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# Empirical identification of the chief digital officer role: A latent Dirichlet allocation approach

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## ABSTRACT

This study examines the global demand for Chief Digital Officers (*CDOs*) to determine a universal *CDO* archetype in terms of competencies and tasks. It uses Bayesian statistics and Latent Dirichlet Allocation (*LDA*) topic modeling to measure multiple dimensions in a sample of 518 job postings for *CDO* positions. Findings show the hybrid nature of newly appointed *CDOs*, who feature a mixture of both business administration and technological skills. Further, the study highlights the pivotal role of *CDOs* in terms of strategic change in companies. The study has three major contributions. First, it showcases the value of *LDA* in job profiling research. Second, it bridges the existing knowledge gaps in *CDO* literature with empirical evidence from a global dataset and identifies a core *CDO* profile based on data extracted through *LDA*. Third, it illustrates the current market requirements for *CDO* positions, which is useful to both companies and candidates.

**Keywords:** Chief digital officer, Latent dirichlet allocation, Job profiling, Digital transformation, Strategic change

## 1. Introduction

The rise of digital technology has resulted in new opportunities for companies across the globe, but it has also led to an increasingly significant need for specific knowledge to make the most of technological advancements. To gain significant advantages over their competitors (Ferreira et al., 2019; Khan et al., 2021), companies often need to acquire specific skills from the job marketplace (Elia et al., 2021; Ferraris et al., 2019). In fact, new professional roles are emerging amid the current digital world (Muninger et al., 2019), as individual skills are deemed crucial to steer the digital transition of companies towards a successful future (Scotto et al., 2022). While a multitude of skills are deemed relevant in the current digital landscape, including digital leadership (El Sawy et al., 2016; Zupancic et al., 2018), knowledge management (Alberti-Alhtaybat et al., 2019) and organisational capabilities (Muninger et al., 2019), the consensus is that digital transformation still revolves around a human component embodied by top management figures (Picone et al., 2021; Zimmermann et al., 2020).

Traditionally, companies have employed chief information officers (*CIOs*) and have made these individuals responsible for everything concerning the firm's information technology (*IT*) infrastructure (Peppard et al., 2011; Taylor & Vithayathil, 2018). Throughout the past decade, however, a new role specifically meant to address the challenges of digital transformation has emerged: chief digital officer (*CDO*) (Singh & Hess, 2017). *CDOs* are generally tasked with coordinating digital initiatives across departments and driving the digital transformation process of their organisations (Tumbas et al., 2018; Verhoef et al., 2021). Previous research has explored managerial roles and positions tied to digital transformation concerning the skill sets required by such positions (Singh & Hess, 2017; Singh et al., 2020), yet it is still lagging when it comes to the new and rapidly emerging *CDO* role (Firk et al., 2021; Singh et al., 2020).

The scientific literature undoubtedly lags when it comes to emerging managerial roles and their key personal characteristics (Mansfeld et al., 2010; Singh and Hess, 2017; Singh et al., 2020). While their importance is clear amid the digital transformation process of a company (Sousa & Rocha, 2019), little is known about their overall profile in terms of individual competencies and tasks. This is especially true for *CDOs*, as they have thus far only been investigated in limited exploratory studies with qualitative approaches (Singh et al., 2020; Tumbas et al., 2018; Tumbas et al., 2017); hence, the strong call for more empirical research on the matter has been echoed by multiple studies (Kessel & Graf-Vlachy, 2021). More specifically, in terms of research gaps, Kunisch et al. (2022) claim that individual characteristics of the *CDO* are yet to be fully understood. In other words, according to Kunisch et al. (2022), we still do not know the answers to the following questions: What does it take to become a *CDO*? Which capabilities are required? What career paths have they followed? What individual characteristics do *CDOs* have in terms of their backgrounds, prior experience and personalities? Similarly, Firk et al. (2021) called for future studies to explore the coordinating role of the *CDO* to understand both their expected key personal characteristics and their need to possess more general management skills. Finally, it has yet to be determined whether *CDOs* play a distinct role compared to *CIOs* (Singh & Hess, 2017; Singh et al., 2020) or whether they are simply a 'new coat of paint' over a well-established managerial position (Gerth & Peppard, 2016; Taylor & Vithayathil, 2018).

Our contribution finds its positioning amid the literature concerning new managerial roles that are emerging in response to digital transformation (El Sawy et al., 2016; Singh & Hess, 2017). More specifically, our research seeks to identify a *CDO* archetype grounded in empirical evidence to deliver a comprehensive understanding of this emerging managerial role and, in doing so, address the research gaps that have yet to be explored. More specifically, the research questions driving the present study are as follows:

**RQ1:** What capabilities are required by organisations for *CDO* positions?

**RQ2:** What are the tasks required of *CDOs* by their organisations?

Drawing on the *CDO* and digital transformation literature, the present study examines the current demand for *CDOs* worldwide by collecting and analysing publicly available data on *CDO* job postings scraped via Python scripts from LinkedIn, Indeed and several other sites (George et al., 2016; Khaouja et al., 2021). To address the research gap mentioned above, our research implemented Bayesian statistics and *LDA* across a large comparative sample of *CDO* job postings to find common emerging themes via topic modelling (Debortoli et al., 2014). *LDA* topic modelling has been used in past business research when attempting to profile emerging professional roles on large chunks of textual content; hence, we deemed it an effective choice in terms of research design (De Mauro et al., 2018; Gurcan & Cagiltay, 2019).

This research provides three main theoretical contributions. First, it sheds light on emerging managerial roles and positions by highlighting the expected key personal characteristics and capabilities (Mansfeld et al., 2010; Singh and Hess, 2017; Singh et al., 2020). We contribute to the literature exploring the individual aspects of digital transformation by highlighting the human component at the core of organisational change (Zimmermann et al., 2020). Second, although several papers have begun to explore the role of *CDOs*, most have employed an exploratory and qualitative approach (Singh et al., 2020; Tumbas et al., 2018; Tumbas et al., 2017). As the scientific debate on the role played by *CDOs* amid digital transformation continues, we advance the literature by complementing previous exploratory research with large-scale quantitative data that both reinforce existing knowledge on the topic (Kessel & Graf-Vlachy, 2021) and shed light on several unanswered questions formulated by previous contributions (Firk et al., 2021; Kunisch et al., 2022). Third, the present study takes an individual perspective on digital transformation, investigating the role of single actors, namely *CDOs*, amid technological change. By profiling the archetype of a *CDO* position, our study enriches the literature by providing an in-depth focus on new skills and competences development for digital strategies (Al Nuaimi et al., 2022; Muninger et al., 2019), the coordinating role of *CDOs* among the corporate structure (Firk et al., 2021), and individual characteristics such as previous career path, prior experience and personal traits (Kunisch et al., 2022). Additionally, from a practical perspective, our results can help guide practitioners to better understand current market requirements and for companies aiming to hire external *CDOs* or develop internal training that meets present and future digital transformation skills (Picone et al., 2021; Zimmermann et al., 2020). Finally, still on a practical perspective, our study strives to provide practitioners with a clear, transparent and replicable method to analyze significantly high amounts of job postings, as means to profile emerging professional roles (George et al., 2016; Khaouja et al., 2021).

The current article is structured as follows: Section 2 provides a review of the literature on *CDOs* and illustrates how the position was created before detailing its evolution. **Section 3** presents an overview of the methodological approach implemented, highlighting the *LDA* technique and the reasons why it was chosen for this article. **Section 4** presents the results as we go through the common themes and trends emerging from the *LDA* analysis of the sample. **Section 5** ties the findings with the literature and highlights divergences and agreements. The study then concludes with a discussion of the managerial and theoretical implications, as well as limitations and directions for future research.

### *1.1. Digital leadership: Market-driven competencies for the digital era*

A global marketplace raised customer expectations and the disruptive impact the Internet has had on organisations has all contributed to significant changes in both the job market and the skills required from top management positions (Bresciani et al., 2021; Vasconcelos et al., 2017). In times of unprecedented uncertainty and digital disruption, top management is required to react quickly and thrive off technological advancements by turning them into competitive advantages (Fitzgerald et al., 2014; Foss & Klein, 2014; Weber et al., 2022). More specifically, companies are required to invest in skill development to react quickly to market changes (Bharadwaj et al., 2013; Ostmeier & Strobel, 2022), to appoint technology leaders who are also well informed on business issues (Foss & Klein, 2014; Taylor & Vithayathil, 2018) and to acquire or develop capabilities related to digital agility, digital networking and big data analytics (Verhoef et al., 2021).

Regarding top management positions in the modern era, El Sawy et al. (2016) defined digital leadership as ‘doing the right things for the strategic success of digitalisation for the enterprise and its business ecosystem.’ Definitions aside, previous research seems to agree on the skills required for

digital leaders, namely digital literacy, business strategy savviness and strong, digital transformation-oriented leadership skills (Benitez et al., 2022; Zeike et al., 2019).

Regarding digital literacy, often associated with life-long learning, it is a broad ‘digital’ concept, which encapsulates the combination of digital knowledge, cognitive knowhow, practical knowhow, competence and digital attitude, all essential in the digital age (Canina & Orero-Blat, 2021; Zeike et al., 2019). In terms of business strategy savviness, Benitez et al. (2022) mentioned how important it is for digital leaders to effectively understand their market, product and customer to create business value through their actions and decision-making (Zupancic et al., 2018). Finally, digital leaders are required to possess sharp leadership skills, most notably in terms of being able to obtain and maintain the trust of their peers and organisation (El Sawy et al., 2016; Weber et al., 2022), while assuming the responsibility of driving forward a strategic vision built on technological advancements (Muninger et al., 2019; Sousa & Rocha, 2019).

While it is generally believed that *CIOs* fall within the definition of digital leaders due to their tripartite nature made of business, technological and leadership skills (Gerth & Peppard, 2016; Taylor & Vithayathil, 2018), little is known about the emerging managerial roles, *CDOs* included, and whether they possess the skills required for them to be labelled as digital leaders (Mansfeld et al., 2010; Singh & Hess, 2017; Singh et al., 2020).

### 1.2. The origin of the chief digital officer role

In response to digital transformation, organisations have introduced a new leadership role—the *CDO* (Rickards et al., 2015). Because this role is still emerging, it currently means different things to different organisations.

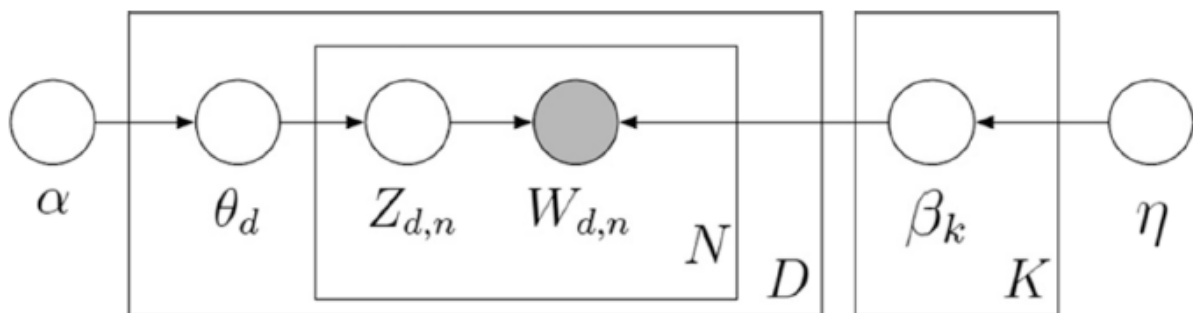


Fig. 1. LDA generation (Blei & Lafferty, 2007).

However, *CDOs* belong to top management positions and are tasked with managing the digital transformation processes of their companies (Kunisch et al., 2020; Tumbas et al., 2017). Although, they differ from other digital executives because their roles are crossfunctional across multiple business units rather than confined within strict functional limits (Kunisch et al., 2022).

Companies started using the job title *CDO* in 2005, but its relevance grew more significantly from 2010 onward, rising in parallel with the technological advancements of the past decade (Kunisch et al., 2020; Seeher et al., 2020; Singh & Hess, 2017) and progressively replacing *CIOs* in top management positions (Barnes et al., 2021). The first known *CDO* was hired by *MTV Networks* in 2005, and the number of *CDOs* has roughly doubled every year until 2015 (Grossman & Rich, 2012). Between 2015 and 2017, the number increased even more rapidly, especially in the manufacturing, construction, finance and insurance industries. Recent studies have found that *CDOs* are especially popular in

Germany and France, whereas fewer *CDOs* are appointed in the United States or the Netherlands (**Firk et al., 2019**).

Although research has been carried out in an attempt to understand the transition from *CIOs* to *CDOs*, it is still unclear whether the *CDO* is both a distinct figure compared to the *CIO* and a natural successor to that role (**El Sawy et al., 2016; Singh & Hess, 2017**), or whether the *CDO* is merely a new 'coat of paint' over the already established role of *CIO*, and maintains its core archetype tasks in terms of skills and tasks (**Barnes et al., 2021; Gerth & Peppard, 2016**). What we do know is that both figures share the tripartite blend of digital, business and interpersonal skills (**Benitez et al., 2022**), yet a comparative interpretation of the two roles through the theoretical lens of digital leadership is still missing.

### *1.3. Chief digital officers in terms of competencies and responsibilities*

Even though the literature on *CDOs* is still in its early stages, several studies have explored its scope and features, albeit mostly with exploratory approaches. **Singh et al. (2020)** found that *CDO* positions are not strictly predetermined when it comes to their tasks and embeddedness within the organisational structure. Instead, they are shaped around the company's needs in terms of digital transformation and its technological strategy. This theory has been supported earlier by **Doonan (2018)**, who suggests that companies could not only benefit from a top management figure specifically devoted to digital transformation implications, but also that the *CDO* role should be adjusted according to the company's digital strategy.

An important literature stream refers to the impact that *CDOs* have had on multiple organisational outcomes, such as digital innovation, customer engagement and strategic change (**Singh & Hess, 2017; Singh et al., 2020; Tumbas et al., 2017**). As noted by **Dumeresque (2014)**, *CDOs* are indeed agents of change and play a major role in driving the company's strategic vision towards its digital transformation future. Finally, **Singh et al. (2020)** further stressed the coordinating role played by *CDOs* in companies, linking their effectiveness directly to the firm's digital strategy.

*CDO* competencies include proficiency in data analytics and customer engagement, along with an understanding of digital innovation (**Tumbas et al., 2017**). Although the literature on the topic of *CDO*-related skills is scarce, the authors agree that *CDOs* must possess unique capabilities that are distinct from those required for other top management positions (**Dumeresque, 2014**). However, as echoed by **Kunisch et al. (2022)**, the *CDO* literature currently lacks systematic, large-scale evidence of the nature and determinants of the *CDO* position because questions such as 'What does it take to become a *CDO*?' and 'Which capabilities are required?' remain unaddressed.

As far as *CDO* tasks are concerned, contradictory evidence has been found in recent research. On one hand, the results of exploratory studies suggest that *CDOs* play a coordinating role across departments as they drive forward the digital change of the company (**Al Nuaimi et al., 2022; Tumbas et al., 2017**). In doing so, *CDOs* seemingly maintain their own distinct identities compared to *CIOs* and other senior *IT* professionals (**Tumbas et al., 2018**). **Kunisch et al. (2020)** stressed the specific importance of *CDOs* amid top management, as *CIOs* may lack the strategic vision and leadership skills needed to manage digital initiatives. However, the boundaries between the two roles appear to be blurred; oftentimes, job descriptions for *CDO* positions mirror the ones for *CIOs* (**Gerth & Peppard, 2016**). Additionally, there is still little evidence of the role they play in stimulating a digital culture within their company (**Firk et al., 2021**). Hence, further research is needed to properly define the boundaries of the *CDO* position, both in terms of skills and tasks (**Kessel & Graf-Vlachy, 2021; Kunisch et al., 2022**).

## 2. Methods

### 2.1. Research design

Researchers in the social sciences have used computational tools to extract information from numerous online data sources (Berger et al., 2020; Scarborough & Crabbe, 2021). *LDA* is considered a highly efficient method for handling big data to extract information from job postings and identify specific professional profiles in terms of skills and competencies (De Mauro et al., 2018; Gurcan & Cagiltay, 2019). *LDA* helps when the data are sparse and high dimensional (George et al., 2016), as it is used to extract latent topics thus reducing the dimensionality of large sets of data (Banks et al., 2019).

Common themes, which will be addressed as ‘dimensions’ in the present study, are latent constructs distributed over a vocabulary of words that employers have used to describe *CDO* job openings (Tirunillai & Tellis, 2014). In our analysis, job openings are referred to as a sequence of  $N$  words and as ‘documents’, while a  $D$  number of reviews, also known as documents, forms a corpus. We assume that we will be able to identify  $K$  dimensions across the corpus, comprising all the *CDO* job openings found in our study.

**Fig. 1** provides a graphical representation of the *LDA* algorithm. Nodes denote random variables; edges denote the dependence between random variables. Shaded nodes denote observed random variables; unshaded nodes denote hidden random variables. The rectangular boxes are ‘plate notation’, which denotes the overall corpora made of a predetermined amount of documents (Blei & Lafferty, 2007). The interaction between the observed documents and the hidden topic structure is manifested in the probabilistic generative process associated with *LDA*—that is, the imaginary random process that is assumed to have produced the observed data.

To better comprehend how *LDA* works, we provide an example as follows: Let  $K$  be a specified number of topics,  $V$  the size of the vocabulary,  $(\vec{\alpha})$  a positive  $K$ -vector, and  $\eta$  a scalar. Let  $\text{Dir}V(\vec{\alpha})$  denote a  $V$ -dimensional Dirichlet with vector parameter  $(\vec{\alpha})$  and  $\text{Dir}K(\eta)$  denote a  $K$  dimensional symmetric Dirichlet with scalar parameter  $\eta$ . For each topic, we draw a distribution over words  $\vec{\beta}_k \sim \text{Dir}V(\eta)$ . For each document, we draw a vector of topic proportions  $\vec{\theta}_d \sim \text{Dir}(\vec{\alpha})$ . For each word, we draw a topic assignment  $Z_{d,n} \sim \text{Mult}(v)$ ,  $Z_{d,n} \in \{1, \dots, K\}$ . Finally, we draw a word  $W_{d,n} \sim \text{Mult}(\vec{\beta}_{Z_{d,n}})$ ,  $W_{d,n} \in \{1, \dots, V\}$ .

To better contextualise the applicability of *LDA* to our research, we consider job postings as  $K$  dimensions with probabilities. Each may contain a set of attributes required from *CDOs* along with the tasks they will be asked to perform. The *LDA* algorithm allows us to first identify the core topics emerging from the corpus, which here will refer to the core competencies required, along with descriptions of their roles. Subsequently, we can determine the degree to which each document contributes to a set dimension. Ultimately, we can profile the role of *CDOs* across the world in terms of both their skills and their roles.

Although multiple textual analysis methods exist, we opted for *LDA* modelling for several reasons. First, *LDA* does not come with preassumptions regarding the structure of large bodies of text (Gurcan & Kose, 2017; Khaouja et al., 2021). This makes for a solid choice when analysing a large amount of data while trying to map the heterogeneity of the dimensions between our samples. For instance, this has allowed us to find the differences between countries and search engines when it comes to *CDO* positions. Furthermore, *LDA* gives us a clear understanding of the frequency with which words have been used in the corpus (Barnes et al., 2021), which allows us to find common recurring patterns in job postings and establish which core characteristics appear in *CDOs* worldwide.

## 2.2. Data processing

Because LDA is an inductive methodology, the selection of a corpus that can convey the profile of *CDOs* is highly important. Drawing on previous research (**Barnes et al., 2021; Gurcan et al., 2019**), we built a corpus of 518 job postings using LinkedIn, Indeed, Glassdoor and other job search websites from January 2021 to December 2021. Because the goal of the research is to understand what it takes to become a *CDO* and what types of tasks *CDOs* perform during their tenure, job postings are the ideal source of information because they feature both the skills required from employers and tasks meant to be performed by newly appointed *CDOs* (**Khaouja et al., 2021**).

The preprocessing stage is crucial when conducting *LDA* analysis because it allows researchers to improve the quality of unstructured data to make it readable for algorithms. Drawing on previous research (**Barnes et al., 2021; Gurcan & Kose, 2017**), we have applied a preprocessing method divided into several subsequent steps. The first step was meant to harmonise the data in one unique target language because a portion of the sample ( $n = 57$ ) was written in a language other than English. Previous *LDA* studies featuring a multilanguage sample either used corpora combining monolingual texts stemming from different countries (**Perez-Encinas & Rodriguez-Pomeda, 2019; Rahmani et al., 2018**), computed one topic model per language (**Chen et al., 2018**) or translated documents into one target language (**Lucas et al., 2015**). We used the third option, and with the help of language experts, we were able to translate the corpora into English.

The next step was to remove punctuation, web links, private tags and meaningless characters, along with stop words, to reduce the word space. The *R* package<sup>TM</sup> was used for these steps. To preserve the meaning in the text content, the stemming process was not applied because the dataset contained technical jargon along with job-specific terms. The results of the preprocessing phase led us to reduce the word space for the dataset from 172,494 unique words to 28,971, while the number of job postings was equal to 518. Regarding the *LDA* equation, each job posting represented an individual vector, while the word space of 28,971 unique words referred to the size of the word vector for each posting. A topic modelling tool, the *M*Achine Learning for Language Toolkit (*MALLET*), was used to analyse the content of the job postings. *MALLET* is a Java-based command line programming tool that has often been employed in *LDA*-based studies (**McCallum, 2002**). The corpora were run through *MALLET* to identify topics.

Several tests were run to verify the validity of the extraction (**Sinha & Larrison, 2020**). Further details on goodness-of-fit testing have also been included in Appendix A. Finally, qualitative, human-assisted methods were also implemented to reach a unanimous level of agreement between the authors. To confirm the validity of the model, we examined the interindividual interpretability of the topic model solution (**Scarborough & Crabbe, 2021**).

## 2.3. Validation

Two distinct qualitative validation techniques were implemented, namely qualitative coding with human raters (Tirunillai & Tellis, 2014) and semantic analysis powered by the Leximancer tool (**George et al., 2016**). Human coders were asked to independently perform manual coding techniques on a set of 100 job postings picked at random from the overall sample and to apply a rigorous, three-step coding protocol. This ultimately led to coders finalizing a set of dimensions related to *CDOs'* nature to be compared with the results derived in the automated analysis. In this way, the authors were able to calculate the reliability of the automated analysis and highlight possible skewness in the results.

The second step involved the use of semantic analysis via Leximancer (Dann, 2010; Malik et al., 2020). Leximancer software has been widely implemented in social science and business research to explore concepts across large datasets through both qualitative and quantitative semantic analysis. The tool works as follows: It iteratively builds up a thesaurus of associated concepts through intelligent proprietary algorithms, resulting in a thematic view of the relationships between concepts indicated by their proximity to the resulting conceptual map. By creating two distinct samples for both skills and tasks, the authors aim to validate the automated results obtained through topic modelling via the qualitative interpretations that can be made based on the algorithmic analysis powered by Leximancer. Results of the qualitative validation process are found in the Appendix.

### 3. Findings

In the following subsections, we illustrate the results of our research. The first subsection is dedicated to explaining model fit statistics that have been performed in an attempt to identify the ideal number of topics to be analysed. Then, we discuss the dimensions of both tasks and skills subsequently by illustrating the common topics emerging from the empirical data sets and pointing out their distribution across the corpora. Finally, the dimensions are discussed in terms of the probability of occurrence, which lets us identify so-called ‘top topics’ amid the acquired data and determine which dimensions are the most prominent. Then, cross-country analysis will be presented because we analyse the emphases each country puts on each dimension in terms of percentage.

#### 3.1. Topic extraction and coherence scores

Model fit statistics from the LDA of CDO job postings suggest that the required tasks can be described in five distinct topics: leadership role, strategic vision, operations, IT and coordination. Meanwhile, the requirements to become CDOs can be brought down to four main dimensions: seniority, business savviness, tech savviness and soft skills. In accordance with previous research, we have conducted several tests to adequately identify the ideal number of topics to be extracted. We have specifically looked for the overall coherence scores because they allow us to best represent the interpretability of topics (Roder et al., 2015). We have run several consecutive models with different numbers of topics to see which one had the highest degree of coherence. In other words, the ideal number of topics depends on how coherent the model is: models with higher coherence have a lower degree of shared words between topics.

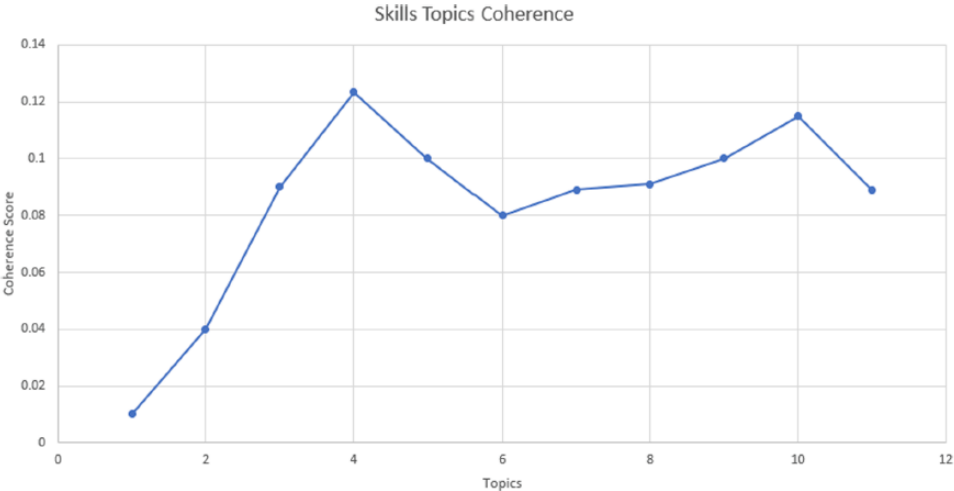
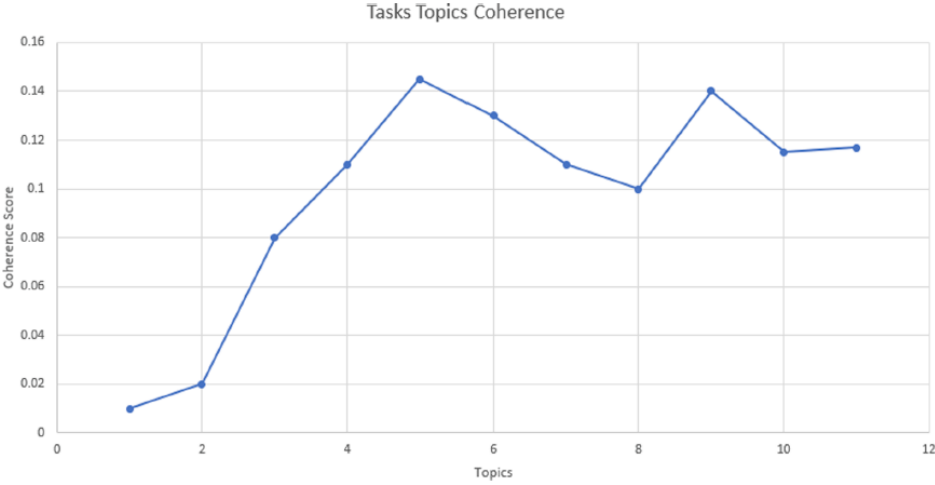


Fig. 2. Skills coherence scores.

Task-wise, we ultimately decided to opt for a five-topic model for better manual interpretation of the data. Skill-wise, we agreed that four dimensions were the ideal size. The model fit statistics and qualitative validation, along with a more detailed look at topic coherence, are shown in **Appendix 1**. **Figs. 2 and 3** provide an overview of the coherence scores for both corpora.



**Fig. 3.** Tasks coherence scores.

Leadership Role	Strategic Vision	Operations	Information Technology	Coordination	Seniority	Business Savviness	Tech Savviness	Soft Skills
Chief	Innovation	Management	Digital	Team	Experience	Digital	Knowledge	Skills
Leadership	Digital	Product	Technology	Growth	Digital	Business	Data	Ability
Services	Change	Development	Develop	Group	Technology	Leadership	Years	Communication
Solutions	Business	Clients	Tools	Ability	Degree	Strategy	Profile	Team
Manage	Strategy	Responsible	Online	Strategy	Years	Vision	Project	Lead
Management	Future	Customers	Data	Social	Profile	Change	Strong	Growth
Transformation	Path	Market	Transformation	Communication	Work	Understanding	Development	Strategic
Technology	Opportunities	Process	Build	Report	Projects	Customer	Software	Level
Reporting	Transformation	Knowledge	Software	Responsible	Data	Transformation	Tool	Report
Figure	Organizational	Systems	Technologies	Data	Leading	Drive	Field	Marketing
Responsible	Focus	Data	Development	Information	People	Innovation	Process	Interact
Team	Key	Online	Code	People	Solutions	Market	Opportunities	Sales
Communication	Opportunity	Services	Marketing	Understanding	Managing	Opportunities	Technology	Required
Solution	Data	Internal	Opportunities	Communicate	Top	Support	Experience	Performance
Business	Technology	Infrastructure	Information	Vision	Team	Services	Excellent	Working

**Fig. 4.** Highest-ranked word stems for each dimension.

High coherence scores mean that the topics are better representative of the overall corpora. In other words, when a model is coherent, there is less confusion as to where each term belongs because they are more unanimously distributed. The above figure illustrates the ideal number of topics for each corpus, which coincides with the highest coherence score reached in both tests.

Regarding *CDO* skills, we have performed the same iterative process, albeit on a distinct corpora made of ‘profile’ sections or equivalent ones found in the job description. In this case, the model with the highest coherence score was a four dimensional one. We have once again performed over 20,000 iterations for each model, as suggested by previous LDA studies on job postings (**Barnes et al., 2021; Gurcan & Kose, 2017**). We have found that the coherence score was not significant enough in models with five or more topics. After manually reviewing the four dimensional model, the researchers agreed on its effectiveness in summarising the large amount of data available. Model fit statistics were performed and added to **Appendix 1**.

Finally, **Fig. 4** shows the nine total dimensions, along with the most recurrent words for each topic. The words are in order of relevance, with the top words being the most recurring.

### *3.2. Topics related to CDO tasks*

#### 3.2.1. Leadership role

The first topic, which we refer to as 'leadership role', includes several terms referring to the formal role played by *CDOs* within organisations. We find both terms related to their high ranking ('chief', 'leadership' and 'manage') and terms related to the technical nature of their task ('technology', 'services', 'solutions' and 'transformation'). This dimension puts emphasis on the essence of *CDOs*, who are mostly considered to be at the same level as other executives, though their scope is focused specifically on digital transformation and technological solutions.

#### 3.2.2. Strategic vision

The next topic is referred to as 'strategic vision'. Similar to the previous topic, this one still contains terms related to technology ('innovation' and 'digital'), yet it features them in a broader context along with others related to strategic vision ('future', 'change', 'business' and 'strategy'). This topic illustrates the hybrid role of *CDOs* because they do not limit themselves to the technical aspects of digital transformation; rather, they are asked to use their strategic vision to practically implement said technological advancements into the core business of the company and make the most out of digital initiatives. Several job postings stress the importance of the hybrid nature of *CDOs* because companies are looking for candidates who are both tech savvy and business savvy to make the most out of both worlds.

#### 3.2.3. Operations

The third topic is addressed with the word 'operational' because it features words related to the practical tasks performed by *CDOs* worldwide in their day-to-day lives. The difference between this topic and the previous one lies in its scope. Although the strategic vision embraces themes that are broader in scope because they refer to the general business strategy of the company, this topic specifically focuses on internal processes both in terms of go-to figures ('responsible', 'management', 'clients' and 'customers') and in terms of business processes ('product', 'development' and 'sales'). What emerges from this topic is the embedded nature of the *CDO* role: they are deemed responsible for their projects, and as such, they are expected to constantly engage with clients while monitoring the firm's internal processes.

#### 3.2.4. Information technology

The fourth topic is tied to the technological tools used by *CDOs* in their daily activities. It features high frequencies of words tied to Industry 4.0, such as 'data', 'technologies' and 'digital', along with more practical ones such as 'tools'. The terms 'develop' and 'build' are a testament to the proactive nature of *CDOs* because they actively oversee the development of tools, software and technological architectures meant to make the most out of digital transformation. Some might argue that the term 'build' can stand for both a specific software version and the verb 'to build'. Unfortunately, this is a

limitation of the *LDA* approach: it does not allow researchers to define the context upon which terms are used. Despite these limitations, the overall sample of the topic is clear enough for us to determine its nature, which was briefly described above.

### 3.2.5. Coordination

The fifth and final dimension can be described as ‘coordination’ because it contains several terms meant to describe the way in which *CDOs* interact with the people around them. More specifically, this dimension features terms such as ‘communication’, ‘team’, ‘social’ and ‘group’, along with developmental terms such as ‘growth’ and ‘ability’. Going back to the second topic for a moment, having a strategic vision is not enough to become a successful *CDO*. In fact, the job postings often stress the importance of being able to effectively communicate said vision to their team and drive towards their goal.

## 3.3. *CDO* skill topics

### 3.3.1. Seniority

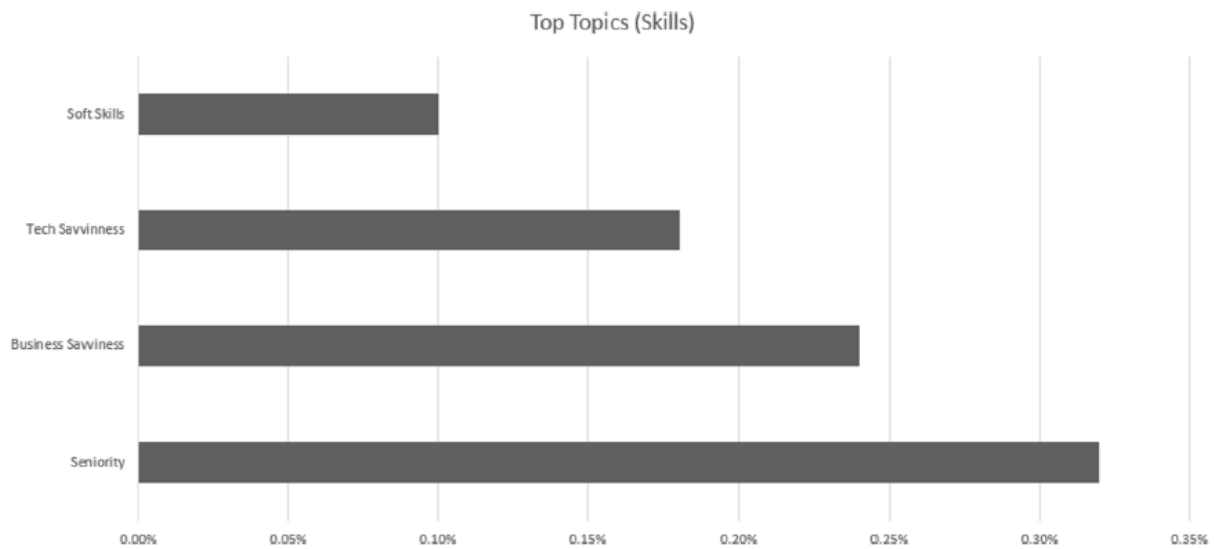
The first dimension when it comes to *CDO* skills is related to seniority. As expected from senior positions, *CDOs* are required to have several years of experience. This dimension features career-related terms such as ‘experience’, ‘years’ and ‘degree’, which indicates the need for *CDOs* to be well educated and possess a strong *CV* overall. Job postings often refer to the experience of managing projects from beginning to end, which is testified by the word ‘project’ being labelled in this dimension.

### 3.3.2. Business savviness

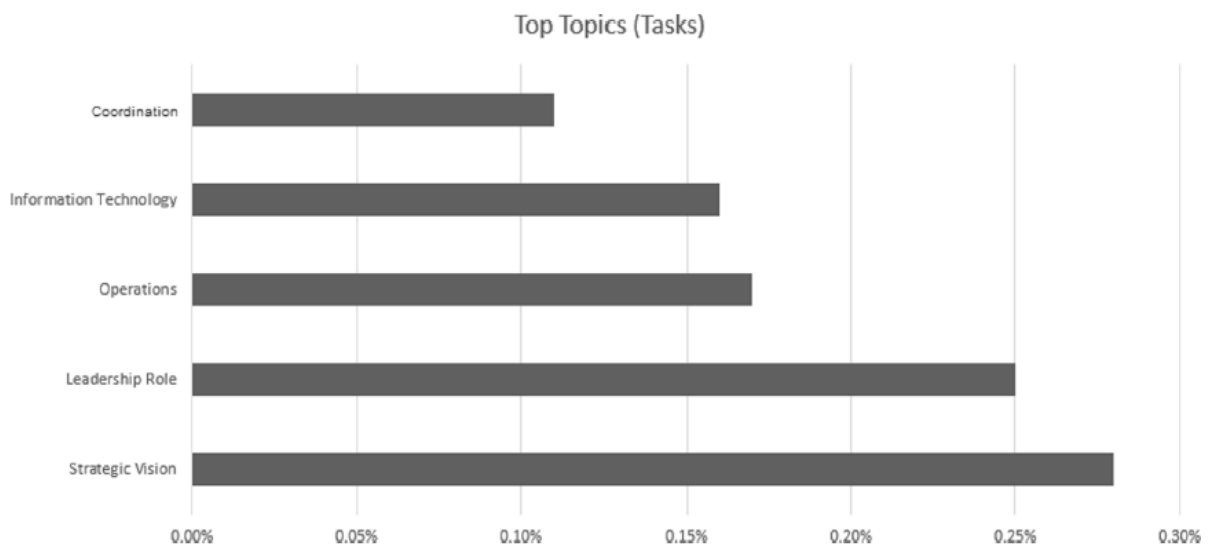
The second dimension is dedicated to the generic managerial skills often required from *CDOs*. This knowledge is referred to as the ability to drive organisational change through means of digital transformation while being able to identify a clear strategic vision, communicate it to the team and peers and later translate it into action. This dimension includes broad business terms such as ‘leadership’, ‘strategy’, ‘vision’ and ‘innovation’, but also marketing-specific ones like ‘customers’ and ‘market’. This dimension illustrates the need for *CDOs* to have tangible business skills and to not limit their scope to the technical aspects of digital transformation.

### 3.3.3. Tech savviness

The third dimension is tied to the digital roots of *CDO* positions. Although they must possess business knowledge, as mentioned above, *CDOs* cannot stray too far from their technical nature. We see plenty of references to computer science-related knowledge in job postings. More specifically, this third dimension features technical terms such as ‘data’, ‘technology’ and ‘software’ but also more operational ones such as ‘processes’, ‘solutions’ and ‘development’. What this dimension is showing is that *CDOs* need to be able to translate their tech savviness into concrete actions, actively drive their team to an objective and know how to optimise internal processes as a result of technological advancements.



**Fig. 5.** Top Topics in the Skills Corpora.



**Fig. 6.** Top Topics in the Tasks Corpora.

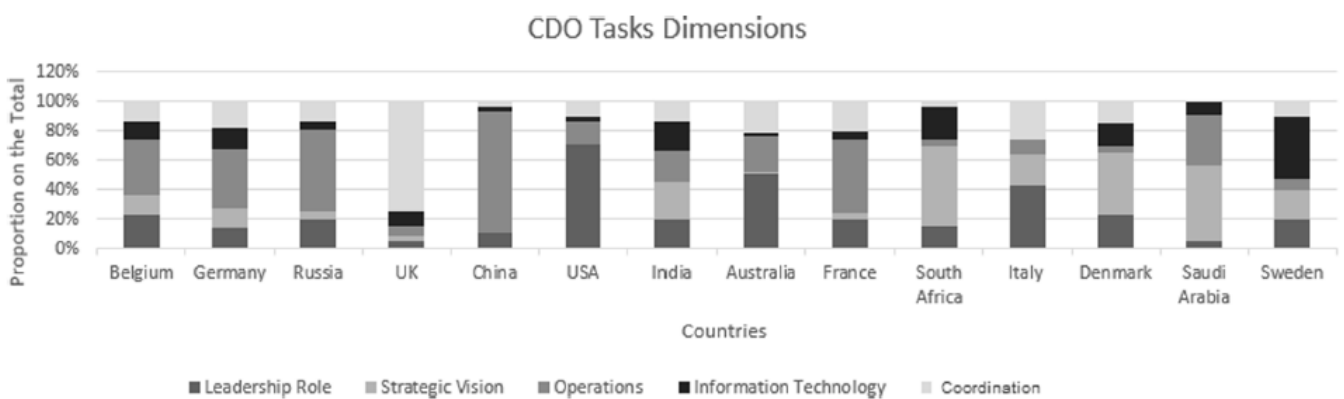
### 3.3.4. Soft skills

Finally, as per many job openings, *CDOs* are required to possess several soft skills, which in the eyes of the employer could prove beneficial to the firm. Terms like ‘communication’, ‘team’ and ‘interact’ show that *CDOs* need to be able to work in a team-based environment because they constantly interact with people they are in charge of and drive them towards organisational goals. *CDOs* are required to be enthusiastic about their role and the change they are agents of, meaning they need to possess a proven track record of being strong communicators and collaborative leaders. Several postings stress the importance of keeping stakeholders engaged and happy with progress, which calls for open communication and integrity.

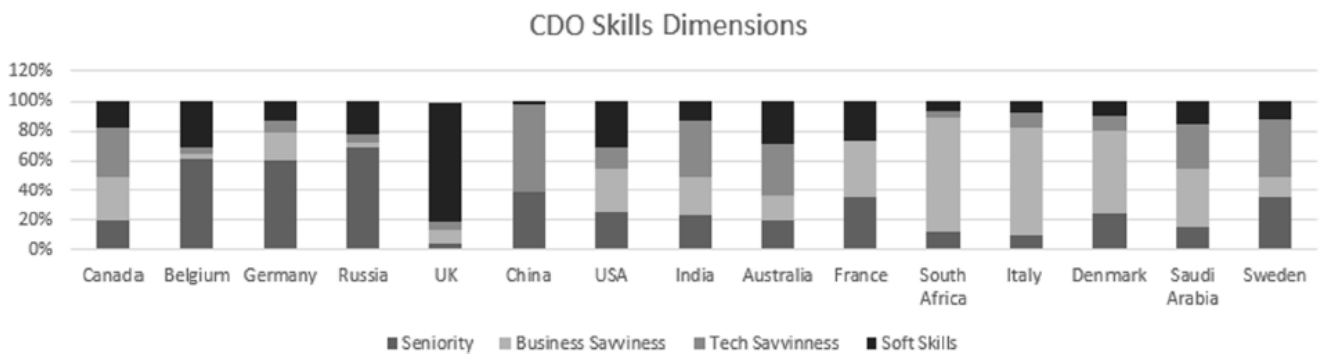
### 3.4. Top topic distribution

**Figs. 5 and 6** show the distribution of the top topics for both tasks and skills. The topic topics are those with the highest probability of appearing in the sample, as per Bayesian statistics. This emphasises the importance of the specific skill sets that are in high demand, along with the *CDO* tasks that are the most essential according to employers. **Fig. 5** shows how seniority is the most important trait to possess when it comes to *CDO* candidates, which is to be expected given the scope of their position and high level of responsibility connected to it. The most interesting takeaway, however, is how core business competencies are in higher demand compared with technical *IT* knowledge.

Similarly, when it comes to the tasks more likely to be required from newly appointed *CDOs*, we see how the dimensions of strategic vision and leadership assume a predominant position compared with the others. Worldwide, *CDOs* are required to play the role of protagonists in the digitalisation of their companies and drive it forward, as guided by their strategic vision. On the other hand, technical roles related to business intelligence and data management appear to be less prominent, which suggests that they are most likely assigned to *CIOs* or *CTOs* rather than *CDOs*



**Fig. 7.** *CDO* tasks dimension.



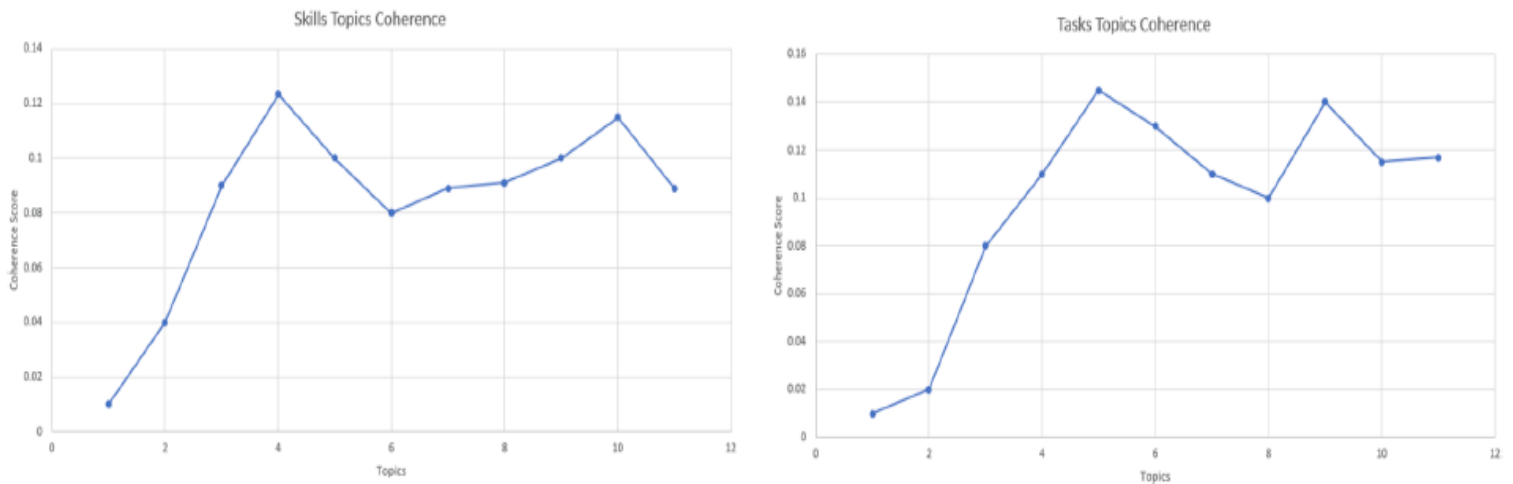
**Fig. 8.** *CDO* skills dimension.

**Fig. A1.** Topic Coherence.

### 3.5. Cross-cultural topic distribution

The application of *LDA* topic modelling has allowed us to identify several dimensions across *CDO* job postings, both in terms of skills and competencies and in terms of tasks to be performed within the workplace. What makes this approach different from the other types of topic modelling is that *LDA* does not divide the cluster into discrete categories. In other words, the dimensions found earlier are heterogeneously distributed across the countries that are a part of our corpora. Each country

contributes to each dimension in a percentage, which can be interpreted as a continuous variable. **Figs. 7 and 8** show how each country contributes to the dimensions of *CDO* tasks and skills, respectively. For example, *CDO* job postings from the United States contain significant emphasis on the tasks related to the leadership position played by CDOs, while there is little in terms of strategic vision and business strategy when compared with other countries' postings. Furthermore, job postings from the UK stress the importance of soft skills the most when compared with other countries, while they put less emphasis on business and technology savviness for future *CDO*s. **Fig. A1. Fig. A2. Fig. A3..**



**Fig. A1.** Topic Coherence.

#### 4. Discussion

We empirically examined the role of *CDO*s in terms of skills and tasks to profile a universally acceptable archetype. In doing so, we are among the first to respond to several calls for more research on *CDO* positions (**Firk et al., 2022**). Our results show that, on average, newly appointed *CDO*s are expected to be digital 'triathletes' (**Gerth & Peppard, 2016; Taylor & Vithayathil, 2018**), as they simultaneously embody a versatile blend of technical, business and soft skills (**Tumbas et al., 2018**). In fact, the complexity of digital transformation naturally requires a broad range of competencies for *CDO*s, as they are asked to drive forward the digital transition of their companies and translate technological advancements into strategic business opportunities (**Muninger et al., 2019; Sousa & Rocha, 2019; Zeike et al., 2019**). We found that *IT* knowledge is a requirement for *CDO* positions (**Canina & Orero-Blat, 2021; Zeike et al., 2019**), but it should accompany the full skills expected from digital leaders, including strategy development, change management and communication. Consequently, our study depicts *CDO*s as digital leaders (**Benitez et al., 2022; Zeike et al., 2019**), as they fit the criteria of digital literacy, business strategy expertise and strong and digital transformation-oriented leadership skills the same way their natural predecessors did (**Gerth & Peppard, 2016; Taylor & Vithayathil, 2018**).

The results of both *LDA* topic modelling and control methodologies unveil the hybrid nature of *CDO*s, as they mix business, *IT* and leadership in one role (**El Sawy et al., 2016**) regarding the tasks to be performed and the skills required. Our findings don't refute completely the position of those who claim the *CDO* is not really a new figure compared to the *CIO*; rather, it is a formal change of label (**Gerth & Peppard, 2016**). In fact, when comparing our results to those formulated by **Barnes et al. (2021)**, we noticed how *CIO*s and *CDO*s share the same hybrid nature. However, by looking deeper into the quantitative data, we see that the incidence of the business-side nature of the *CDO* profiles is much more prominent than that of the remaining two. This assumption is backed by the *LDA* analysis of the

dataset. This evidence ultimately backs the theories of those who considered *CDOs* and *CIOs* as distinct entities (Singh & Hess, 2017; Tumbas et al., 2018) by reinforcing the assumption that *CDO* is progressively assuming its own identity amid the top management hierarchy (Benitez et al., 2022).

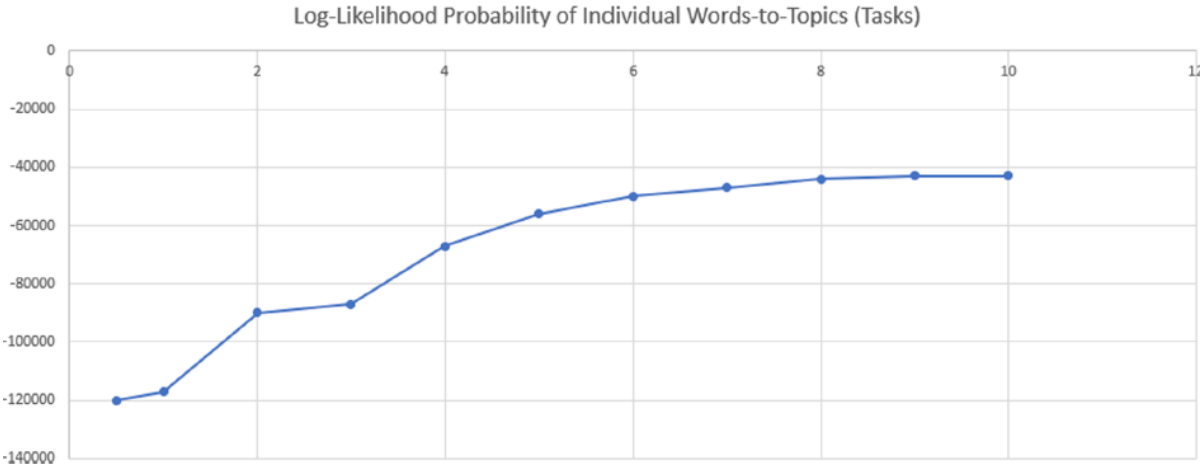


Fig. A2. Log-Likelihood (Skills).

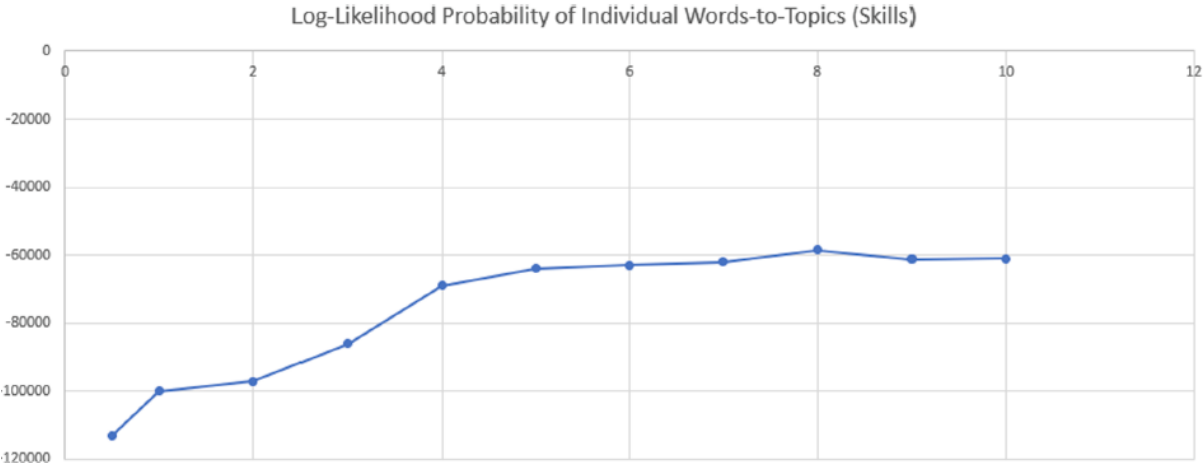


Fig. A3. Log-Likelihood (Tasks).

Finally, on an individual level, our empirical findings address several gaps left unexplored by previous research (Dumeresque, 2014; Kunisch et al., 2022; Tumbas et al., 2018). Our analysis found that, along with seniority, which is essential for top management positions, job descriptions put a more significant emphasis on business development skills compared to *IT* skills. This evidence suggests that companies prioritize business skill sets when appointing *IT* leaders (Foss & Klein, 2014; Taylor & Vithayathil, 2018) to be able to react quickly and proactively towards the disruptive changes put forward by digital transformation. Additionally, our findings shed light on the coordinating role of *CDO*, which has been a point of discourse for the scientific literature (Firk et al., 2021). Our evidence shows that *CDOs* are, in fact, expected to coordinate several actors and business functions (El Sawy et al., 2016; Weber et al., 2022).

The sample also provides an answer to how *CDO* job postings are distributed throughout the world and what country-specific differences arise in postings (Firk et al., 2019; Kessel & Graf-Vlachy, 2021). Firk et al. (2019) mentioned that *CDO* positions are noticeably more relevant in France and Germany

than in the rest of the world. However, we notice that *CDOs* are also popular in the UK and Spain. In the Americas, both Canada and the United States have the highest number of *CDO* job postings. Meanwhile, in the Asia-Pacific region, Australia has the highest number of postings, as Russia and China are still somewhat lagging Western countries, as suggested by previous research (**Chhachhi et al., 2016**). Most notably, Scandinavian countries are still dominated by *CIO* postings, and the same applies to Russia, China and Japan (**Firk et al., 2019**).

In conclusion, our study addressed the following research questions: Regarding *RQ1*, we identified several key competences required from *CDOs*. We confirm the exploratory findings of **Tumbas et al. (2017)**, reinforcing the hybrid nature of *CDOs* and the importance of strategic vision as a means of successfully implementing digital transformation. Our study shows the need for *CDOs* to combine business administration knowledge with IT technical knowledge (**Bresciani et al., 2021; Vas-concelos et al., 2017**), along with the communication skills and seniority needed for a top management coordinating role (**Foss & Klein, 2014; Taylor & Vithayathil, 2018**). This finding effectively bridges the gap identified by **Kunisch et al. (2020)**.

Regarding *RQ2*, our study identified a series of recurrent tasks required by *CDOs*. Our research confirms the findings of **Singh et al. (2020)** and **Doonan (2018)** regarding companies' tendency to seek both managerial and technical competencies in newly appointed *CDOs*. We find the need for strategic vision (**Dumeresque, 2014**), strategic change and innovation (**Singh et al., 2020; Tumbas et al., 2017**), leadership (**Tumbas et al., 2018**) and coordination among departments (**Tumbas et al., 2017**). Additionally, our study demonstrates that coordination among multiple actors is at the core of several *CDO* job postings (**Al Nuaimi et al., 2022; Tumbas et al., 2017**). In doing so, we answer the questions posed by **Firk et al. (2021)** on whether *CDOs* tend to assume a coordinating position among companies. Furthermore, our study finds the managerial soul of *CDOs* to be predominant over the technical one, unlike *CIOs* (**Gerth & Peppard, 2016**) and how the job market is gradually shifting towards leaders who are well informed on business issues (**Taylor & Vithayathil, 2018**). Overall, what we found links back to digital transformation literature by corroborating the importance of problem solving, flexibility and agility in today's volatile and ever-changing market (**Bresciani et al., 2021; Sousa & Rocha, 2019; Vas-concelos et al., 2017**). This finding gives a more comprehensive look at what *CDOs* are expected to do, effectively filling the research gap noted by several authors (**Dumeresque, 2014; Kessel & Graf-Vlachy, 2021**).

## 5. Theoretical and managerial implications

Our study contributes to the literature on digital transformation and *CDOs* in several ways. The main theoretical contribution of the research is to provide an empirical archetype of the *CDO* position in terms of both skills and tasks (**Kessel & Graf-Vlachy, 2021**). In doing so, we answer the call for quantitative approaches to investigate the emergence of *CDOs* (**Singh et al., 2020; Tumbas et al., 2018; Tumbas et al., 2017**). The empirical identification is grounded in the digital transformation literature and contributes to the stream of individual aspects and key capabilities required to master the phenomenon (**Kunisch et al., 2022**).

A second theoretical contribution of the work is to the discourse regarding the differences between *CIO* and *CDO* positions (**Gerth & Peppard, 2016**) and digital leadership literature (**Mansfeld et al., 2010; Singh & Hess, 2017; Singh et al., 2020**). Aligning with the recent work of **Kunisch et al. (2022)**, we propose that *CDOs* are developing a unique and distinct identity despite sharing significant common ground with *CIOs* (**Barnes et al., 2021**). Therefore, the findings of this study suggest that, while *CDOs* share with *CIOs* their tripartite nature made of business, *IT* and soft skills, the way these

three aspects are distributed is significantly different compared to *CIOs* (El Sawy et al., 2016; Singh & Hess, 2017). In fact, the *IT* background of *CDOs* is often taken as a mere prerequisite, whereas job postings stress the importance of business-related skills and tasks, such as strategic vision, management expertise and more. This result partially contradicts the results of Gerth and Peppard (2016), among others, and reinforces the previously published literature on *CDOs*, which stressed their distinct nature (Singh & Hess, 2017; Tumbas et al., 2018).

Additionally, our findings also contribute to digital transformation literature (Fitzgerald et al., 2014; Foss & Klein, 2014; Weber et al., 2022) by highlighting how essential it is to feature technology leaders who are well informed on business issues (Taylor & Vithayathil, 2018), able to drive organisations forward (El Sawy et al., 2016; Weber et al., 2022) and that can meet the criteria set for digital leaders (Benitez et al., 2022; Verhoef et al., 2021; Zeike et al., 2019). Our study also answers the question posed by Firk et al. (2021): *CDOs* are, in fact, coordinating figures amid top management and ensuring that their leadership and soft skills coordinate several functions and actors around them (Mansfeld et al., 2010).

From a practical perspective, the insights of our study offer several implications for managers, ownership, practitioners and management. First, our study strengthens the validity of *LDA* topic modelling in job posting analysis (Debortoli et al., 2014; Gurcan & Cagiltay, 2019), while providing a clear, transparent and replicable research protocol that could be adopted by practitioners worldwide when in need of analysing different managerial (Tirunillai & Tellis, 2014).

Second, our study suggests that major differences emerge when comparing job postings from different countries (Chhachhi et al. 2016). This implication can be useful to managers interested in applying for *CDO* positions, as it clearly demonstrates how the role is tailored to the company's needs and could vary significantly on a case-by-case basis.

## 6. Limitations and future research

There are some limitations that could be addressed by future research on *CDOs*. The main limitation is the limited sample size at our disposal. As the years go by and the *CDO* role matures, future studies could implement a longitudinal approach to better understand the evolution of the position over time. Longitudinal studies would benefit from a larger sample size and more data. Second, the present study features the limitations of *LDA* as a methodological approach. Although *LDA* has been successfully applied in several studies in the past, it does feature some intrinsic defects. For instance, the *LDA* algorithm is unable to discern the context within which words are used—only their frequencies with other words (Erosheva et al., 2004). This could potentially lead to small discrepancies in the results.

Finally, future research could explore the discrepancies found across countries to better understand the reasons why *CDOs* are not evenly distributed. Cross-cultural analysis could help identify the reasons behind this phenomenon, providing us with useful insights (Firk et al., 2019). A cross-cultural study could not only explain the discrepancies found in our results, but also highlight the importance of culture as a factor influencing those differences (Ferraris et al., 2020). Additionally, future research could interpret the data through the use of different theoretical lenses, such as knowledge-based view and dynamic capabilities theories, in an effort to gain a different perspective on the topic (Forliano et al., 2022). Similarly, future research could apply the same comparative logic to cross-sectional studies in an effort to identify which industries are leading the charge when it comes to *CDOs*. Finally, qualitative research based on semi-structured interviews on a panel of *CDOs* could help strengthen the findings of the research and possibly add further insights on the theoretical contributions of the

study. Future qualitative research could, for instance, investigate emerging differences between companies from different industries, or featuring different sizes.

## Appendix

In the main text, topic coherence was reported to determine the number dimensions contained in *CDO* job descriptions as calculated from *LDA*. For the purposes of this study, coherence is the most useful fit statistic because it best represents the interpretability of topics (Roder et al., 2015). However we have also included the log-likelihood of individual words being found in the assigned topic. Results can be found in the charts below.

Computer-assisted qualitative data analysis software, such as Leximancer, can be used to conduct research on large datasets and help minimise the researcher's bias that could present itself when manual coding is involved (Malik et al., 2020). In other words, the Leximancer algorithm drives the emergent key words, themes (clusters of words) and patterns, rather than categories predetermined by the researcher. In this way, the authors can compare the results obtained from both techniques and highlight possible differences between them.

Two distinct analyses were carried out. One included sets of documents related to *CDO* skills, and the other included documents on tasks. Fig. A4 illustrates the results of the skills corpora of the documents. Although Leximancer's thematic map shows more than four topics, we can clearly distinguish the themes that emerged through the *LDA* analysis. On the top right, we see both the communication and leadership skill sets, with recurring keywords such as 'communication', 'ability' and 'reporting' that were found previously through *LDA*. Still consistent with *LDA*, we find the red bubble automatically labelled as 'strategy' to be inclusive of all business-related skill sets. The one discrepancy found between *LDA* and semantic analysis is tied to the construct of 'seniority'. While through *LDA*, the construct emerged as a clear-cut dimension, here it is merged with several other topics, and most notably with the keywords related to business skills.

Fig. A5 illustrates the results of the tasks corpora. Here, the tripartite nature of the *CDO* is clearly shown as three major themes emerging from the semantic analysis: the business development side, the core technical side and the coordinating role of a leader. While the *LDA* technique has led us to keep the concepts of leadership and coordination distinct despite their similarities, here we find them grouped under the same bubble, which is labelled 'team'. What we labelled 'operations' via *LDA* can be found in the green 'development' bubble, while 'strategic vision' and 'information technology' appear in the red bubble, which is expectedly most prominent. More specifically, we find *IT* terms closer to the 'development' bubble, almost bridging the two themes due to their interconnection between strategic change and project delivery. Meanwhile, the strategic portion of the sample was scattered throughout the remaining areas of the red bubble.



Following the semantic analysis, a three-step coding protocol was applied. Coders analysed a selected sample of 100 job postings randomly selected from the sample. Adopting Corbin and Strauss's (1990) approach, we coded the content of the job postings to identify the zero-, first-and second-order categories demonstrated in the recent literature. After an initial analysis of the content, double checks were made through discussions of each coding result. Where diverging positions arose, a third person was introduced into the discussion to provide a different point of view.

More specifically, during the first step of coding, coders grouped up statements with similar intentions into so-called zero-order categories. Subsequently, patterns between zero-order categories for axial coding were identified and grouped into first-order categories. These categories were triangulated with secondary data, including corporate consulting reports on *CDOs*. The final step was to conduct selective coding to regroup the first-order categories into second-order categories. A multistep reliability test was conducted following the coding of the content. The first step was to check for internal consistency, which was achieved by integrating the independent coding sheets of each researcher (Ulaga & Reinartz, 2011). Inter-rater reliability was tested by employing three academic scholars who were not involved in the study yet had a relevant background in research on topics related to business and digital transformation. We measured their agreement with the coding results to calculate Cohen's kappa (Cohen, 1960).

**Table A1** Coding results.

Zero-Order Concepts	First-Order Concepts	Second-Order Concepts
CDOs are expected to turn technological advancements into competitive advantages	strategic change	Business
In today's volatile market, CDOs need to react quick to changes		
In CDO profiles, business strategy expertise is most prominent compared to other top management positions	business development	
A CDO is expected to create business value and development	vision	
CDOs are asked to envision a future for their company and drive it forward through digital transformation		
Thanks to their hybrid background of skills, CDOs are expected to use creativity when envisioning the future	operations	Technical
Customer-oriented attitude is essential when delivering goods and services	digital literacy	
A strong IT background is needed for CDO positions		
Despite being more business oriented than CIOs, CDOs are still expected to operate in a high tech environment	communication	Coordination
Soft skills are vital for CDOs as they are expected to effectively communicate their vision to the people around them	team leadership	
CDOs are top managers and, as such, they are expect to lead a team by example		
CDOs are expected to be brilliant leaders and help people around them work together towards a digitised future	coordination	
Organisation wise, CDOs often play a coordinating role between multiple departments		
CDOs are expected to keep tabs with both customers and management, hence the need for coordination	seniority	Seniority
Much like every top management position, years of relevant experience are needed to become a CDO		

Ultimately, the coding process led to the results shown in Table 1. Nine first-order codes were identified: strategic change, business development, vision, project management, digital literacy, communication, team leadership, coordination and seniority. To measure the reliability index, we adopted the threshold of 0.70 set by Rust and Cooil (1994). Our score was 0.82 rounded up; hence, it was statistically significant enough to indicate substantial agreement. Finally, in the last step to ensure content validity, we constituted a panel of nine experts with backgrounds in social science, business administration, digital transformation and organisation research. We asked them to read and review the coding of our sample and suggest changes. Their suggestions were ultimately incorporated into **Table A1**, which can be seen below.

From a comparative point of view, the coding results fall in line with the results found through LDA analysis and semantic analysis via Lex-Imancer, albeit with minor differences due to the qualitative and interpretative nature of the methodology being applied. What has emerged from the analysis is the tripartite nature of *CDOs*, being able to mix business, *IT* and leadership skills. First-order concepts are

comparable to the dimensions found via *LDA*, with the only difference being that coders opted to analyse both skills and tasks comprehensively, rather than keeping the distinct. Overall, coders were able to clearly determine the tripartite nature of *CDOs*, the relevance of their coordinating role and the predominant business-related soul of their role.

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