al., 2016; Singh & Hess, 2017; Tumbas et al., 2017), they also determine the need for a CDO in the first place (see Figure 9). Some of these determining factors are the existing executive team and their roles in digital transformation as well as company external and internal drivers (Haffke et al., 2016; Locoro & Ravarini, 2017; Singh & Hess, 2017; Tumbas et al., 2017). For fine graining these insights, this study investigates CEO, especially certain CEO characteristics, and

CIO as relevant representatives of the executive team as well as company internal complexity and external pressure from rapid market growth (see also chapter 3) in the light of their influence on CDO presence. Following the results from chapter 4, only a CEO's openness to strategic change, approximated by a short tenure as CEO, and the internal complexity of a company, represented by large size, lead companies to employ a CDO, while the other factors could not be verified as determining reasons for CDO presence. In fact, for these other factors it can also not be concluded that they would provide reasoning for the opposite decision, i.e., not employing a CDO. Consequently, it might be arguable that both upper echelons theory and contingency theory provide only limited explanatory power regarding CDO presence in companies as only some hypothesized effects could be verified. One possible reason for these findings might be that other factors than the ones hypothesized play a more important role in this regard for each theoretical viewpoint. In the light of upper echelons theory, more predictive power might be derived from other characteristics of CEOs and how these impact the CEO's perception for deciding about employing a CDO or not (e.g., other career experience, socioeconomic roots (Hambrick & Mason, 1984)). Similarly, contingency theory might provide more grounds for prediction CDO presence based on other relevant contingencies such as digital readiness and digital entrants in the industry as derived by Firk et al. (2019). Another potential explanation might be grounded in taking a (additional) different theoretical point of view. Since Hambrick and Cannella (2004) or Menz and Scheef (2014) came to similar conclusions when studying COO or CSO presence in companies respectively, they argued for drawing upon different theoretical perspectives, for instance, institutional theory (e.g., DiMaggio & Powell, 1983; Marquis & Tilcsik, 2016), i.e., the imitation of peers' behavior and therefore deciding for hiring a CDO.[125] By adapting an upper echelons theory perspective with regards to executive appointment decisions, this study certainly contributes towards that thought.[126]

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[125] As it can be seen by the high quality of the chosen instrumental variable in section 5.6.2, i.e., average CDO adoption rates by year and industry, the approach of drawing from institutional theory appears to be promising.

[126] As the results of this study compared to existing research on influencing factors for CDO presence as presented in section 2.4.4 are also partially mismatching (as discussed in chapter 4), it becomes evident that future research efforts in this field are still required.

Following from the decision to hire a CDO within the company, one would expect a company to also benefit from corresponding performance implications under these conditions. Overall, the analyses presented in chapter 5 do not confirm this expectation given the presented assessment of classical performance measures, i.e., *ROA* and *Tobin's Q*. Although CDOs are able to realize "quick-wins" resulting in increasing *ROA* in the beginning of their tenures based on the results in section 5.5.3, a long-term benefit cannot be observed. Identified as part of the first research question in chapter 2, some of the initial tasks of CDOs include aligning all ongoing digital activities and initiatives of a company and defining a joint strategic direction resulting in quickly implemented optimizations and performance improvement (e.g., Locoro & Ravarini, 2017; Tumbas et al., 2017; Ulrich & Lehmann, 2018). Yet, as already argued, for example, by Kotter (1995), transforming companies is time and resource intensive and thus, realization of financial benefits typically involves a longer time period.

Still, certain CDO characteristics and their combination with characteristics of CEO and CIO presence are significantly affecting company performance. While the analyses in chapter 4 unveiled that early tenure CEOs are more likely to employ a CDO within their top management team, the hypothesis that CDOs, which are complemented by early tenure CEOs, are contributing to better company performance cannot be verified. Instead, derived results show that CDOs increase company performance significantly higher when being complemented by late tenure CEOs. This means that although early tenure CDOs are more likely to employ a CDO, they are not able to provide an environment in which the CDO is able to comprehensively fulfill their task. Entrusting a CDO with conducting digital transformation alone is not solving all challenges of this transformational project, since the success of a CDO is strongly linked to an environment in which they can successfully operate and which should be created by the CEO and the entire top management team (Hess et al., 2016; Singh et al., 2019). On the contrary, late tenure CEOs are capable of supporting the CDO such that their impact positively affects company performance, although such CEOs are less likely to hire a CDO. Consequently, early tenure CEOs are required to create a more supportive environment for their CDOs while late tenure CEOs should consider hiring a CDO more often as they appear to be an effective team in digital transformation.

Similarly, the results in section 5.6.3 show that although larger scale companies are more likely to employ a CDO as hypothesized, CDOs are not able to significantly increase company performance given this contingency. Instead the results point towards the opposite effect, i.e., that with increasing company size, resulting performance implications of CDOs are non-beneficial for the company as both *ROA* and *Tobin's Q* decrease in this setting.[127] In terms of high external market pressure, neither a positive nor a negative effect of CDO presence in such a setting could be observed.

When considering the hypothesized advantage of certain CDO characteristics in order to achieve increasing company performance, not all expected effects could be verified. The results show that there is no significant benefit from either hiring a CDO, who possesses an educational background in STEM, or a CDO with another education. Yet, when considering whether a company already employs a CIO within the top management team, derived insights suggest that employing a non-STEM background CDO is significantly more harmful for company performance. Thus, for companies, which already have a CIO running the IT department, it is advisable to also assure that the newly appointed CDO is sufficiently equipped with relevant technical knowledge, represented by an education in STEM. Unlike hypothesized, complementation of CIO as technical-side manager and CDO as business-side manager is not leading to the expected benefit for company performance. Instead, it appears that it is more important that both CDO and CIO are able to communicate on the same grounds of technical knowledge. It remains unclear how both C-level executives distinguish between their roles, e.g., clarification who is responsible for developing sufficient digital business models as part of the digital transformation. As stated, for example, by Haffke et al. (2016), a clear definition of the required CDO role type depends on the orientation of the CIO role. Thus, future scholars should analyze this relationship in more detail (e.g., by differentiating between different levels of experiences or focus of CIOs) regarding the implications on company performance. Further, despite the results from chapter 4,

[127] Note that based on the general analyses, these effects were non-significant. Yet, based on endogeneity-corrected approaches and the winsorized data sets, significance regarding these effects was observed. For more details, see sections 5.6.2 and 5.6.3.

this result suggests that CEOs should consider the opinion of their CIO when deciding about employing a CDO. With regards to complementation of a CEO's educational background and the CDO's background, the results do not point towards an advantage for any of both.

Regarding a CDO's experience from outside the company or even outside the industry, the analyses unveiled that employing a CDO from the same industry (confirming the hypothesis) or even from within the company (refuting the hypothesis) is more beneficial for company performance. This underlines the importance of knowledge regarding internal stakeholders, departments, functions, activities and processes such that cross-functional internal collaboration can be fostered for successfully driving digital transformation (e.g., Capitani, 2018; Singh & Hess, 2017; Ulrich & Lehmann, 2018; Vial, 2019). Especially, given that the CEO joined the company from outside, the combined effect of company insider or industry insider CDO and company outsider CEO on company performance multiplies as the achieved increase in performance is significantly higher than if such CEOs are paired with company outsider or industry outsider CDOs respectively. These results underline the assumption that company outsider CEOs require a CDO in digital transformation, who is familiar with company internal aspects or at least with the company's industry.

The analyses of chapter 5 also unveiled that all described effects are only observable regarding *ROA*, but not for *Tobin's Q*. By definition, this implies that companies are more effective in utilizing their assets for generating net income. On the other hand, lacking evidence regarding the impact on *Tobin's Q*, as a measure of the financial market's view on the value of a company, can be interpreted such as that either markets do not value the efforts of CDOs or that the activities of CDOs are not visible by financial market participants.[128] In either case, companies should therefore make their digital transformation efforts more visible to the financial markets in order to

[128] Note that another approach to understanding the impact of CDOs on market based company performance was planned by measuring abnormal stock returns as part of an event study (McWilliams & Siegel, 1997). For most companies of this study's sample, CDO appointments were not publicly announced such that an event study methodology could not be applied. Still, this clearly shows that most companies do not actively communicate about their CDOs and arguably also not about their CDO's achievements.

secure benefits with regards to *Tobin's Q*, at least if optimization for market-based performance measures is relevant for the company.

From a theoretical point of view, the derived framework combining human capital theory, contingency theory and the resource-based view is certainly providing well grounds for predicting performance implications of CDOs given varying settings (see section 3.4). As some hypotheses were not verified by this study's analyses, the theoretical fit of the framework for hypothesizing about performance implications still requires further fine-graining and testing. Similar to before, one reason for failing to verify some hypotheses might be grounded in analyzing less relevant factors and not considering other influencing components when assessing CDO performance implications. For example, in the light of human capital theory, additional CDO characteristics, which are relevant in the context of digital transformation, should be considered for identifying differences in performance implications of CDOs. Likewise, other contingencies should be analyzed such as digital readiness as pointed out before in the context of predicting CDO presence in companies (Firk et al., 2019). As stated in chapter 2, top management team support, especially from the CEO, is crucial for a CDO's ability to successfully drive digital transformation (e.g., Bülchmann, 2017; Haffke et al., 2016; Singh & Hess, 2017; Zisler et al., 2016). Thus, investigating the organizational integration of CDOs and the level of CEO and top or middle management team support might unveil further insights regarding CDO performance implications.

Overall, the analysis in chapter 5 showed that pure CDO presence does not result in increased company performance. Although short-term benefits could be identified in terms of *ROA*, the long-term effect was not significantly improving company performance. Instead, the results in Table 20 and Table 21 indicate a negative long-term effect on company performance. Although these results are in line with previous research on other individual C-level executives (Hambrick & Cannella, 2004; Menz & Scheef, 2014; Nath & Mahajan, 2008), the question arises why companies or CEOs

still opt for employing a CDO.[129] One possible answer might be that there are unobservable reasons or benefits for companies and CEOs leading them to accept potential negative performance implications.[130] Yet, as the negative effect was not significant, companies do not suffer systematic performance decreases by employing a CDO. As long as the digital transformation process succeeds, entrusting a CDO with this tasks might be worth the additional costs due to the additional organizational layer (Hambrick & Cannella, 2004) and added executive on the company's monthly payroll (Drechsler et al., 2019; Friedrich & Péladeau, 2015). Thus, investigating, for example, the level of success regarding the degree of implementation of digital transformation should be considered as more relevant measure for a CDO's impact within the company. For instance, Kanashiro and Rivera (2019) investigated the impact of CSuOs in the light of environmental performance, yet also without verifying the expected effect. Overall, these insights call for further assessment of a CDO's impact within companies as well as of other C-level executives.

To sum up, Table 25 summarizes all hypotheses and corresponding results as derived in chapter 3 and assessed throughout chapters 4 and 5.

[129] Especially since previous studies in this field point towards partially different results regarding hypothesized performance implications (see chapter 5), this questions becomes even more relevant.
[130] Note that certain types of unobserved effects are addressed by the chosen methodological approach, but not specifically tested. See section 5.6.2.

Hypoth-esis	Expected Effect	Observed effect	Meaning
1	The likelihood of having a CDO within the company will be influenced by a CEO's perception of the company situation depending on their characteristics.	a) Company outsider CEOs are not more likely to employ a CDO. b) CEOs, who are early in their tenure, are more likely to employ a CDO. c) CEOs, without an education in STEM, are not more likely to employ a CDO.	Partially confirmed. One of three CEO characteristics influence CEO perception and consequently CDO presence as hypothesized.
2	The likelihood of having a CDO within the company will be influenced by organizational and environmental company contingencies.	a) CDO presence is more likely in complex companies (large size). b) CDO presence is not affected by higher dynamic industry (stronger sales growth). c) CDO presence is not influenced by CIO absence.	Partially confirmed. One of three contingency factors influence CDO presence as hypothesized.
3	The presence of CDOs will positively impact company performance and the impact will be more positive (or less negative) depending on their human capital characteristics.	a) CDO presence in general does not impact company performance. b) Company outsider CDOs do not positively affect company performance. Instead, the opposite effect was observed, i.e., company insider CDOs increase company performance. c) Industry insider CDOs improve company performance. d) CDOs with a background in STEM do not impact company performance.	Partially confirmed. One of three human capital characteristics affects company performance as hypothesized.
4	CDOs will impact company performance more positively (or less negatively) depending on human capital compositions of CDO, CEO and CIO	a) Non-STEM background CDOs and CIOs do not impact company performance. Instead, STEM background CDOs and CIOs contribute to increasing company performance. b) STEM background CDOs and non-STEM background CEOs do not affect company performance. c) CDOs and early tenure CEOs do not affect company performance. Instead, CDOs and late tenure CEOs are able to improve company performance. d) Company insider CDOs and company outsider CEOs positively impact company performance. e) Industry insider CDOs and company outsider CEOs positively impact company performance.	Partially confirmed. Two of five human capital compositions of CDO, CEO and CIO affect company performance as hypothesized.

Table 25: Summary of Results from Hypothesis Testing
Source: Own illustration.

Hypoth-esis	Expected Effect	Observed effect	Meaning
5	CDOs will impact company performance more positively (or less negatively) depending on organizational and environmental company contingencies.	a) CDOs in more complex companies (large size) do not contribute to improving company performance. b) CDOs in companies within higher dynamic industry (stronger sales growth) are not able to improve company performance.	Not confirmed.

Table 25 (continued): Summary of Results from Hypothesis Testing
Source: Own illustration.

Finally, depending on the company's need and the targeted results of digital transformation (Haffke et al., 2016; Singh & Hess, 2017), a CDO can be typically categorized by a certain role type, i.e., innovator, communicator and collaborator (see Table 5). Therefore, derived results from the systematic literature review in chapter 2 regarding different CDO role types and the individual focus on tasks and responsibilities combined with corresponding required skills and competencies might guide companies for searching a suitable candidate when employing a CDO. Especially when companies consider optimizing for *ROA*, the results of this thesis also provide guidance regarding which characteristics to look for in a potential CDO candidate, given specific company conditions.

6.1.2 Conceptualization

Similar to previous scholars, who investigated other C-level executives like CSO, CMO or COO (e.g., Hambrick & Cannella, 2004; Menz & Scheef, 2014; D. M. Zorn, 2004), this study extends CDO research by jointly investigating both mechanisms for CDO appointment decisions and consecutive performance implications for the company as interrelated effects, while still incorporating existing results in the field. Especially the developed theoretical framework (see chapter 3), which is comprised of several theoretical viewpoints, allows for a holistic approach to discuss the concept of CDO employment and resulting company performance consequences. As one major extension to the top management team literature, conceptualizing and assessing of different C-level structure compositions, i.e., CDO, CEO and CIO characteristics and presence, by combining human capital theory and the resource-based view, opens

new paths for future scholars to extend knowledge about C-level performance implications. As highlighted by Menz (2012), research on individual C-level members helps better understanding top management team processes and strategic decision making, but is still at its beginning and not fully addressing the fit between multiple top management team members. Thus, this study provides a starting point to further study and fine grain analyses of top management team compositions and corresponding implications such as performance consequences (Beckman & Burton, 2011; Hambrick, 2007; Menz, 2012). Not only is this approach to conceptualization new in research on individual top management team members, but also does it allow to exploit a more detailed level of analysis compared to previous studies in which scholars combined several demographical characteristics in one single measure (Beckman & Burton, 2011; B. Cannella et al., 2008; Menz, 2012). While this does not impose a drawback of previous scholars' efforts, the approach presented in this study provides additional grounds for approaching top management team research from various angles. Finally, theory as presented in chapter 3 becomes combined in a more holistic framework and extended by the viewpoint from a rather newly created and modern C-level executive, namely the CDO.

6.1.3 Methodology

Although all chosen methodological approaches as presented throughout this study are not new in top management team research, the combination of PSM (see section 5.5) based on a GEE model (see section 4.4[131]) and fixed effects regression models (see section 5.4) is still mostly unexploited by scholars. Only Kanashiro and Rivera (2019) based their analyses for assessing environmental performance implications of CSuOs on a similar approach. Still, their underlying probit model for estimating the propensity of CSuO presence is rather simple without considering the correlation structure within the underlying panel data, i.e., within companies, and incorporated measures within their model are not comprehensively accounting for all potential influences on CSuO presence. By basing PSM on a GEE model, which accounts for within panel correlation structures and which is based on a variety of relevant

[131] Adjusted for *ROE* as described in section 5.5.3.

measures regarding CDO presence, this study exploits a new way of combining established methodologies. As derived in section 5.5.2, estimating regression models on matched samples as a result of PSM, i.e., pooled regression adjustment, potentially leads to more robust estimation results (Negi & Wooldridge, 2020; Rosenbaum & Rubin, 1983; Rubin & Thomas, 2000) and should be therefore considered by scholars when endogeneity concerns have to be addressed (see section 5.5.1). In addition, this approach also allows for investigating both medium-term and long-term effects based on difference-in-difference analyses of matched samples and regression models over the full sampling period respectively.

6.2 Limitations

Apart from the derived results and just described implications, this study is also not free from limitations, which should be considered by scholars and practitioners when interpreting the herein presented results.

Although the theoretical framework as described in chapter 3 is tailored to comprehensively cover all relevant aspects for estimating their influence on decision making, such as CDO appointment decisions, and company performance, it is undoubtable that many other aspects play a crucial role in such decision making processes and which influence company performance as well. Especially, effects, which are unobservable from the outside, might affect strategic decisions significantly and the derived impact of hypothesized variables might be blurred. As pointed out before, further extending the theoretical lens to other theories might be helping to reduce this issue.

Also, such effects could be captured by also including primary data within the study. Yet, due to the chosen approach and practical reasons, this study is based on secondary data. In general, measures for strategic actions and company performance as retrieved from secondary data also potentially depend on factors, which are not necessarily related with the intended measured effect (Dalton & Aguinis, 2013; Venkatraman & Ramanujam, 1986). Economic factors like recessions could thus also be reflected in measures like *ROA* next to the actual performance of the company (G. Wang et al., 2016).

Another issue of secondary data is that this type of data does not allow for direct observation of the true inference, for example, of CEO characteristics and the underlying decision-making process of hiring a CDO (Clark & Soulsby, 2007). Like other studies based on similar panel data sets, it is thus difficult to observe the true process of how CEOs perceive a situation and thus make strategic decisions and actions (Karaevli & Zajac, 2013). Similarly, it remains not directly observable how certain CDO characteristics translate into their actual actions leading to changes in company performance.

Also, unlike primary data, secondary data is not directly verified by scholars themselves. Therefore, issues arising from different reporting styles or personal preferences in resumes are not avoidable. For example, the true timing of starting a new position might be later than reported because the person is taking some time off work in between changing positions. Similarly, it remains not fully verifiable whether all CDO positions included in the sample are fulfilling all inclusion criteria as described in section 4.2.1 or not. Thus, it could be possible that some included CDOs are not operating on a global company-wide level and therefore their impact on company-performance is limited by the nature of their specific position within the company. Another concern might be that it remains open whether all CDOs and their respective companies actually undergo a digital transformation process, which was implicitly assumed by pure CDO presence.

The underlying sample of this study is also subject to limitations. As companies within the panel data set were selected from all S&P 500 constituents at the end of the sampling time frame (see section 4.2.1), the sample might be suffering survivor bias as some companies might have dropped out of the S&P 500 index during the sample period, for example, due to bankruptcy (Studenmund, 2014). Yet, as the reason for a new company to become a S&P 500 constituent is not only bankruptcy of an existing constituent, but also potentially by simply outperforming and thus replacing an existing constituent, this issue might be bounded.

Further, although the sample is large in size, the ratio of companies with a CDO compared to companies without a CDO is relatively small (5,988 company-observations of which 459 observations are for companies, which employ a CDO).

Therefore, some statistical results might be influenced by the proportions within the sample. Still, these proportions are similar to other comparable studies (Firk et al., 2019; Kanashiro & Rivera, 2019; Roh et al., 2016). The sample also consists of US companies only, while companies from other regions such as Europe are not part of the sample. On the one hand, this implies potential limitations regarding generalizability of derived insights for companies outside of the US. On the other hand, comparison of US companies with, for example, European companies is limited as well due to differences in each country's economic and governmental environment. Similarly, only large companies are included in the sample whereas smaller scale companies are not considered due to potential limitations in availability of public data of small companies.

To a certain degree, these underlying issues are all endogeneity related issues. Although endogeneity is addressed thoroughly throughout this study by exploiting varying methodologies, robustness checks and profound data sources including verification with other sources (see, for example, sections 4.5.2, 5.5.1 and 5.6.2), endogeneity is never fully avoidable. Thus, more studies with varying scientific approaches and different viewpoints are required in order to assess research questions like the ones addressed in this study and to further validate derived results.

6.3 Future Research

Following insights from the systematic literature review in chapter 2 and the previous discussion within this chapter, several research opportunities for future scholars can be identified. In the following, some of these potential research options will be presented.

Within this study, the concept of exploring the influence of complementary human capital characteristics of CDOs and other top management team members on company performance is introduced. While a first set of potentially relevant CEO and CIO characteristics is derived and assessed regarding their impact on company performance combined with relevant CDO characteristics, future scholars could further explore this concept by introducing other relevant characteristics of not only top management team members, but also company contingencies and their combinations.

For example, herein only a CIO's presence is assumed to represent general IT affinity and proficiency in STEM. Thus, CIO characteristics could be assessed on a more detailed level such as their orientation, which can either strongly focus on supplying IT resources or also on exploring of IT innovations (Haffke et al., 2016). Not only would it be possible to extend this construct regarding implications for company performance by including characteristics of other C-level managers like CMOs (Zisler et al., 2016) or CFOs (Hesse, 2015) as they should be considered in digital transformation as well, but also would it be worthwhile to assess the concept of individual and combined influence of different C-level managers on the CDO appointment decision itself. It would also be useful to explore the role of the middle management (Westerman, Bonnet, & McAfee, 2014) in strategic actions like CDO employment and corresponding performance implications in order to improve the understanding of individual top management team members in general (Menz, 2012). As highlighted, for example, by Haffke et al. (2016) or Zisler et al. (2016), reporting structures play a crucial role for the ability and authority to fulfill all aspects of digital transformation, for example, between CDO, CIO and CEO. Thus, future scholars could incorporate such structures more detailed within their analyses as well.

Since the results of this study do not provide evidence for benefits of CDO presence regarding the performance of a company, future scholars could further explore alternative measures for identifying the impact of CDOs and for answering the question why companies decide to employ a CDO. For example, Gerth and Peppard (2016) argued for the importance of measuring business success, i.e., realization of planned strategic and organizational benefits, instead of traditional project success based on cost and schedule. In section 2.5, the comparison of the CDO to other relevant C-level executives unveiled that, for instance, similar to CDOs, Chief Technology Officers are leading technological innovation within a company such that effective operations within research and development (R&D) departments are ensured (Medcof, 2008). Following technological investments as part of digital transformation activities, CDOs also contribution to organizational performance, for instance, by achieving a more

advanced digital maturity level of the company (Kane et al., 2017).[132] Thus, future scholars could investigate changes regarding R&D related costs and investments,[133] or digital maturity of companies following a CDO appointment.

As already mentioned before, the underlying sample of this study is based on US companies listed in the S&P 500 index. Another research opportunity could be to extend this sample, for example, by including additional US companies, e.g., S&P 1,500 companies, or by also considering companies outside of the US. Not only would a larger sample size increase the statistical power of presented analyses, but also derived results would empower scholars to consider regional differences and derive results, which are adjusted correspondingly. Another research opportunity could be taken by repeating this study in the future based on an even longer time horizon. As it can be seen in Figure 14, many CDO position within the underlying sample of this study were created in the last three years of the observation period. Therefore, extending the sampling period in the future might unveil more detailed insights of the long-term impact of CDOs in digital transformation. Especially since transformational projects are very time consuming (Kotter, 1995), taking a longer time horizon into account appears to be reasonable. Similar to adapting the underlying sample, an alternative for future scholars lies within the application of different research methodologies. For example, including primary data in the analyses based on interviews or approaching the question regarding a CDO's impact within the company by exploiting qualitative research methods might yield further promising results.

Finally, transferring the approach of this study to research on other C-level executives could be a promising avenue for future research as well. For instance, extending the research on CMOs of Nath and Mahajan (2008), CSOs of Menz and Scheef (2014), COOs of Hambrick and Cannella (2004) or CSuOs of Kanashiro and Rivera (2019) by including the concepts introduced in this study could provide additional insights to the

[132] For different digital maturity models and approaches/variables on how to measure them, see, for example, the review of Schwer et al. (2018).
[133] An initial investigation of the impact of CDO presence on spending on R&D or operational expenditure in line with models described in section 5.6 did not provide any insights regarding significant changes of these measures. Thus, future scholars might explore a more fine-grained approach for such measures.

ones already derived by each scholar. Future research might also investigate C-level positions, which did not receive as much attention as the ones highlighted throughout this study.

Appendix

List of Appendices

Appendix A: Details Characterization of the Chief Digital Officer Position

Task/responsibility	Frequency mentions	Task/responsibility	Frequency mentions
Coordinate DT activities	14	Hire employees	2
Improve customer experience	12	Exploit data analytics	2
Question and improve existing business	11	Launch DT activities	2
Establish new business model	10	Governance framework for DT	2
Drive DT	10	Partner and improve with externals	2
Apply digital technology	8	Company effects from DT	1
Educate about digital	8	Launch digital collaboration tools	1
Implement DT strategy	8	Digital innovation lab	1
Strengthen collaboration	8	Establish base for DT	1
Define DT strategy	7	Harmonize DT with company values	1
Strengthen cultural change	7	Anchor DT in board	1
Assess market trends and technologies	6	Align old and new business models	1
Communicate about digital	5	Perform M&A activities	1
Drive innovation	5	Establish new customer segments	1
Understand DT	3	Reposition the company	1
Communicate DT strategy	3	Create transparency	1
Cover DT marketing	3	Advance human resources (HR)	1
Act as change manager	3	Website and system architecture related activities	1
Fast development	3	Reorganize and reorientate IT	1

Table A1: Systematic Literature Review. Results CDO Tasks and Responsibilities
Source: Own illustration.

Task/responsibility	Frequency mentions	Task/responsibility	Frequency mentions
(Digital) Technologies competencies	9	Design thinking skills	1
Functional knowledge	5	Development skills	1
Strategic skills	5	Empathy	1
Leadership skills	4	High frustration tolerance	1
Change management skills	3	IT infrastructure competencies	1
Communication skills	3	Knowledge in relevant operative environments	1
Customer needs	3	Knowledge in the field of social media	1
Data analysis skills	3	Negotiation and mediation skills	1
Interpersonal skills	3	Open minded skills	1
Motivational skills	3	Passion for learning	1
Visionary	3	Positive mindset skills	1
Agile skills	2	Perseverance	1
Business knowledge	3	Process management skills	1
Business thinking	2	Product development skills	1
Flexibility	2	Project management skills	1
Inspirational skills	2	Relationship building competencies	1
IT architecture competencies	2	Reliability	1
Problem solving skills	2	Resilience skills	1
Skills in managing conflicts	2	Risk taking skills	1
Assertiveness	1	Self-organizational skills	1
Assess rewards skills	1	Skills to overcome functional silos	1
Capability to overcome automation tasks	1	Knowledge regarding traditional value chains in production and service provider industries	1
Charisma skills	1	Team player skills	1
Charming	1	Transformation skills	1
Data analytics skills	1		

Table A2: Systematic Literature Review. Results CDO Tasks and Responsibilities
Source: Own illustration.

Appendix B: GEE Model Results for Tobin's Q Based Model

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
CEO company outsider (t-1) *H1a*		0.022 (0.837)			0.003 (0.976)	0.039 (0.715)			0.020 (0.848)
CEO tenure (t-1) *H1b*			-0.013** (0.026)		-0.013** (0.028)		-0.012** (0.038)		-0.012** (0.042)
CEO STEM background (t-1) *H1c*				0.027 (0.745)	0.013 (0.876)			0.017 (0.837)	0.003 (0.967)
Company size (t-1)						0.109** (0.015)	0.101** (0.025)	0.108** (0.015)	0.101** (0.022)
Industry revenue growth (t-2 to t-1)						-0.112 (0.597)	-0.087 (0.681)	-0.111 (0.602)	-0.088 (0.678)
CIO presence (t-1)						-0.015 (0.838)	-0.020 (0.778)	-0.015 (0.841)	-0.020 (0.780)
Company age (t-1)	0.001 (0.262)	0.001 (0.260)	0.001 (0.449)	0.001 (0.269)	0.001 (0.459)	0.001 (0.555)	0.000 (0.773)	0.001 (0.581)	0.000 (0.761)
Risk (t-1)	0.119 (0.548)	0.118 (0.553)	0.129 (0.500)	0.117 (0.552)	0.128 (0.503)	0.141 (0.461)	0.151 (0.413)	0.141 (0.456)	0.150 (0.417)
Segments (t-1)	0.012 (0.393)	0.012 (0.388)	0.012 (0.363)	0.011 (0.399)	0.012 (0.365)	0.006 (0.660)	0.007 (0.614)	0.006 (0.669)	0.007 (0.611)
Tobin's Q (t-1)	-0.031 (0.132)	-0.031 (0.132)	-0.029 (0.147)	-0.031 (0.130)	-0.029 (0.146)	-0.006 (0.782)	-0.006 (0.773)	-0.006 (0.774)	-0.006 (0.772)
Revenue growth (t-2 to t-1)	-0.007 (0.738)	-0.008 (0.731)	-0.004 (0.825)	-0.008 (0.731)	-0.004 (0.819)	-0.014 (0.721)	-0.010 (0.757)	-0.014 (0.728)	-0.010 (0.749)
Leverage (t-1)	0.533*** (0.000)	0.533*** (0.000)	0.543*** (0.000)	0.533*** (0.000)	0.544*** (0.000)	0.507*** (0.001)	0.517*** (0.001)	0.508*** (0.001)	0.517*** (0.001)
Industry Tobin's Q (t-1)	0.298*** (0.002)	0.298*** (0.002)	0.300*** (0.002)	0.298*** (0.002)	0.299*** (0.002)	0.286*** (0.003)	0.288*** (0.003)	0.285*** (0.003)	0.288*** (0.003)
CEO age (t-1)	-0.006 (0.345)	-0.006 (0.328)	0.002 (0.772)	-0.006 (0.347)	0.002 (0.773)	-0.006 (0.292)	0.001 (0.884)	-0.006 (0.324)	0.001 (0.907)

***, ** and * indicate significance at the 1%, 5%, and 10% level, respectively.
P-values are provided in parentheses. Standard errors are clustered by company.

Table B1: GEE Model. Dependent Variable: CDO Existence (t) (for Tobin's Q Based Model) – Hypothesis 1
Source: Own illustration.

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
CEO gender (t-1)	0.189	0.189	0.179	0.189	0.179	0.185	0.176	0.186	0.175
	(0.281)	(0.282)	(0.298)	(0.285)	(0.301)	(0.302)	(0.317)	(0.301)	(0.319)
Year (t-1)	0.175***	0.175***	0.175***	0.175***	0.175***	0.171***	0.171***	0.171***	0.171***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Intercept	-355.630***	-355.631***	-354.899***	-355.281***	-354.711***	-348.652***	-348.317***	-348.518***	-348.224***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Wald chi^2	181.0***	188.5***	199.5***	181.7***	203.0***	182.4***	189.2***	171.1***	195.0***
Industry effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Marginal R^2	0.117	0.117	0.120	0.117	0.120	0.124	0.127	0.125	0.127
N	5,988	5,988	5,988	5,988	5,988	5,988	5,988	5,988	5,988

***, ** and * indicate significance at the 1%, 5%, and 10% level, respectively.
P-values are provided in parentheses. Standard errors are clustered by company.

Table B1 (continued): GEE Model. Dependent Variable: CDO Existence (t) (for Tobin's Q Based Model) – Hypothesis 1
Source: Own illustration.

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
CEO company outsider (t-1)					0.021	0.003	0.003
					(0.847)	(0.981)	(0.974)
CEO newness (tenure) (t-1)					-0.012**	-0.013**	-0.013**
					(0.043)	(0.028)	(0.028)
CEO STEM background (t-1)					0.004	0.013	0.012
					(0.962)	(0.874)	(0.883)
Company size (t-1) *H2a*	0.109**			0.109**	0.101**		
	(0.016)			(0.016)	(0.022)		
Industry revenue growth (t-2 to t-1) *H2b*		-0.107		-0.111		-0.082	
		(0.616)		(0.601)		(0.702)	
CIO presence (t-1) *H2c*			-0.013	-0.015			-0.019
			(0.864)	(0.838)			(0.798)
Company age (t-1)	0.001	0.001	0.001	0.001	0.000	0.001	0.001
	(0.587)	(0.263)	(0.258)	(0.575)	(0.779)	(0.461)	(0.447)
Risk (t-1)	0.153	0.109	0.119	0.143	0.157	0.120	0.128
	(0.409)	(0.596)	(0.548)	(0.453)	(0.379)	(0.543)	(0.503)
Segments (t-1)	0.007	0.011	0.012	0.006	0.008	0.011	0.012
	(0.617)	(0.433)	(0.395)	(0.667)	(0.570)	(0.396)	(0.368)
Tobin's Q (t-1)	-0.006	-0.031	-0.031	-0.006	-0.006	-0.029	-0.029
	(0.782)	(0.130)	(0.134)	(0.781)	(0.770)	(0.144)	(0.149)
Revenue growth (t-2 to t-1)	-0.017	-0.005	-0.007	-0.014	-0.013	-0.003	-0.004
	(0.712)	(0.784)	(0.742)	(0.732)	(0.723)	(0.869)	(0.829)
Leverage (t-1)	0.508***	0.532***	0.533***	0.507***	0.518***	0.543***	0.544***
	(0.001)	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)
Industry Tobin's Q (t-1)	0.287***	0.296***	0.298***	0.285***	0.001	0.002	0.002
	(0.003)	(0.002)	(0.002)	(0.003)	(0.922)	(0.773)	(0.760)
CEO age (t-1)	-0.006	-0.006	-0.006	-0.006	0.174	0.178	0.179
	(0.319)	(0.344)	(0.349)	(0.322)	(0.321)	(0.301)	(0.299)

***, ** and * indicate significance at the 1%, 5%, and 10% level, respectively.
P-values are provided in parentheses. Standard errors are clustered by company.

Table B2: GEE Model. Dependent Variable: CDO Existence (t) (for Tobin's Q Based Model) – Hypothesis 2
Source: Own illustration.

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
CEO gender (t-1)	0.185	0.189	0.190	0.186	0.289***	0.298***	0.299***
	(0.299)	(0.281)	(0.279)	(0.299)	(0.003)	(0.002)	(0.002)
Year (t-1)	0.171***	0.176***	0.176***	0.171***	0.170***	0.175***	0.175***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Intercept	-347.601***	-356.363***	-356.016***	-348.713***	-347.093***	-355.247***	-355.306***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Wald chi^2	171.8***	179.9***	181.5***	171.0***	195.4***	202.1***	203.8***
Industry effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Marginal R^2	0.125	0.117	0.117	0.125	0.127	0.120	0.120
N	5,988	5,988	5,988	5,988	5,988	5,988	5,988

***, ** and * indicate significance at the 1%, 5%, and 10% level, respectively.
P-values are provided in parentheses. Standard errors are clustered by company.

Table B2 (continued): GEE Model. Dependent Variable: CDO Existence (t) (for Tobin's Q Based Model) – Hypothesis 2
Source: Own illustration.

Appendix C: Summary Statistics of Variables Included in the Fixed Effects Model (Unmatched Sample)

Variable	Obser-vations	Mean	Standard deviation	1st percentile	99th percentile
(1) ROA	5,988	0.062	0.075	-0.167	0.258
(2) Tobin's Q	5,988	1.872	1.624	0.140	8.184
(3) CDO existence	5,988	0.077	0.266	0.000	1.000
(4) CDO company outsider[134]	459	0.660	0.474	0.000	1.000
(5) CDO industry outsider[134]	459	0.551	0.498	0.000	1.000
(6) CDO STEM background[134]	433	0.494	0.501	0.000	1.000
(7) CEO company outsider	5,988	0.193	0.395	0.000	1.000
(8) CEO tenure	5,988	6.666	7.073	0.000	33.000
(9) CEO STEM background	5,988	0.344	0.475	0.000	1.000
(10) CIO presence	5,988	0.229	0.420	0.000	1.000
(11) Company age	5,988	69.496	48.851	5.000	208.000
(12) Risk	5,988	0.297	0.160	0.123	0.931
(13) Segments	5,988	3.848	2.676	1.000	14.000
(14) Previous ROE	5,988	0.163	3.668	-1.442	1.986
(15) Company size	5,988	9.676	1.476	6.470	13.723
(16) Revenue growth	5,988	0.095	0.668	-0.380	0.832
(17) Leverage	5,988	0.622	0.218	0.124	1.163
(18) CEO age	5,988	56.907	6.610	42.000	76.000
(19) CEO gender	5,988	1.036	0.186	1.000	2.000
(20) Previous industry ROE	5,988	0.146	0.050	0.040	0.235
(21) Industry revenue growth	5,988	0.056	0.064	-0.169	0.246
(22) Year	5,988	2,013.181	3.728	2,007.000	2,019.000

Table C1: Summary Statistics of Variables Included in the Fixed Effects Model (Unmatched Sample)
Source: Own illustration.

[134] Note that by creating categorical variables as described in section 5.2.2, the number of observations was in line with other variables, i.e., 5,988. Further, as explained before, the variable for describing a CDO's educational background consists of 26 company-year observations less due to their unobservable educations.

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