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Does a CDO enhance Company Inventiveness? An Empirical Study on new Managerial Positions and Innovation

Ruben R Salas
INCAE Business School, ruben.ramirezs@incae.edu

Carla Fernandez-Corrales
INCAE Business School, carla.fernandez@incae.edu

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Completed Research

Ruben R Salas
INCAE Business School
ruben.ramirezs@incae.edu

Carla Fernández-Corrales
INCAE Business School
carla.fernandez@incae.edu

Abstract

Digital technology has advanced rapidly in the last few years. Consequently, companies need to transform their business and operations models to keep up with these advances, placing digital transformation (DT) as a top priority. Beyond the possible effects of using more digital technologies, is more innovation. One way in which companies can stimulate DT is by creating a new top-management position, the Chief Digital Officer (CDO). Although evidence has been found about the relationship between digital technologies and innovation, the role of the CDO as an enabler has been less studied. We use difference-in-difference estimators to measure this effect, using a unique dataset with 39 companies that appointed a CDO and 39 comparable companies that did not as a control group. We find a significant increase in patent filings as early as the first year CDO's appointment. We find evidence that a managerial role can have an effect on innovation.

Keywords

Digital Transformation, Chief Digital Officer, Innovation, Managerial Positions

Introduction

Digital technology has radically changed the economy through new products and services, business models, and ecosystems (Iansiti & Lakhani, 2020). With the need for firms to transform their operations to keep up with digital advances (McAfee & Brynjolfsson, 2017), companies are putting digital transformation (DT) at the top of their strategic agendas (Björkdahl, 2020). A relatively new phenomenon, the addition of a Chief Digital Officer (CDO) to top management teams as an instrument to drive their digital transformation efforts, has grown consistently in recent years (Horlacher & Hess, 2016), from a position debuting in S&P 1500 in 2003 with a documented exponential growth that accelerated after 2009 to achieve more than 5% of companies in the index by less than a decade (Kunisch et al., 2020).

Despite increasing scholarly attention to the CDO position (Kunisch et al., 2020; Reck & Fliaster, 2019; Singh & Hess, 2020; Tumbas et al., 2017, 2018), empirical evidence on the benefits of hiring a CDO remains scarce. For instance, although we know that digital transformation has brought great benefits to those who have adopted it (Bock et al., 2017) and substantial research has established a positive relationship between digital transformation and various types of innovation, the question of whether hiring a CDO makes any difference in the inventiveness of a company remains underexplored. This is an interesting question because it allows establishing whether creating a new management role is effectively a mechanism by which the benefits of digital transformation can be achieved. In this study, we analyze the role of the CDO as the responsible for digital transformation (Horlacher & Hess, 2016), and we drew upon literature on the effect of organizational changes and managerial attitudes based on adoption theory (Damanpour & Schneider, 2006; Dewar & Dutton, 1986), to understand the role of CDOs regarding technological innovation in companies.

We perform a difference-in-differences (DID) analysis using a unique dataset based on the CDO's appointment according to firms' public information and CDO position search on LinkedIn to explore this relationship. The choose for a difference-in-differences was motivated by dealing with different years in the pre and post implementation for the position at each company, and thus, different possible year fixed effects along the data, that has been recently discussed in econometrics mechanisms. As a measure for innovation, we consult patent filings from several IP offices through the Google Patents database and compare the before and after for the CDO appointment in a panel structure, matching the firms with CDO with control group companies in the same industry. Our empirical results suggest that the presence of a CDO can substantially improve the number of patents filed by a company, suggesting a positive relationship.

We believe our study contributes to the literature in three major ways. First, our study contributes to the literature on DT and innovation by examining how the formalization of a new top management position focused on the integration of technology in various areas of the company can function as a driving mechanism for innovation and have a positive impact on the number of patents issued by the firm. Second, our study advances the novel literature on the role of the CDO in organizations by providing empirical evidence that allows us to understand better the role of the CDO in digital transformation and innovation, while exploring ways on how IT changes organizations (Brynjolfsson, 2021). To our knowledge, no previous studies have analyzed this relationship, except Firk et al. (2021), which focused on the interaction with the top management team more than the CDO appointment itself. Additionally, in our study, we use a dataset that extends the work from previous studies (e.g., Horlacher & Hess, 2016; Singh & Hess, 2020; Tumbas et al., 2018) to analyze the position within a specific industry to measure its impacts with comparable firms, adding global scope by including firms outside of the U.S. and combining public and private companies.

Finally, our study provides some important methodological innovations. While previous research has focused on case studies (Horlacher & Hess, 2016; Singh & Hess, 2020; Tumbas et al., 2017, 2018), we applied a difference-in-differences model, an increasingly used approach in the literature on strategic management, however often overlooking some assumptions (Li & Certo, 2021). To achieve a rigorous model application, we did a fixed-effects propensity scores matching regression (Ho et al., 2007) and corroborated results with difference-in-difference for multiple-time periods to generate double-robust estimands (Callaway & Sant'Anna, 2021). Both designs showed consistent and comparable results. The rest of the paper is organized as follows. First, we present the most influential theories related to the study of digital transformation and innovation and the emergent CDO position literature. Next, we discuss our research methods: dataset collection, measures, and model specifications. Then we present our results and compare findings. Concluding remarks are shown in the final section as well as implications.

Theoretical Motivation

Digital Transformation and Innovation

Although digital transformation (DT) is a topic of central attention for scholars and practitioners in a more digital economy (Iansiti & Lakhani, 2020), several contributions to literature still consider the field and theories in its infancy, with opportunities for a unified perspective (Appio et al., 2021). While digital technologies are associated with several positive impacts for organizations, such as operational efficiency, organizational performance, and industry and society improvements (Vial, 2019), the need for novel theorizing on digital innovation management is often argued (Hinings et al., 2018) where there is one example of a comprehensive theoretical background around the relationship between digital technologies and organizational innovation.

Some authors have studied absorptive capacity (ACAP) theory to examine whether and how IT-enabled knowledge capability affects firm innovation and argue that IT-enabled knowledge capabilities enhance firm innovation by facilitating the creation of patent inventions and the introduction of new products and services into the market (Joshi et al., 2010). Later theories, however, relate the analysis of innovation in a context of entrepreneurial processes, where the theory of technological affordances considers aspects of *generativity* and *convergence* as characteristics of organizational innovation related to digital technologies (Yoo et al., 2012). Building upon those affordances, some other authors (Nambisan et al., 2019a) elaborate on the digital technologies' impact on factors such as *openness* of new ideas and interconnection of players (such as API and Internet collaboration), or the *affordability* as infrastructure facilitates interactions among subjects that weren't possible before, such as blockchain, and finally, g*enerativity* as digital

technologies' capacity to produce unprompted change or recombination by large, varied, uncoordinated entities or actors.

Among these theories, one common factor is the role of digital artifacts in digitalizing current physical assets and creating new representations or ideas (Kallinikos et al., 2013), which provide firms a broader scope of affordances generativity capabilities. Those digital assets also could generate by-products that were not anticipated either by the firm that created them or the users (Yoo et al., 2012). For instance, jogging information is captured by devices intended to perform training exercises that later lead to nutritional recommendations and meal subscriptions for personalized user goals. In this sense, those by-products of data and digital artifacts may lead to derivative innovation as a side effect of the original innovation effort. Thus, in order to innovate in the context of digital transformation, firms gain the ability to develop new ideas or business models with the more abundant digital artifacts produced in a new order economy and big data environment. More recent studies also bring new theoretical perspectives explaining DT and innovation adoption relationship by innovation diffusion theory while examining factors that contribute to or hinder a firm's DT, suggesting DT could be treated as an innovation within the firm (Steiber et al., 2021). Also, innovation through digital technologies has been explored by selling theory as the capacity and efficiency of the Chief Information Officer to sell issues in the organization (Chen et al., 2021)

Around innovation at firms and benefits associated with digital technologies, evidence suggests that technological change affect entries and exits of organizations (Anderson & Tushman, 1990) and that cycles of technological change, and we argue DT is one, are triggered by technological discontinuities such as new IT affordances as radical product and process innovations, that result in significant cost, performance and quality improvements (Poole & Ven, 2021). As outcomes for organization change, we find new logics that direct, motivate and legitimate the behavior of actors, both individual and collective or existing, meanings, relationships, and boundaries for population and community (Poole & Ven, 2021). From those outcomes, literature shows changes in logic are likely to occur first, creating conditions for constructing new roles and new types of organizations (Scott et al., 2000).

We study one of those organizational changes around DT at the top management level, as the role of Chief Digital Officer (CDO), which has been recently subject of study as a mechanism for formalizing and directing efforts as the main responsible of DT at the firm level (Horlacher & Hess, 2016; Tumbas et al., 2017). While most of the research around the position has characterized the role and explained its emergence across industries, empirical evidence of its possible benefits is scarce. Some studies have recently explored digital knowledge in top management and the interaction with CEO and board executives (Firk et al., 2021); we propose to look at the effects and formalization of the position among firms within an industry sector to answer how the CDO's appointment may influence organizational inventiveness, through patents fillings as proxy for innovation.

The Chief Digital Officer, new managerial roles, and innovation

Scholars have shed light on the role of Information Technology (IT) at firms, commonly attributed from top-level to the Chief Information Officer (CIO), and found increasing demands in addition to the traditional technology operations handling, referred to more business innovation initiatives (Horlacher & Hess, 2016). Similarly, some studies found that the role of CIO as solely responsible for information systems could be perceived as a technical specialist, with limited agenda for additional responsibilities in the strategic perspective for the business (Tumbas et al., 2017). Thus, some discussion suggests the CIO could evolve with two separated streams (Haffke et al., 2021). From the supply-side of the business, IT plays a role in supporting firm's operations efficiently and providing services related to its technological infrastructure. From the demand-side, it is related to innovation, business growth, and the creation of new business value through IT and for driving the digital efforts at leadership committees, cross-functional innovation groups and boards, thus, giving space to this position to be split and moving the demand-side to the CDO role.

On the motivations for a position like this, from an economic point of view, it is known that firms that have invested heavily in innovative management techniques, business models, work processes, and human resource practices, will pursue to amplify their investments into information, communication and technology assets (Brynjolfsson, 2011), and thus, the mechanism of creating a role provides formalism, resources allocation and decision making power to bring benefits associated with firm digital investments. Other reasons come from a possible weak political position of the IS department, no trusted relationship

between IT and other areas such as marketing, and in general, lack of strategic digital direction (Tumbas et al., 2017).

We find some literature describing the position on distinct functions depending on industry and organizational characteristics, some authors describe the CDO as a possible evangelist, coordinator, innovator, or digital advocate (Haffke et al., 2021), and other roles associated are: Entrepreneur (in charge of implementing digital innovation among other duties), Spokesperson, Leader, and Monitor (to look for emerging innovations and trends) (Horlacher & Hess, 2016). Others categorize it as the digital accelerator, digital marketer, and digital harmonizer (Tumbas et al., 2017). We found a common factor towards innovator or intrapreneur with a clear objective for bringing innovation, which is documented as one of the focal domains where the position has been studied to drive business value among digital analytics and customer engagement (Tumbas et al., 2017).

We know that organizational changes such as creating a new role can affect innovation. Specifically, managers could introduce innovation to close the performance gap and thus allocate resources for adoption, affecting the rate and speed of adopting innovations in organizations (Damanpour & Gopalakrishnan, 1998). Managers can influence workers' motivation and job satisfaction, create a social climate to improve morale, and encourage and reward innovation and change. Thus, innovation adoption can be the direct result of managerial choice or imposed by external conditions (Damanpour & Schneider, 2006). More specifically, within the phases of innovation adoption (initiation, adoption decision, and implementation), it is on the adoption decision where top organizational echelons such as managers, committees, and boards, decide to adopt the innovation and allocate resources to it.

Top managers affect innovation adoption because they modulate the process of scanning the environment and formulate policies to respond to environmental change. They control resources and influence major decisions, especially strategic (Damanpour & Schneider, 2006). Some studies on organizational changes also describes how formal changes at the organizational level may affect innovation processes, benefiting a centralized budget and R&D structure, that increases breadth and impact of innovations (Argyres et al., 2020), which is consistent with centralizing the digital transformation budged under the accountability of a unique chief officer.

Given factors in favor of both benefits on innovation from digital technologies and the possibility of an organizational change and a new managerial position also affecting innovation, in this study, we are interested in the mechanism of implementing a CDO, enhancing DT efforts, on firm's innovation. We use a different identification strategy to rule out this possible alternative explanation and explore which theoretical mechanism is more plausible in the empirical part.

Methodology

Sample

For our empirical analysis, we construct a unique dataset that combines data from LinkedIn and companies' public information to determine the beginning of the CDO role at firms and the Google Patents database to obtain the patents fillings for the firm analyzed, around the date the position was hired or created. As previous studies on innovation at the firm level and the impact of executives' characteristics using patents production as a proxy measure, we also looked for data in medical companies (Katila et al., 2017). Using the search terms "Chief Digital" and "CDO" within the medical industry, more than 583 results were analyzed. We exclude other positions results and those from big firms with more than a hundred thousand employees or global scopes such as Sanofi, Bayer, Pfizer, and others that could attribute innovation and patent production to other variables, or that could have several CDOs in distinct geographies or divisions that would make difficult to isolate results.

Once this position of interest for a company was identified, the information was revised with the company's public information and cross-search verification. If the position existed for more than one year, we include it in our dataset. From the company's profile, we collect the country (as a reference when the company operates in multiple locations), the date of hiring the CDO, and complement the dataset for companies with Dun & Bradstreet company's profile information to include estimated revenue (millions USD), number of employees, year of foundation and if the firm is public or not.

In addition, we looked for patents' information for companies with CDO positions both after and before the hiring date to create panel data with measurable differences around the hiring event. Those companies with sufficient patents information were preserved as the treated group. The control group database to complement the treated companies was built by matching the search with employee's category (size) and country within the same medical sector. Once the same search mechanisms identified the matching candidates' companies, the patent requirements around the hiring time were applied to add to the database. We collected the most similar companies with no CDO to compare to the treated group. The number of patents for both treated and control companies was summarized yearly. The summary statistics for the database and the comparison for control vs. treatment groups are presented in Table 1 (Furman et al., 2021). Patents' information is collected from the year 2000 up to 2021, in the case of companies with CDOs, the cohorts included come from 2016 up to 2020, for a post-hiring period from 2 up to 5 years.

	CDO Companies	Control Group	Diff.	*p*-value
Main sample (before CDO)				
Mean number of patents (all years)	534.49	632.72	-98.23	0.69
Mean number of patents/year	31.30	38.14	-6.84	0.08
Mean number of patents U.S companies	444.33	595.04	-150.70	0.59
Mean number of patents European companies	801.09	780.00	21.09	0.97
Firms profiles (all dataset)				
Mean year of firm foundation	1,967	1,960	7	0.56
Mean revenue/year in USD millions	7,762	7,903	-140	0.97
Mean number of employees	18,138	16,774	1,364	0.78
Mean public company indictor	0.28	0.41	-0.13	0.24
Number of firms	39	39		
Number of records	783	763		

Notes: This table shows the averages of the data for companies that hired the CDO position with the associated control group defined by matching. The last two columns show differences with the associated significance level. The *p*-values are the result of a *t*-test with unequal variances.

Table 1. Summary Statistics before Chief Digital Officer (CDO) hiring

Variables

To measure innovation impact on firms, we use the number of patents as a source to approximate innovation among firms as in previous similar studies (Crosby, 2000; Firk et al., 2021; Katila, 2000). Since the number of patents fillings is zero for some firm-year observations, we take the ten-base log of the number of patents plus one to address variable skewness. We test our treatment dummy variable as one if the company has hired a CDO and zero otherwise.

Analysis

Our main purpose in this study is to examine how a CDO hiring may affect the number of patent filings of the organization in the post-hiring period. We apply difference-in-difference OLS regressions. To do so, we compare the companies with the CDO position and those in the control group without it. Although the control group of companies was built using matching to the treated firms along with a set of relevant, observable characteristics (Shi et al., 2017), we implement the suggestions of (Ho et al., 2007) for improving the estimating treatment effects and reducing model dependency, by preprocessing data to generate propensity scores that allow the model to be more robust and less sensitive to modeling assumptions.

The propensity scores are estimated using a generalized additive model where we include the firm-level variables of transformed log yearly revenue, log number of employees, year of foundation, and a dummy variable to indicate whether the company is publicly traded or not. Thus, to examine how an organizational response to digital transformation at the firm level by appointing a top executive position of CDO, we propose a fixed-effects OLS regression to estimate the effects on patent production before and after hiring a CDO position between treatment and control firms weighted by propensity scores.

$$Y_{it} = \alpha_t + \delta_i + \beta \times treatment_i \times post\text{–}hiring\ period_t + X_{it} + \epsilon_{it} \quad (1)$$

Where i indexes firm and t indexes time (year). Y_{it} is the dependent variable of interest (i.e., log-transformed number of patents), and α_t and δ_i are year and firm fixed-effects, respectively, and X_{it} represents a vector of control variables. In this analysis, we are interested in the significance level and magnitude of the difference estimator β, which represents the interaction of the treatment and the time and company fixed effects in the post-hiring period. In addition, as recently documented literature into econometrics, difference-in-differences has received attention when staggered periods are used, since it may lead to contaminated estimators and several shortcomings of two-way fixed effect regressions (Sun & Abraham, 2020). Thus, we validate our results using (Callaway & Sant'Anna, 2021) weighted averages linear regression considering parallel trends assumptions and also assuming that once the position of CDO is created, it will continue as treatment all relative years. This method would add a double-robust estimator and weight the different cohorts of companies at different years of CDO hiring.

Results

Table 2 reports descriptive statistics and correlations for variables examined in this study, where we test the main effect of this study. Table 3 shows results from fixed-effects OLS regression for the dependent variable of log number of patents plus one. Model 1 does not include any control variable, and the coefficient of the interaction term for treatment and post-hiring CDO is positive and statistically significant (β = 0.221, p-value < 0.01). Models 2 and 3 include firm and time fixed-effects, and both show a positive and significant interaction (β = 0.148, p-value < 0.01), very similar for both models despite control variables present.

In terms of patents impact, compared with firms that did not hire a CDO, firms that created the position will perceive a 40.6% (10^0.147 - 1) increase in the number of patents from the pre-hiring period to the post-hiring. These findings are consistent with the positive direction in which the DT and the mechanism of enhancing its efforts by a managerial position could bring to the company. When initial OLS results are compared with double-robust, new difference-in-difference techniques model (Callaway & Sant'Anna, 2021) estimates provide a clearly visually upward trend on estimates for the post-hiring period in Figure 1. This model includes ten years before and four after hiring. As expected and part of the limitation of this study, the variance tends to increase as fewer companies have implemented the CDO with longer exposure.

Variables	Mean.	Std.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) Patents per year	35.05	70.22	1.00								
(2) Log Patents + 1 per year	1.062	0.679	0.69	1.00							
(3) Year	2011.2	6.2	-0.01	0.10	1.00						
(4) CDO hiring indicator	0.51	0.50	-0.04	0.10	-0.02	1.00					
(5) Year the CDO started	2018.0	1.2	-0.15	-0.07	0.02	-0.02	1.00				
(6) Firm number of employees	18,416	21,919	0.25	0.38	-0.05	0.04	0.07	1.00			
(7) Firm year of foundation	1958.1	51.6	-0.25	-0.27	0.11	0.09	0.21	-0.13	1.00		
(8) Public company indicator	0.36	0.48	0.31	0.27	-0.02	-0.11	-0.08	0.23	-0.10	1.00	
(9) Revenue in USD millions	8482.9	15439.0	0.19	0.27	-0.05	-0.01	-0.14	0.45	-0.18	0.21	1.00

Notes: this table shows relevant numerical variables available in the dataset.

Table 2. Summary statistics and cross-sectional correlation matrix

	(1)	(2)	(3)
CDO x Post	0.221*** (0.05)	0.148*** (0.03)	0.148*** (0.03)
Log number of employees			-0.09*** (0.03)
Log revenue (USD)			-0.21*** (0.04)
Public company			-1.26*** (0.16)
Year of foundation			0.00 (0.00)
Constant	1.05 (0.02)	-0.12 (0.11)	1.96 (3.43)
R^2	0.01	0.78	0.78
Observations	1526	1526	1526
Controls: Company & year fixed effects	No	Yes	Yes

Notes: This table shows the log number of patents + 1 as a dependent variable for all models. Standard errors are indicated in parenthesis, and log revenue USD is in million USD. *Significant codes for coefficients are: $p < 0.01$ '***', $p < 0.05$ '**', $p < 0.1$ '*'

Table 3. Chief Digital Officer Hiring effect on Patents

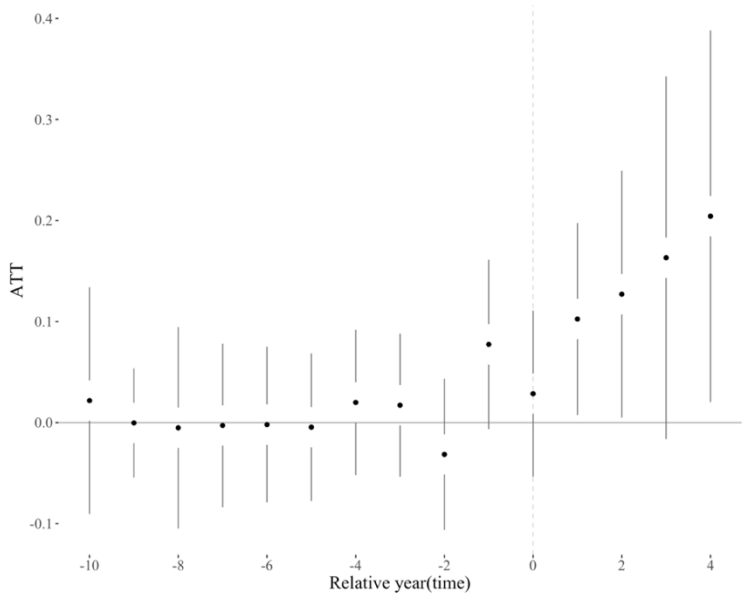

Figure 1. CDO hiring effect on patents

Notes: In this figure, we show average treatment on treated effects on firm-level for hiring a CDO in charge of digital transformation, on patent production after the relative year of hiring using a staggered differences-in-differences design with multiple times period using (Callaway & Sant'Anna, 2021)

On the patents impacts, the overall estimator for this model is also positive and significant (β = 0.125, Std. Error = 0.05, p-value < 0.05), however, it shows a more conservative estimation for the impact on patents of 33.4% (10^0.125 - 1).

Concluding Remarks

We found that, once the CDO position was created, there was sustained growth in the number of patents filed by the company. As early as one year after appointing a CDO, companies filed 26% more patents on average than the control group, and up to 60% more on average four years after the appointment (Figure 1). These results allow incorporation of latest methodological advances in the difference-in-differences model (Callaway & Sant'Anna, 2021) to correct a possible overestimation of the effects. These results also corroborate our position that top managers positively affect innovation.

Theoretical implications, include confirmation on a top management position that has a positive impact on the inventiveness of companies (Damanpour & Schneider, 2006), however, expanding with empirical results a position focused on digital transformation. Findings in this study also shed light on the CDO as a mechanism through which digital transformation generates innovation in companies. Previous studies have shown this relationship (Joshi et al., 2010; Nambisan et al., 2019; Yoo et al., 2012), but until now, no study to our knowledge, has focused on the position of the CDO as a facilitator of this phenomenon with empirical results.

The practical implications of this research relate to the importance of position creation in organizations. Although for some practitioners, the CDO position is replacing the CIO, the relationship between the CIO and the CDO is meaningful (Tumbas et al., 2017), and our results suggest that creating the position is worthwhile because it could bring demand-side initiatives and innovation, in addition to the operational efficiency and the support of technological infrastructure addressed to the existing CIO, however, we find no evidence towards a replacement but positive benefits associated with the CDO. Moreover, there are some questions about whether the position will be a temporary trend in organizations (Deloitte, 2018), and thus we provide not only empirical evidence for the position to be still growing and benefits associated to it that suggest long-term existence.

Our results, which show positive effects on innovation up to four years after hiring, allow us to argue that since organizations must take leverage on various technologies, such as the internet of things, virtual reality, blockchain, or other emerging and ever-expanding domains (Tumbas et al., 2017), the position is here to stay. Our study has some limitations. In the first place, the use of patents as a proxy for innovation has well-known shortcomings as it might over or underestimate the number of innovations (Bell et al., 2019). Second, as the appointment of a CDO is a recent trend, the cohorts in our data reflect few CDOs in the same industry. Replications of this study can be carried out in the next few years to corroborate the results with a larger dataset.

Future Research

Overall, although our results are broadly consistent with previous studies on top managers and innovation, we are unable to examine the specific mediation mechanisms since we cannot analyze the behavior of the CDO. Further research can focus on topics we analyzed during this study such as exploring the characteristics of the CDOs in greater depth, the specific tasks and different assignments across companies and industries, since there are still several roles associated with this position. Finally, there are important questions regarding the legal and R&D relationship not only with the CDO position but in general with the digital technologies implications that could affect patent fillings, and underlaying mechanisms that explain deeper the empirical results discussed.

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