Lohmüller et al. Triple Helix (2018) 5:2
https://doi.org/10.1186/s40604-018-0050-z

Triple Helix

RESEARCH Open Access

Hidden Chief Technology Officers: the surfacing of a subterranean organizational role

Bertram Lohmüller, Alexander Petrikhin* and Norbert Wagemann

* Correspondence: alexander.petrikhin@steinbeis.education
SGIT Steinbeis Global Institute Tübingen, Steinbeis-University Berlin, Konrad-Adenauer-Straße 13, 72072 Tübingen, Germany

Abstract

Our research focuses on 'Hidden CTOs' defined as executives who perform technology manager functions without having official titles related to technological issues in contrast to executives who have an official position related to technological issues (general abbreviation CTOs––Chief Technology Officers).
This paper presents an analysis of data collected from a number of executives via an international business environment, namely a study of their core functional activities, areas of responsibility, and of how the core stakeholders influence their "managerial power" within and outside of the parent companies/organizations. The empirical results of the study were obtained from the international cluster project "Intelligent use of biomass along the Danube: R&D network formation with German, Hungarian, Slovak and Romanian partners".
The first results demonstrate a strong correlation between the technology manager's functional priority and specifics of various business sectors and technologies applied there.

Keywords: Chief Technology Officer (CTO), "Hidden CTO", External and internal stakeholders, Sources of organizational influence, Open innovations

(隐形)首席技术官:一个地下组织角色的表象

摘 要:我们的研究主要集中在"隐形首席技术官(Hidden CTOs), 即履行技术经理职能的行政人员,但没有与技术问题相关的官方头衔,与那些与技术问题有关的行政人员(普遍缩写为CTO - 首席技术官)形成对比。
本文分析了从具有国际商业环境的一些行政人员那里收集来的数据,即研究他们的核心职能活动、责任领域以及核心利益相关者如何影响其母公司/组织的内部和外部"管理权力"。这一研究的实证结果来自国际集群项目"沿多瑙河生物质智能利用:德国-匈牙利-斯洛伐克-罗马尼亚合作伙伴研发网络的形成"。
第一批研究结果表明:在技术经理的功能优先性和各种商业部门及在那里应用的技术的具体情况之间存在着强相关性。

关键词: 首席技术官(CTO), "隐形首席技术官", 外部和内部利益相关者, 组织影响力来源, 开放创新

Résumé

Notre recherche porte sur les "directeurs techniques cachés", c'est. à dire des cadres qui exercent des fonctions de gestionnaire de technologie sans avoir un titre officiel en relation avec cette fonction contrairement aux cadres qui ont une position officielle liée aux problèmes technologiques (abbréviation générale CTO - Chief Technology Officers). Cet article présente une analyse des données collectées auprès d'un certain nombre de cadres via un environnement commercial international, à savoir l'étude du coeur de leurs activités fonctionnelles, de leurs domaines de responsabilité et de l' influence des actionnaires sur leur « pouvoir managérial » à l'intérieur et à l'extérieur des sociétés/ organisations mères. Les résultats empiriques de l'étude ont été obtenus à partir du projet de conglomérat international «Utilisation intelligente de la biomasse le long du Danube: formation d'un réseau de R&D avec des partenaires allemands, hongrois, slovaques et roumains». Les premiers résultats montrent une forte corrélation entre la priorité fonctionnelle du gestionnaire de technologie et les spécificités des différents secteurs d'activités et technologies qui y sont appliqués.

Mots clés: Directeur technique (CTO), CTO caché, parties prenantes externes et internes, sources d'influence organisationnelle, innovations ouvertes

Resumo

Nossa pesquisa se concentra em "CTOs ocultos" (executivos que executam funções de gerente de tecnologia sem ter títulos oficiais relacionados aos problemas tecnológicos diferente de executivos que possuem uma posição oficial relacionada a questões tecnológicas (abreviatura geral: CTOs - Chief Technology Officers ou Diretor de Tecnologia).
Este artigo apresenta uma análise dos dados coletados de vários executivos através de um ambiente de negócios internacional, um estudo de suas principais atividades funcionais, áreas de responsabilidade e de como os principais interessados influenciam seu "poder gerencial" dentro e fora das empresas-mãe. Os resultados empíricos do estudo foram obtidos do projeto de cluster internacional "Uso inteligente de biomassa ao longo do Danúbio: formação de rede de R & D com parceiros alemães, húngaros, eslovacos e romenos".
Os primeiros resultados demonstram uma forte correlação entre a prioridade funcional do gerente de tecnologia e as especificidades de vários setores de negócios e tecnologias aplicadas lá.

Palavras-chave: Diretor de tecnologia (CTO), "CTO escondido", stakeholders externos e internos, fontes de influência organizacional, inovações abertas

(Невидимые) Технические директора: определение скрытой роли в организации

Аннотация: наше исследование посвящено «Невидимым техническим директорам» (руководителям, которые выполняют управленческие функции в области технологий, не имея соответствующего указания в официальном названии должности, в сравнении с теми руководителями, должность которых имеет подобное наименование; стандартное сокращение chief technology officer (CTO) – технический директор).
В настоящем исследовании произведен анализ данных, собранных в ходе опроса
(Continued on next page)

(Continued from previous page)
нескольких руководителей, работающих в международном бизнесе, а именно проведено изучение их ключевых функциональных задач, зон ответственности и того, какое влияние партнеры оказывают на принятие ими решений внутри и за пределами родительских компаний/организаций. Эмпирические результаты исследования были получены от организаторов международного кластера «Рациональное использование биомассы Дуная: формирование исследовательской сети между немецкими, венгерскими, словацкими и румынскими партнерами». Первичные результаты демонстрируют устойчивую зависимость между профессиональными задачами менеджеров по технологиям, спецификой различных секторов экономики и технологиями, применяемыми в этой сфере.

Ключевые слова: Технический директор, chief technology officer, «Невидимый» технический директор, внешние и внутренние партнеры, источники влияния в организации, открытые инновации

Resumen

Nuestra investigación se centra en el "CTO Oculto," un ejecutivo que hace las veces de director de tecnología sin ostentar ese título oficialmente (CTO es director de tecnología, del inglés Chief Technology Officer).
Este documento presenta un análisis de datos recopilados de varios ejecutivos, incluyendo sus actividades funcionales centrales, áreas de responsabilidad, y cómo su "poder gerencial" dentro y fuera de su organizaciones es determinado en parte por terceros. Este artículo es parte de un proyecto de investigación colaborativa íntitulado "Uso inteligente de la biomasa a lo largo del Danubio: formación de redes de I+D con socios alemanes, húngaros, eslovacos, y rumanos".
Nuestros resultados muestran como las prioridades de los CTO Ocultos no son homogéneas, sino que corresponden a las necesidades específicas de los respectivos negocios y sectores tecnológicos.

Palabras clave: Director de tecnología (CTO), "CTO oculto", partes interesadas externas e internas, fuentes de influencia organizacional, innovaciones abiertas

Multilingual abstract

Please see Additional file 1 for translation of the abstract into Arabic.

Introduction

Contemporary, efficient, and balanced technology management implementation stands in need of a new perception of technologies. It means that they should be recognized not as a static but rather as a dynamic phenomenon. In other words, the value of technologies should be perceived through the fact that they are an instrument that opens new opportunities and prospects for further development and improvement. Generally speaking, technologies help not only to achieve some static results such as received knowledge, desired parameters, and an approved scheme of action but also to initiate important changes in management and social life.

Perhaps the most obvious example of such an impact is an increasing influence of information technologies in general and digitalization in particular. Broadly speaking, the present living conditions of individuals, business units, and society as a whole depend

on technological dynamics more than ever before. Consequently, nowadays, it is not enough to just productively manage the already proven tried and tested and reliable technologies, it is also necessary to continuously develop and adjust them to the internal organizational requirements and external macroeconomic indicators.

In the context of a heavy dependence on the "technology factor," new forms of proactive management, i.e., some "dynamic shaping of technologies" and continuous directing, become crucial. Needless to say that the abovementioned "dynamic perception" of technologies naturally implies the need for organizational agility as well as the ability to take into account a variety of prospects rather than asserting and promoting one's own—dominant within the company/organization—point of view. It means that modern technology executives cannot perform their professional activities based only on the "internal" professional relation. The proactive approach forces them to forecast and think out of the box, i.e., search for potential partners, experts, and cooperation. Moreover, due to the increasing interactive impact on the direct processes of production and management that is exerted by clients, end users are no longer perceived as passive objects, but rather as the subjects of management who actively participate in managerial processes.

In other words, modern technology executives, if they want to be truly efficient under high informational pressure conditions, are encouraged to develop and strengthen long-term relationships with the entire spectrum of both internal and external stakeholders. Individual experts, social communities, competitors, partners, non-profit organizations, intermediaries, and suppliers who are able to influence the management process directly or indirectly should be taken into account. Such organizational flexibility can help executives to balance between the internal organizational capabilities and external requirements/conditions of the socio-economic environment. In practice, this opens a possibility to timely realize recruitment strategies and/or retrain personnel, adapt and/or reorganize business processes, attract and/or reallocate resources and facilities, etc.

Standardized tasks and solutions are gradually becoming a thing of the past. The production and management cycles become shorter and customizable. All these lead to the fact that under the influence of rapidly developing technologies, synergies between technological and managerial expertise are required. As a result, the competitiveness of modern business to a greater extent depends on some employees' technical competences, those who are responsible for the choice, practical introduction, and effective management of appropriate technologies and people (Tidd 2005, etc.). Many companies have addressed this need through the appointment of the "Chief Technology Officer (CTO) position" (Smith 2002, p.2), which is becoming increasingly important in the organizational structure of many present-day companies and organizations. According to Smith, "a chief technology officer (CTO) is a high-level corporate officer who is in charge of all technology needs, including information technology of the organization" (Smith 2003, p. 9).

It is important to note that in the relevant literature, the "CTO" position is conceptualized as some kind of collective notion that unites various official posts and professional functionality of technology executives in the general sense of this word. This conceptualization can be explained by the fact that nowadays nearly every company and organization depends on the mentioned "dynamics of technologies." It can be

manifested on different levels, for instance, in terms of a separate industry, market, or even regarding global competition. On the other hand, various technologies and types of business imply special nuances and characteristics of the management activity. Thus, the term CTO should always be elaborated and characterized through the prism of the specific technological and economic conditions of each particular business case. Otherwise, a direct generalization of the notion leads to the blurring of the meaning and confusion in the use of the term. As a result of this, in the real business practice, some executives in the technology management field partially or fully perform the CTO functions, even if they do not have this official position. In such cases, technologies are managed by the so-called "Hidden CTOs". This phenomenon is especially evident in small and medium-sized enterprises (SMEs).

Paradoxically, in spite of the fact that numerous scientific conferences, books, and magazines are devoted to the issue of technologies and their efficient management, the vast majority of managers, even if they directly perform the CTO functions, do not always recognize it. Having other official posts, many of such technology executives have to combine the CTO's activities with other responsibilities. This, in its turn, leads to the fact that these Hidden CTOs are often perceived more as managers in a general sense. As a result of this, the technical specifications of their functionality might remain unclear. This situation quite often leads to the reduction of their managerial capacity and improper prioritization. To avoid this, the managers who are strongly influenced by technological factors should have a clear understanding of the implemented managerial and technical roles (Earl and Feeny 2000; Roberts 2001; Carrow et al. 2005, etc.).

This paper is based on the analysis of the technology managers' activity within the framework of the international project "Intelligent use of biomass along the Danube." The partnership was initiated in the form of an "open innovation" project with the aim of creating new products, services, and more effective ways of using/managing biomass technologies. Industrial and academic partners from Germany, Hungary, Romania, and Slovakia were involved in the cluster. It is notable that the managers in question did not carry the official CTO title. At the same time, all of them performed the functions of this position to a high degree. Due to the different size and specifics of the organizations/companies involved, the Hidden CTOs had various managerial focuses and priority of functions/responsibilities. As a result, they were influenced by various sets of stakeholders.

The main goal of the research paper is to investigate the functional activity of the technology executives (Hidden CTO) through (1) an analysis of their interaction with the key internal and external stakeholders, (2) the identification of the main sources of their managerial influence within the parent organizations, and (3) the research of their personal and organizational motivation in terms of international research cooperation initiation.

Literature review

Despite the fact that technologies were recognized as an important factor of competitiveness quite a while ago, the CTO position is relatively new. It emerged in the 1980s of the twentieth century in the process of a gradual functional distinction from the R&D laboratory director post (Smith 2002; Parker 2002; Dehmar

2003, etc.). According to Smith, the first CTOs were created in heavy production, namely in large companies such as General Electric, Allied-Signal, and ALCOA and then gradually spread to various industries and business sectors (Smith 2002). So, by the 1990s, the position was appointed in the computer industry, service-provider companies (e.g., Internet) and government organizations. By 2000, the geography of business sectors and industries that adopted this position was significantly expanded by "companies seeking to leverage technology within products and services" (Smith 2002, p.3). In his research, Smith mentioned around 392,000 hits of the Google search for corporate announcements of a new CTO appointment.

These announcements cover various industries, e.g., IT, computers, and research organizations like SAS, Intel, and Fraunhofer Institute; Heavy production companies like Siemens, ALCOA, and Chevron Texaco; Service providers like Federal Express, National Association of Convenience Stores, and Hewitt Associates; Government agencies like the CIA, Air Force Research Laboratory, and the City of Washington D.C. (Smith 2003).

Presently, the CTO position may be found not only in large corporations, companies, and organizations but also in medium-sized and even small-scale businesses, especially when this position is combined with another. Nowadays, thousands of "CTOs operate in companies of different sizes and in various industries around the world to perform a variety of technology management related tasks" (Herstatt 2006).

It seems only logical that such a wide spread of the CTO position would be widely reflected in economic and business literature. However, the situation is directly the opposite. Most researchers note an insufficient number of works on the CTO issue (Smith 2003; Herstatt et al. 2006; Medcof 2007, etc.). The present study fully confirms this statement. Moreover, there exist a number of open and hidden contradictions between various concepts and approaches to the CTO characteristics and functions. According to the German Common Library Network (GBV), EBSCO (Academic source premier and business source premier), and Proquest database, the first articles on the CTO issue go back to the beginning of the 1990s (Herstatt et al. 2006). The symbolic foundation stone was laid down by Adler and Ferdows in their empirical research of 100 most successful industrial companies in the USA in 1985. The authors identified 25 CTOs who considered themselves as the most senior and technically responsible employees within their own organization/company. The article was only seven pages long and was dedicated to the core responsibilities, origin, and organizational authority of the CTO position (Adler and Ferdows 1990).

By now, the scope of the CTO concept, the set of their functions and organizational role remain a burning and contentious issue. Summarizing the various aspects of the state-of-the-art analysis regarding the CTO position, the following key features can be recognized: importance of the technology factor for the CTO position appointment, the relative novelty of the position, openness to interpretation in terms of the performed responsibilities, underestimation of the position in the business practice, the regional specificities of the CTO's functionality, the generalization of the technology executives' functionality under the CTO abbreviation, and micro and macroeconomic dynamics of the CTO position functional focus.

Importance of the technology factor

There are prerequisites for the CTO position appointment that are directly related to the importance of the technology factor in the business processes. The most essential are (1) the technological intensity of an industry (Uttal et al. 1992), (2) the importance of technology for a company/organization functioning and/or development (Pala 2006; Thurlings et al. 1996), (3) the importance of technology from the chairman's/Board of Directors/Shareholders' perception (For instance, the desire to switch from the classical to green energy technologies otherwise to implement complete transformation of corporate culture by means of new technology solutions involvement into internal corporate processes, etc. (Bridenbaugh 1992; Medcof 2006, etc.)), and (4) the importance of technology to corporate strategy (Uttal et al. 1992; Smith 2002; Scott 2001).

These prerequisites, either separately or in combination, can contribute to the appointment of the CTO position in the company/organization, depending on each particular business situation.

The novelty of the position

The CTO position is relatively new. Many authors mention that the actual period of the position existence is very short for a clear functional position boundaries definition (e.g., Smith 2002). Thus, modern CTOs often combine their directly related to technology management responsibilities with various tasks from other organizational functions. Such a state of things brings about a situation when many senior executives express confusion about the CTO's exact role.

Openness to interpretation

In the connection with previous points, the research literature indicates that the CTO position is open to interpretation and requires more attention (Herstatt et al. 2006; Medcof 2007; Smith 2011). "The role of the Chief Technology Officer (CTO) is one of the least defined and understood corporate executive roles. Despite it, this role has been gaining prominence in many organizations, as witnessed with the newly created position of Chief Technology Officer of the United States" (Long 2007).

Underestimation of the position in the business practice

Uttal et al. 1992argue that many CTOs believe that both they, and technologies, in general, are undervalued by their organizations and that they do not possess enough influence in their organizations. In the present author's opinion, this characteristic logically follows from previous one. Moreover, "even though the role of the CTO is becoming ever more important, it is still not established in many corporations" (Bohlin 1994). As a rule, in this case, executives who are related to technology issues perform the CTO function without having this official status.

The presence of regional specificities of the CTO's functionality

The CTO position has regional specifics. This was verified and ascertained by Roberts in his large empirical survey implemented in 2001: over 90% of Japanese companies involved the CTO position into the structure of top management team, while in Europe, this applied to 35% and in the USA only to 8%. However, empirical studies that

were conducted in Japan in 2007 did not confirm this proposition. According to Herstatt, who analyzed data from about 100 large electrical engineering companies in Japan, less than 20% of the large Japanese Electrical Engineering Companies had an official CTO position (Herstatt et al. 2006). Among Japan machinery and electrical companies, Nagahira identified even smaller proportions: this figure varies in the area 10% (Nagahira et al. 2007). At the same time, Roberts' statement concerning a possible geographical differentiation between CTOs hierarchical specifics was fully confirmed. In Japanese largest corporations, the CTO position is associated with the highest corporate level; at the same time, around 60% of the European and US companies which appointed this position report that within their organizational structure, the CTO is at a lower hierarchical level. Some researchers link this situation with the trend towards outsourcing, which has caused a significant reduction in the size and function of European and American R&D laboratories (Gwynne 1996; Cannon 2005). As a result of such "decentralization," the CTO's functional specifics in geographical areas discussed vary significantly: in Japan, CTOs have a stronger focus on technology and strategic development, in Europe and USA—on management and operational conditions of technologies use.

The generalization of the technology executives' functionality under the CTO abbreviation

CTO is a generic term, an abbreviation that implies different actual official positions within a company/organization. Almost all studies directly or indirectly indicate that the CTO notion implies various hidden organizational positions. For instance, Deschamps states that CTOs will naturally be found in research-intensive industries, such as pharmaceuticals or chemicals under a variety of titles, e.g., Vice president Science and R&D, Scientific Director, Corporate Research Officer, and Research Vice-president (Deschamps 2000). Hoven demonstrates even more variations, connecting such diversity with the peculiarities of business. "Managers with a diverse range of titles, including Technical Director, Technology Director, Chief Scientist, Chief Engineer, Vice President of R&D, and Innovation Director, are collectively or individually responsible for technology management. Given this variety, we use the CTO label to refer to all senior executives responsible for innovation and technology management, regardless of the specific title the role may carry in particular organizations" (Hoven 2012, p.25). According to Smith, the CTO position is occupied by people with diverse backgrounds, as is common in other executive positions like the CEO (Chief Executive Officer), COO (Chief Operating Officer), and CIO (Chief Information Officer). Thus, the CTO position is often confused or interchangeable with them (Smith 2003).

Micro and macroeconomic dynamics of the CTO position functional focus

CTOs' functions and responsibilities were historically transformed due to macroeconomic conditions. Most clearly, this can be traced in the topic of R&D generations, which demonstrates a change in the functional focus of research laboratories in general and their managers in particular due to technological changes at the level of industries and global markets (Roussel et al. 1991; Erickson 1993; Rothwell 1994; Nobelius 2004). It should also be noted that the functional dynamics of the CTO position may be

characterized through on the microeconomic level. Although these changes are more difficult to identify since they are not determined by clearly observed historical trends but by the peculiarities of each individual business case (Smith 2002; Hart 2008; Hoven 2012).

Due to the characteristics mentioned above, a conclusion can be drawn that the CTO position has a nature that complicates its analysis. For instance, "if compare it to CEO (Chief Executive Officer) post, the nature and functional specifics of the CTO position has a rather low public profile. These executives have few opportunities to take a public stand, and/or answer questions from external journalists or industry analysts. Moreover, many of the things on which they work tend to be obscure for the non-specialists and in any case subject to corporate secrecy rules" (Deschamps 2000).

Summarizing the main conclusions from literature review regarding the CTO position, it can be postulated that on the one hand, this position can be characterized as an actively spreading function in the contemporary business. On the other hand, as an as ambiguous, versatile notion that requires a more detailed and comprehensive analysis.

Moreover, despite a number of comprehensive publications, the total number of studies on the CTO issue remains relatively low. As a result, many important aspects of the CTO's nature remain unexplored. This article is aimed at revealing and analyzing some of the most significant points of the CTO position while paying special attention to the functional specifics of the technology executives in SMEs. This topic should be thoroughly explored since modern technology management in small and medium-sized enterprises in most cases implies functional combinations of the direct CTO functions with other organizational responsibilities and activities. As a result of such mixed set of functionality, modern technology managers can perform the CTO functions even without recognizing it. As the empirical part of the present research will prove, this situation quite often leads to a decrease in managerial efficiency, an incomplete use of managerial potential or incorrect prioritization.

A new approach for the CTO position roles and function investigation

The mentioned previously characteristics of the CTO position led to the ambiguity of its perception. In the most distinct form, the controversy surrounding the CTO organizational position boils down to its role in the strategic decision-making process. Some researchers advocate the priority of the strategic level, yet others deny its domination. A striking example of supporting Scott's ideas can be found in the research conducted by Roger D. Smith, where the "strategic focus" is considered as the CTO's core activity (Smith 2002). However, this position is not shared by all the specialists in the area. Critically assessing the points expressed by Scott and Smith, some researchers indicate a number of examples from the real industrial practice, where the CTO's strategic activities do not play a primary role, and the CTO's responsibility focuses more on a number of important operational factors. The identified factors are, for example; (1) the actual company performance (Roberts 2001; Hartley 2011); (2) the operational management of the key stakeholders, including CEO (Wolff 1991; O'Neill 1992; Bridenbaugh 1992a, b; Robb 1994); (3) the maintenance of the CTO's influence to strengthen managerial leverages (Finkelstein and Hambrick 1996; Roberto 2003; Medcof 2008). A stipulation must be made at this point: the abovementioned researchers do not completely deny the importance of the strategic component. They note that the CTOs' operational functioning is a platform for engaging them into the

strategic decision-making group. For instance, Roberto stresses the fact that even senior managers spend only about 20% of their time on the strategic activity, the other 80% is used for standard operational tasks (see Table 1).

In our view, both positions shed a certain light on the notion in question. This contradiction only proves the complexity and variability of the CTO's practical functioning. In practice, an individual CTO performs a unique set of activities and possesses responsibilities which are determined by the internal and external peculiarities of the company/enterprise functioning. Certainly, a manager can operate in the context of the strategic level priority, giving it more value than the tactical one and vice versa.

It is important to note that the peculiarities of the CTO's practical functioning, i.e., the system of priorities, areas of responsibility, and levels of organizational influence, are largely determined by the nature of his or her business connections with the key stakeholders which were scrutinized by Roger D. Smith (2002). The author identified CTO's core business relationships which can be considered as the "empower" of the CTO's organizational role and the source of his or her personal influence. According to Smith, the CTO is "operating as an effective member of the executive team." This requires that the "CTOs nurture relationships with a number of people and groups within and out own company." The author describes in detail the basic principles of the CTO's interaction with the following functional positions and business units: Chief Executive Officer and Executive Committees, Chief Information Officer, Chief Scientists, Research and Development Laboratories, Sales and Marketing.

However, in spite of the obvious advantages of the study, Smith does not draw a clear line between the internal and external stakeholders in an explicit way. As a result of this, the analysis of the "side stakeholders" in his study has a superficial character. Moreover, some stakeholders in each particular business situation may belong to the organization or be an independent unit, e.g., R&D may be a part of the organization or be represented by an external partner organization. The pattern can also be of the mixed nature, e.g., the board of directors controlled by shareholders. Based on Smith's findings, and in order to overcome the mentioned disadvantages of his reasoning, a stakeholders' model was developed by Lohmüller and Petrikhin (Fig. 1).

It should be noted that the model in question is a logical generalization which aims to demonstrate the complexity and multi-dimensional level of relationships

Table 1 Ranking percentage of meeting time spent on various activities by top management teams

Type of Activity	Percentage of Meeting Time Spent on Activity
Monitoring/ evaluating of financial/ operating performance	23.2
Updates/reviews of major projects and Initiatives	22.2
Planning/ formulation of business unit strategy	20.1
Review/ discussion of important human resource issues	14.6
Evaluation/ discussion of administrative policies/ procedures	6.6
Other activities	5.8
Review/ discussion of organization structure/ reporting relationships	4.2
Review/ approval of major capital appropriation requests	3.5

Source: Roberto 2003, p.124

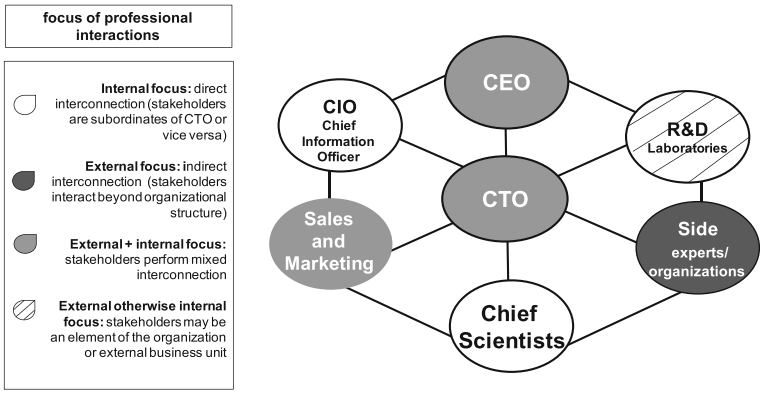

Fig. 1 "CTO's key stakeholders' model." The figure was developed at the Steinbeis Global Institute Tübingen by Lohmüller and Petrikhin in 2016. The model is a result of the analysis of Smith's 2002 research, where the author identifies the CTO's core business relationships which can be considered as the rationale behind the CTO's organizational role and the source of his or her personal influence. However, in the study in question, Smith does not concentrate on the division of internal and external stakeholders (the division itself is implicit). The "CTO's key stakeholders' model" is based on the categorization of the key stakeholders from the viewpoint of their belonging to the organizational structure and according to the main focus of communicative interaction. For instance, the sales and marketing department is described here as an external-internal stakeholder. This is directly related to the fact that this department is obviously an organization element, and its communicational channels are directed more to the end consumers who are interested in the results of technology applications rather than their functionality within a company/organization. It should be mentioned that this model is a logical generalization which aims at demonstrating the complexity and multi-dimensional character of relationships between a CTO and the core stakeholders. Besides that, each unique business case should be considered in the context of its internal and external characteristics, such as market conditions, low restrictions, the number of employees, technologies applied, and sources. Based on such unique quantitative and qualitative characteristics, a combination of the key stakeholders can vary significantly

between the CTO position and its core stakeholders. Besides that, each unique business case should be considered in the context of its internal and external characteristics, such as market conditions, low restrictions, number of employees, technologies applied, and sources. Based on such unique quantitative and qualitative characteristics, a combination of the key stakeholders can significantly vary. In real practice, relationships between the "key players" of the decision-making process are often intricate and complicated by multi-functionality and overlapping areas of responsibility. In this view, the suggested model may be used as an initial tool for the CTO's internal-external communication net identification and its further specification.

The perspective of the CTO's functional activity through the prism of interaction with the key stakeholders demonstrates that productive CTOs should have time to perform the tripartite task simultaneously: establish, maintain, and constantly develop the "in and outdoor communication" in the context of different dimensions and levels of technologies use. In other words, "successful" CTOs should combine personal functional expertise with corporate process management skills. They need to have a deep understanding of technology and sound business judgment so that they can add substance to problem-solving and develop solutions that work.

This situation is directly linked to the fact that the modern decision-making processes are characterized by the unprecedented level of ambiguity and complexity. This means that modern CTOs should perform their functions under the conditions when it is impossible to have absolutely all the necessary data, facts, factors, scenarios, etc. for the "right"

decision. That is why CTOs should be able to set a priority system, use relevant assessment criteria, and build a strong business and professional "in and outdoor" relationships (Petrikhin 2017).

Even successful and experienced managers in real practice may encounter non-standard situations and conditions when knowledge and skills obtained in the established logic of technologies use do not work. This situation quite often leads to the need for transformation of familiar management principles, tools, methodologies, and styles. In this context, the CTO position implies the ability to explain the requirements and conditions of technology use to the internal and external stakeholders, direct performers, and supporters of managerial processes, sometimes even clients. Or, in other words, one of the most significant functions of the modern CTOs is to connect the "technology perspective" with, on the one hand, a general strategy and functional conditions of a company/organization and, on the other hand, with the socio-economic situation in the context of macroeconomic parameters.

Like a separate player in a football team, a CTO should be able to operate efficiently with others and thus be a productive element of the system. It means not only to influence but also to be influenced. Or, in other words, the CTO's organizational success is directly linked to his or her ability to manage and to be manageable. It is extremely important to assess the situation as a whole and be able to take or give away the initiative when it is most appropriate. A CTO should not only be a team-player who has the ability to understand the actions, motives, and perspectives of the core stakeholders but also a good individual player who is able to take responsibility and bring his or her own vision into the team. This ability to influence always has its logical foundation. And the technological competence is only one possible source of it. As a rule, all leaders have a set of qualities and skills that affect people around them. The most obvious of such factors are charisma, talent, oratory, publicity, and social connections. Of course, each leader has his or her own combination of such "unique personal and social characteristics." If viewed outside the pure economic context, the organizational characteristics may be considered as some social skills and abilities, i.e., public recognition, social bonds, and credibility. In the most general sense, we deal here with the ability to communicate and influence via social or organizational relations.

In 1992, Finkelstein attempted to classify the main sources of CTOs' influence. He argues that "power and influence play an important role in upper echelons strategic leadership and so understanding the sources of power of top team members is critical to understanding the strategic decision-making processes there." He identified four power bases typical of CTOs: structural, expertise, ownership, and prestige.

According to the author, the combination of the four forces has a direct influence on the style and methods of CTOs' managerial activities. In other words, each CTO has a unique set of skills and sources of organizational influence that directly reflects his level of responsibilities, authority, and hierarchical position.

Despite the fact that Finkelstein's study provided a detailed and conceptual description of each power category and was confirmed by empirical methods which demonstrated its reliability and validity, the actual practice shows that it is very important to indicate interconnections among the "power" categories in the context of the dynamic CTO's activity. A matrix structure can do it more self-explanatory and precisely. Drawing on Finkelstein's ideas, the following classification of CTO's

sources of influence was designed by Petrikhin & Lohmüller (Fig. 2). This is a matrix model that reflects the internal and external, personal and individual aspects of CTO's power.

It is important to note that unlike with Finkelstein, the "ownership power" is considered here not as a separate category of managerial influence, but as an additional factor that may directly or indirectly influence the mentioned aspects of the CTO's position organizational potential. Obviously, that the mentioned in the matrix structure four classes of managerial power can be an attribute of the manager, regardless of whether he is simultaneously the owner of the enterprise or not, or if he combines or does not have the CTO position functions.

Let us now have a closer look at the most significant components of each category: (1) CTO's social influence on behalf of own organization via interaction with core stakeholders at external (outdoor/socio-economic environment) level: the position, role, and place of an organization in the socio-cultural environment; intensity and social importance of the business area/industry; role in dialog with partners; role in dialog with marketing; role of implemented products/services/technologies in the socio-cultural environment. (2) CTO's social influence on core stakeholders via personal social connections and abilities at external (outdoor/socio-economic environment) level: communication skills, social status, professional/scientific relationships, prestige, personal relationships, and membership in boards and communities. (3) CTO's organizational influence on core stakeholders via occupied position and formal managerial mechanisms at internal (in-house) level: the formal ability to transform business processes within the company, the formal ability to select required people/involve people from different departments, the formal ability to build internal networks, the level of influence on the general organization/company strategy, the level of influence on the financial policy, the ability to choose and apply target technologies, and methodology of getting and selecting information. (4) CTO's organizational influence on core stakeholders via personal (technical, managerial, individual) skills and characteristics at internal (in-house) level: technological competences; managerial competencies; leadership,

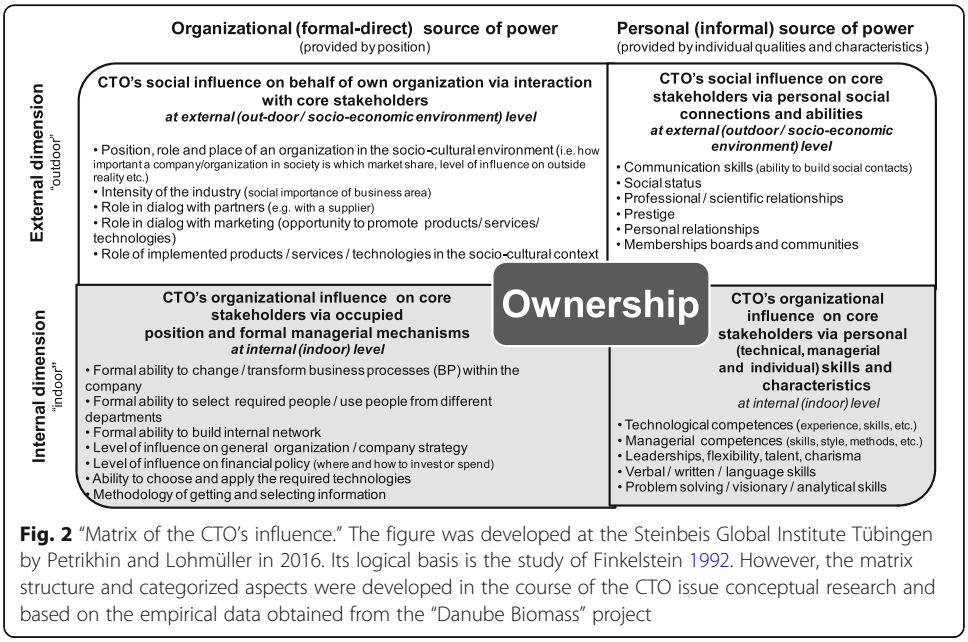

Fig. 2 "Matrix of the CTO's influence." The figure was developed at the Steinbeis Global Institute Tübingen by Petrikhin and Lohmüller in 2016. Its logical basis is the study of Finkelstein 1992. However, the matrix structure and categorized aspects were developed in the course of the CTO issue conceptual research and based on the empirical data obtained from the "Danube Biomass" project

flexibility, talent, charisma, verbal/written language skills, and problem-solving/visionary/analytical skills.

Furthermore, the ownership factor—a partial or complete combination of the CTO and CEO positions and reliable long-term professional relations between them—is able to enhance his or her impact at both external and internal levels of interaction, as well as directly or indirectly affect some personal characteristics, e.g., management style changing, new social/organizational status, and publicity increase. The factor of ownership is able to penetrate all the matrix levels and strengthen the impact of each mentioned power. But such a position combination can bring not only positive effects. "The CTO must earn the trust and confidence of the CEO. With other stakeholders, the CTO may have earned the respect and confidence of peers and superiors through technical prowess and performance. But, in terms of relations CEO-CTO, it requires business prowess and financial performance" (Larson 2001). In the case, when a CEO simultaneously holds also the CTO position, his or her organizational power strives to its logical maximum. In the real practice, it quite often leads to the decision-making flexibility loss and strengthening of the authoritarian management style.

Needless to say that a unique combination of CTOs' managerial forces directly depends on a set of the key stakeholders as well as the architecture of "key player" interconnections. The "CTO matrix" cannot provide universal solutions, i.e., for each CTO, the matrix would have a different content configuration. Due to the practical relevance of the CTO position, it is essential to further research its complex nature and a variety of functional roles, sources of managerial power, and areas of responsibility via interactions with the key stakeholders.

Methods/experimental

The empirical part of this research is based on the international project "Intelligent use of biomass along the Danube: R&D network formation with German, Hungarian, Slovak and Romanian partners." This technological and economic project-cooperation is aimed at developing a research cluster with a focus on biomass use in the Danube region. In general, the main conclusions of this article rely on an analysis of the CTOs involved in the R&D project, i.e., the range of their functions, areas of responsibility, professional interconnections, success factors, organizational potentials, and limitations. It is important to note that all technology and innovation managers involved into the international project "Danube Biomass" perform the functions of the CTO, even if they do not hold this official position. Consequently, in the context of the present study, these managers are named Hidden CTOs. This term was introduced by us, taking into account the state-of-the-art analysis. As was mentioned before, almost all empirical and conceptual research on CTO issue automatically imply under this post a set of various managerial positions that are united by a close relationship with the technological aspects of management.

In the process of project implementation in each partner organization, one person was identified as a Hidden CTO. For their identification, the following criteria were applied: (1) active participation and a high level of influence in his or her own organization/company decision-making team, (2) functions and responsibilities related to technology application or/and development, (3) synergy of managerial and technical professional competences, (4) active interaction with internal and external stakeholders

in the context of biomass technologies use or/and development, and (5) experience in international R&D projects.

Within their organizations, these managers have the following official positions: managing director, general manager, director of a research center, scientific director, head of R&D department, head of a faculty, vice dean, and head of a research laboratory.

The outlined criteria of Hidden CTOs were discussed in the structured workshops in order to answer to following questions: (1) How are the official positions held by the identified managers defined in the project companies/organizations? (2) What areas of responsibility do these persons have? (3) What sets of core functions with regard to technology management are implemented by them?

It should be noted that in spite of an absence of the official CTO position, all mentioned managers performed the CTO's functions in the range from 30 to 83%. For their functional activity analysis, the classification of the CTO's responsibilities developed by Adler and Ferdows 1990 was used.

The respondents stated that their core functionality is in line with the CTO's responsibilities provided in Table 2. The percentage of "functional involvement" was calculated on the basis of the data obtained by means of a combination of closed and open questions. The study showed that the Hidden CTOs from the "Danube Biomass" project have a higher level of "functional involvement" in the areas of responsibilities discussed than the official CTOs. This fact is directly related to the proportional imbalance between the project members' operational and strategic responsibilities in terms of technology application and development, i.e., representatives of industrial partners showed the greatest degree of adherence to operational functionality, representatives of academic partners—to the strategic.

It should be noted that at the organizational level in spite of the fact that all the project participants are closely associated with "biomass technologies," the meaning of this term has peculiarities of interpretation in each company/organization. The meanings range from "technologies in the area of agro-forestry" to "satellite technologies for volume and energy potential biomass assessment." The CTOs' functional features and areas of responsibility also vary considerably. In terms of the decision-making procedures and the key internal-external stakeholders' influence, all the partner organizations were classified according to their organizational structure status: universities, private research institutes, and companies. Table 3 gives an overview of the partners involved into the project.

Despite the fact that the project participants represent different countries, each category has common, at least to some extent, organizational tendencies, and properties. With regard to the CTOs' organizational and personal sources of managerial influence, potentials, and limitations, the study showed strong interconnections of these aspects with the organizational structures and main requests/motivations to participate in the project.

The Hidden CTOs' motivation, functional roles as well as the key internal-external stakeholders' drivers in the organizations participating in the project were identified in the structured workshops conducted in the target countries. The workshops were designed in the form of a 2-day meeting. The first day was dedicated to sharing information about the participating organizations, the partners' research competencies, business relations, and experience in international project cooperation. On the second

Table 2 The most frequent CTO's responsibilities (Based on Adler, Ferdows, 1990)

Responsibility	Description	Frequency for CTO's: according to Adler & Ferdows research	Frequency for hidden CTO's: according to the 'Biomass' project
Coordination among business units' technological efforts to ensure synergy and economies of scale	Avoiding duplication of effort in different business units und assisting in the transfer of technology from one unit to another. The common theme among these tasks was coordination between the business units and corporate research, across the business units, and across functional areas. This corresponds to what Porter calls "horizontal strategy", in this case horizontal technology strategy.	60%	75%
Representation of technology within the top management team	Being voice of technology in the top management team. The focus of these tasks was within pushing for a long-term view of technology, nutriting in fact technology development projects, and providing expert opinion on technological questions	52%	83%
Supervision of new technology development	Directly supervised technology activities in a company.	28%	70%
Assessment of technological aspects of major strategic initiatives	The assessment of the technological implications of proposed new acquisitions, joint ventures, strategic alliances, and lines of business (also long-term trends in the relevant technologies)	28%	30%
Management of the external technology environment	Dealt directly with organizations and individuals (regular agents) outside the corporation. Funded research and collect signals about important technical development. Second group: ensuring that corporation's product and processes complied with relevant regulations, identifying trends in regulatory constrains, and orchestrating the corporation's effort to influence the regulatory process.	20%	35%

Source: Lohmueller, Petrikhin 2017, IPDMC24, Reykjavik Conference; based on the Danube Biomass project workshops protocols and interviews analysis

day, the practical opportunities and research facilities of the organizations were in focus. This 2-day structure was standard for the meetings in all the project member countries. For each meeting, a detailed report was created with the main partnership activities, agreements, and plans for prospective cooperation. These reports formed the basis for the comparative analysis.

Additionally, the Hidden CTOs of the partner organizations were interviewed. The interviews were designed by drawing on a semi-structured questionnaire. Each interview was based on the interview-questionnaire and conducted by three researchers. One of them carried out the interviewer role, while the others monitored the situation, took notes, and performed ranking. Furthermore, the background information on the organizational characteristics and CTOs' functioning was collected. These data were

used to do an in-depth analysis. All the information from the workshops, interviews, and open sources was structured to identify the key drivers of CTO activities and their personal and organizational motivation for participating in international R&D networks. In order to do this, the researchers made written comments, and after the workshops, the results were analyzed together in a structured way during internal meetings. The cross-organizational analysis is based on the framework by Yin (1994).

In order to analyze the obtained data from questionnaire research and performed interviews in the target countries, the practical instruments for the CTOs' activity such as "the CTO's key stakeholders' model" and "the matrix of CTO's influence" were used.

Results and discussion

The empirical study was mostly focused on the technology management processes at the personal level, i.e., managerial characteristics of each particular Hidden CTO project-participant and organizational level, i.e., managerial particularities of each separate company/organization project-participant. In general, the study showed that the personal managerial manner of the technology executives in many ways is determined not only by the individual qualities of the managers as personal social connection, abilities, skills, and characteristics but also by the specifics of the organization as formal managerial mechanisms, specifics of applied technologies, place of an organization/company in the socio-cultural environment, etc.

The data regarding personal specifics of technology executives' functionality in terms of cooperation with internal and external stakeholders obtained from interviews and workshops were systemized with the help of the "CTO's key stakeholders' model" (Fig. 1). The results are shown in Table 4 below. On the scale from one to five, the influence of stakeholders was raked. "Five" indicates the highest influence on projects CTOs' professional functionality and "one" indicates the lowest level of stakeholders/business units' impact.

With regard to the key sources of the CTOs' influence in the decision-making process and their hidden motivations and managerial limitations, a set of the key drivers was identified. The most relevant of them are listed in Table 5 below. The data were structured according to the four dimensions of the "Matrix of CTO's influence" (Fig. 2) and additionally ranked. On the scale from one to five, five indicates the highest influence on Hidden CTOs' functionality and one indicates that the significance of the corresponding factor is low.

The results of the empirical research confirm that there is a strong correlation between the Hidden CTOs' characteristics of professional relations as well as the managerial functioning and personal/organizational motivation to participate in the R&D projects, on the one hand, and the organizational specifics, on the other. All the categories of the organizations demonstrated overall common trends and properties of the technology management functional specifics. The radar given in Fig. 3 shows the organizational and CTOs' perspective for the three types of organizations investigated in the research: research institutes, universities, and companies. In the organization perspective, the dependence on stakeholders, the level of participation in research projects, and the technological focus are given. In the CTOs' perspective, the CTOs' position of CTO, the motivation for project participation, and the influence of the organization on CTO decisions are described.

Table 3 Specifics of project organizations/companies and CTOs functionality

Specifics	Germany	Hungary	Romania	Slovakia
№ and organizational specifics of project participants	1 University 3 Companies 2 Research institutes	1 University	1 University 1 Company 1 Research institute	1 University 1 Research institute
№ and background of direct project participants	2 Administration 5 Business 3 Top managers 3 Professors 4 Researchers	1 Administration 4 Professors 2 Researchers	2 Administration 4 Business 1 Top manager 3 Professors 4 Researchers	1Administration 4 Professors 2 Researchers
Specific of biomass technology use	Ecosystem service/ Biogas technologies/ small-scaled harvesting technologies / water treatment & bioenergy	Biomass from agro forestry	Biomass from forestry and invasive alien plant / biomass from agriculture and crops	Biotechnology and food sciences/ agro biology/ biomass production from fast-growing trees, agriculture and crops/ biogas technologies
Main organizational requests/ motivation of project participation	Technologies practical approbation and further development/ technologies transfer/ competences and long-term connections development via cluster activities	Participation in biomass cluster/ long-term research and development connections/ energy-mix technologies/ Erosion protection and soil treatment	Long-term research and development connections/ Harvesting technologies/energy-mix technologies/ water retention technologies in terms of biomass cultures	Energy-mix technologies/ drought resistance technologies/ long-term research and development connections
Official positions combined with CTO's functions	Managerial directors, heads of department, head of R&D department	Vice dean	Director of research center, scientific director, general manager	Head of faculty, head of research laboratory

Source: Lohmueller, Petrikhin 2017, IPDMC24, Reykjavik Conference; based on the Danube Biomass project workshops protocols and interviews analysis

All the universities taking part in the project demonstrate the following features (a general trend with varying degrees): high dependence on external stakeholders such as foundations and ministries, a medium-low initiative of R&D project participation, orientation towards long-term cooperation, and strategic technology development and knowledge exchange. The project team members defined at the universities as the Hidden CTOs also exhibit similar characteristics: a high negative influence of the lack of the official CTO position, they perform lots of non-technological functions, and as a rule, the overlapping of their areas of responsibility has a negative impact on the technology

Table 4 Ranking the level of significance of the project CTO's key stakeholders

Stakeholder	Stakeholder's importance: from 0 = low to 5 = high (own estimation)									
	Germany			Hungary	Romania			Slovakia		Total
	Res. Instit.	Univ.	Com.	Univ.	Res. Instit.	Univ.	Com.	Univ.	Res. Instit.	
Head of Org. (CEO)	5	5	5	4	4	4	5	4	4	**40**
Head of Information (CIO)	4	3	4	3	4	3	4	3	4	**32**
Sales & Marketing	5	2	5	2	4	2	5	2	4	**31**
Chief Scientist (CSO)	4	3	4	2	4	2	5	2	4	**30**
External Stakeholder	2	4	3	2	4	2	4	3	4	**28**
R&D Department	5	4	3	4	5	4	3	4	5	**37**

Source: A survey conducted in the study. Lohmüller, Petrikhin and Wagemann, 2016

Table 5 Specifics of the CTOs' managerial influence

Dimension	Key drivers	Universities	Companies	Research ins.
External-Organisational	Involvement in joint development and testing of technologies with different kind of partners and sponsors	5	3	4
	National, regional and international project experience (already successfully implemented projects and practical results)	5	4	5
	Knowledge of related national and international laws conditions (the Danube region context)	5	4	4
	Request of necessary knowledge, technologies and competences (e.g., related subjects and directions of R&D activities influencing efficiency of internal functioning)	3	5	5
	Industry and R&D partners in the related fields (presence or absence)	4	5	3
	External economic factors: market demand of green energy, green tariff (presence or absence), cost of the direct competitors of the "biomass products" (energy, fuel, food crops, etc.)	2	5	4
	External socio-environmental factors: willingness of the local communities to use biomass products, possibility to provide jobs in the context of biomass production and processing, environmental conditions and laws	3	5	3
Internal-Organisational	Qualification of the team in the field of biomass technologies	3	3	5
	Communication and management style of the organization	5	5	4
	Internal rules of data proceeding	3	4	4
	General strategy for participation in international research (presence or absence and possibility for adaptation)	5	2	3
	Ability to use own personnel in the combined work (basic/project work)	5	4	2
	Ability to attract domestic funding resources	5	2	4
	Presence of general strategy of technology development and its correlation with the general strategy of a company/organization	2	2	3
External-Personal	Prestige and social status of the CTO	4	2	3
	CTO's professional/scientific relations	5	3	4
	Memberships/participation in external communities and organizations	3	2	3
Internal-Personal	CTO's personal technological qualifications (expert qualities)	3	2	4
	CTO's communication skills	3	4	3
	CTO's management qualifications	4	2	3

Source: A survey conducted in the study. Lohmueller, Petrikhin and Wagemann, 2016

development and innovation promotion; their motivation in the project participation from the organizational position may be characterized as medium, from the viewpoint of their personal interest as low; the managerial influence on the strategic decisions in terms of technology use and development was evaluated as medium-low.

All the companies taking part in the project demonstrate the following features (a general trend with varying degrees): low dependence on external stakeholders and high dependence on "mixed" stakeholders, e.g., CEO, Marketing and Sales department; medium-high initiative of R&D projects participation; orientation towards

Fig. 3 "CTO's and organization/companies specifics through organizational categorization." The figure was developed at the Steinbeis Global Institute Tübingen by Lohmüller and Petrikhin in 2017 based on the Danube Biomass project workshop protocol and interview analysis. The figure represents organization in the form of the "radar" information indicating the specifics of the different types of the project 'Hidden CTOs' personal and organizational characteristics

short-term, focused cooperation and operational technology application. The project team members defined at the companies as the Hidden CTOs also exhibit similar characteristics: a low negative influence of the lack of the official CTO position, i.e., they perform lots of non-technological functions, and as a rule, the overlapping of their areas of responsibility has a positive impact on the technology development and innovation promotion due to high numbers of managerial leverages; their motivation in the project participation from the organizational position may be characterized as high, from the view point of their personal interest as medium; the managerial influence on the strategic decisions in terms of technology use and development was evaluated as high.

All the research institutes taking part in the project demonstrate the following features: medium dependence on external stakeholders and high dependence on internal stakeholders, e.g., CIO, CS, R&D laboratories, and centers; the highest initiative of R&D project participation; a relatively balanced orientation towards operational and strategic technology application with a focus on the practical results obtained from the project activity and long-term scientific relation maintenance. The project team members defined at the companies as the Hidden CTOs also exhibit similar characteristics: a medium negative influence of the lack of the official CTO position, i.e., this mostly negative side of the issue was expressed as imbalance of the operational and strategic

priority of their technological responsibilities; their motivation in the project participation from the organizational position may be characterized as high, from the viewpoint of their personal interest as high, too; the managerial influence on the strategic decisions in terms of technology use and development was evaluated as medium.

It is important to note that although the reliability of the obtained dataset is high, the current research results should not be interpreted on the universal scale since the investigated academic and business units may not fully represent the general trend of technology management specifics. The prospects for future research include an investigation of a wider number of organizations and companies, especially those where a CTO is an official position. It should also be taken into account that an analysis of CTOs' sources of organizational and personal managerial power is limited due to regional and time factors. Nevertheless, the chosen methodology of the current study contributed significantly to the reliability and validity of the results. In future research projects, the position of Hidden CTOs needs to be further studied. It is important to get a better understanding of the balance of their activities and areas of responsibility.

The following aspects can be recommended for future investigation:

(1) The Hidden CTO's / CTO's role in promoting innovation. Due to the fact that modern technologies strongly depend on global competition and open cooperation factors, the next phase of our research will focus on the analysis of the CTO position impact on innovations development. The main goal here will be monitoring and assessing in more details not only closed (within an organization) but also open (developed together with partners and clients) innovations; (2) The corporate culture and level of social responsibility of companies and organizations should also be further researched. Hidden CTO/CTO's functional activities are strongly influenced not just by the core stakeholder combination but also by the architecture of their interaction/subordination, which is directly reflected in the main managerial principles and corporate culture characteristics. In this connection, it is essential to analyze the most successful enterprises where the "technology factor" plays a critical role and identify the main similarities of the success factors of CTO's functionality in terms of the maintenance and development of the corporate culture; (3) CTOs' professional activities in terms of open cluster cooperation, analyzing the process of soft management mechanisms arrangement and approval among cluster partners; researching the cross-organizational influence on internal management processes; examination the processes of technology managers' interaction with external for cluster stakeholders and business units, (4) Analysis of changes in the functional specificity and level of managerial power in the context of a cluster/project activity joining.

Conclusions and recommendations

Nowadays the decision-making process that excludes the "technology factor" is fraught with different risks: financial, strategic, tactical, etc. That is why the role of technologies in organizations should not be underestimated since technologies are a significant competitive condition. Consequently, there is an urgent need for an expert opinion on management issues from the technology perspective. In big companies, the role of the

CTOs is getting more important. In medium and small enterprises (SMEs), this position is often combined with other roles.

In order to identify the Hidden CTOs in SMEs, it is necessary to define clear criteria for their profile and responsibilities, even if this position is not officially present in organizations/companies, but the influence of the "technology factor" on the managerial activity is high. The present research bridges this gap by specifying such aspects as (1) participation and a high level of influence in the organization/company decision-making team, (2) the functions and responsibilities related to technology application or/and development, (3) the synergy of managerial and technical professional competences, (4) an active interaction with the internal and external stakeholders as regards technologies use or/and development, (5) experience in international R&D projects.

A clear understanding of the innate features of this position allows managers to prioritize logically and correctly; act in a more balanced way (taking into account the peculiarities of parallel functionality) and build a more pragmatic and purposeful relationship with the core stakeholders, direct performers, and supporters of managerial processes.

It is obvious that the CTOs' roles and levels of their influence vary considerably depending on a number of external and internal factors, such as different features of industry and markets, organizational characteristics of an enterprise, corporate culture, general strategy, and the number of employees. In this connection, the efficient implementation of technology management necessarily implies a need for "managerial tools" that can be customized and adapted to each particular business case.

Moreover, the modern conditions of a highly dynamic socio-economic environment determine unprecedented high standards for the CTO functioning. Nowadays, the requirements of this position involve not only the need for a wide range of technological and managerial competencies but also advanced leadership skills. Productive CTOs can no longer rely only on the routine processes, technological solutions, and knowledge which bring immediate results. A high level of international competition, open markets, and technology circulation encourage CTOs to look into the future and be innovation promoters. This means not only technologies improvement in the narrow sense but also innovative business processes, "clever" financing, original ways of the corporate culture organization, advanced models of communication and information exchange, etc. Thus, the synergy between management and technology represented by the CTO position can secure long-term success for a company/organization and promote it to the top level all over the world.

Taking into account the results, it is possible to outline the following implications for the initiators and participants of international research projects: (1) For the big projects, a balanced combination of universities, research institutes, and companies is required. Each of these organizations brings their own advantages for developing an international research project; (2) For the small and medium-sized projects, the most attractive partners are research institutes. They have the most balanced combination of the strategic and operational levels of technology application, as well as tend to have good contacts with both academic and business partners; (3) The organizational structure of research institutions and functions of the Hidden CTO position there actively encourage participation in international projects.

Implications for managers in the technological field are (1) Even if an organization does not have an official CTO position, a manager can perform a number of the

CTO's functions; (2) The identification of the Hidden CTO's activity helps to better understand a company's priorities and achieve a balance between the strategic and operational levels of technologies implementation. Therefore, the functions of Hidden CTOs need to be clarified and described in a systematic way; (3) A manager should constantly analyze business activity through interactions with the key stakeholders and identify organizational and personal priorities of his or her own functionality. This may significantly improve the level of managerial efficiency and realize hidden managerial potentials.

Overall, our research demonstrates that the modern CTOs' managerial efficiency increasingly depends on leadership skills and building up strong relationships with the core external and internal stakeholders. Although this general trend definitely has peculiar features in various categories of organizations, its influence can be observed in all companies without exception.

Additional file

Additional file 1: Translation of the abstract into Arabic. (PDF 251 kb)

Abbreviations

BP: Business processes; CEO: Chief Executive Officer; CIO: Chief Information Officer; COO: Chief Operating Officer; CTO: Chief Technology Officer; EBSCO: Academic Source Premier and Business Source Premier; GBV: German Common Library Network; Hidden CTO: Hidden Chief Technology Officer; IT: Information Technology; R&D: Research and development; SAS: Statistical Analysis System; SGIT: Steinbeis Global Institute Tübingen; SMEs: Small and medium-sized enterprises

Acknowledgements

The authors of this article would like to acknowledge and express sincere thanks to all participants of the "Danube Biomass" project and especially to Hidden CTOs actively participated in the research activities.

Funding

This study was funded by the German Federal Ministry of Education and Research: Support Code 01DS15011 for the research activities and workshops in the target countries as traveling costs, personnel costs, and workshop costs and the Steinbeis Global Institute Tübingen | Steinbeis University Berlin for the infrastructure for scientific work and funding for writing the article.

Availability of data and materials

The data will be shared only in aggregated and anonymous form, due to the partnership agreement on the personal data non-disclosure (between the "Intelligent use of biomass along the Danube" project participants).

Authors' contributions

BL supervised the development of the work, performed the analysis on all empirical data, developed the conception and design, interpreted the data, made a critical revision of the article and provided a final approval of the version to be published and acted as a corresponding author. AP performed analysis on all empirical and conceptual data, developed conception and design, interpreted data, drafted the article, wrote the manuscript, and acted as a corresponding author. NW performed analysis on all empirical data, interpreted data, helped to evaluate and edit the manuscript and acted as a co-author. All authors read and approved the final manuscript.

Authors' information

Prof. Bertram Lohmüller, Ph.D. Core competencies: innovation and technology management, strategy development, global business development, marketing, entering into new markets, benchmarking, practice-oriented management training programs, project management, East European markets.
Alexander Petrikhin, Ph.D. Core competencies: technology management, project management, marketing, business administration and human resources, social philosophy and sociology, and philosophy of science.
Norbert Wagemann, M.Sc. Core competencies: Resource Management, Renewable Energies, Energy Conversion, Storage, Engineering, Process Engineering, Material Flow Management, New Systems of Bioeconomy, Agroforestry and Aquacity.

Competing interests

All authors have no conflict of interest to report. The authors agree to use the published findings and related empirical data (reflected in the article) from the master thesis "Specifics and core functions of the CTO position" and "Hidden CTOs" in the technology management processes. Based on the international project "Intelligent use of biomass along the Danube: R&D network formation with German, Hungarian, Slovak and Romanian partners" written by Dr. Alexander Petrikhin and to publish the findings and related empirical data (reflected in the article) on the Steinbeis Global Institute Tübingen (SGIT) site (consistent with any limitations set by publisher requirements).

Publisher's Note

Received: 21 April 2017 Accepted: 20 March 2018
Published online: 12 April 2018

References

Adler PS, Ferdows K (1990) The chief technology officer. California Manage Rev J 32(3):55–62
Bohlin NH, Vantrappen HJ, and Wechsler (1994) The chief technology officer as an agent of change. Arthur D. Little Prism J Fourth Quarter 1994: 75–85
Bridenbaugh P (1992a) Credibility between CEO and CTO: a CTO's perspective. Res Technol Manage J 35(6):27–33
Cannon (2005) What it means to be a CTO. Res Technol Manage 48(3):12–14
Carrow JC, Schooler R, Quinn P (2005) Title of subordinate document. In: Advancing to the CTO/CIO level: best practices and strategies for success. Exec blueprints. Available via http://www.carrowconsulting.com/CarrowResume.pdf
Delmar DR (2003) The rise of the CSO. J Bus Strat 24(2):8–10
Deschamps J-P (2000) The emerging leadership role of the chief technology (or chief research) officer. Insights. Alliance for technology-based. No. 6, July 2000
Earl MJ, Feeny D (2000) Opinion: how to be a CEO for the information age. Sloan Manage Rev J 41(2):11–23
Finkelstein S (1992) Power in Top Management Teams: dimensions, Measurement, and Validation. Academy of Management J 35 (3): 505–53.
Finkelstein S, Hambrick DC (1996) Strategic leadership: top executives and their effects on organizations. In: West's. Strategic management series. West Pub. Co, Minneapolis/St. Paul, pp 209–262
Gwynne P (1996) The CTO as line manager. Res Technol Manage J 39(2):14–18
Hart S (2008) Title of subordinate document. In: Achieving success as a CTO leading CTOs on building IT's reputation, capitalizing on employee strengths, and creating a productive environment Available via https://www.viasat.com/files/assets/HartChapter.pdf
Hartley S (2011) The effectiveness of the chief technology officer. Res Technol Manage J 54(3):28–35
Herstatt C et al (2006) Title of subordinate document. In: The chief technology officer (CTO) in theory and practice: a literature review and results from field research in Japan, working papers/Technologie- und Innovationsmanagement, Technische Universität Hamburg-Harburg, no. 41 The Version is available at: https://pdfs.semanticscholar.org/bb4e/91b6c7bf72ab5469c06b6ff94ed78878f118.pdf
Hoven C (2012) Dynamic technology leadership. The adaptive role of the CTO. Res Technol Manage J 55(5):24–33
Larson F (2001) Management for the new millennium-the challenge of change. Research Technology Management, 44(6). Available via https://www.questia.com/library/journal/1G1-80346387/management-for-the-new-millennium-the-challenge-of
Long (2007) Title of subordinate document. In: Role of the chief technology officer [Web log post]. Available via: https://chieftechnologyofficer.wordpress.com/2009/08/27/role-of-the-chief-technology-officer/
Medcof J (2006) Title of subordinate document. In: The chief technology officer and organizational power and influence. The Michael G. DeGroote School of Business Available via: https://www.cs.princeton.edu/courses/archive/spring12/cos448/web/readings/medcof.p
Medcof J (2007) The chief technology officer as technology leader. Proceedings of the Annual Meeting of the Administrative Sciences Association of Canada, Technology and Innovation Management Division, DeGroote School of Business, McMaster University
Medcof J (2008) The organizational influence of the chief technology officer. R&D Manag 38(4):406–420
Nagahira A, Masaki T, Herstatt C et al (2007) Title of subordinate document. In: The role of chief technology officer regarding R&D Management in Japanese Corporations. SCEJ 72nd Annual Meeting, Kyoto 2007. Available at https://www.jstage.jst.go.jp/article/scej/2007/0/2007_0_549/_pdf
Pala O (2006) Do CTOs affect performance? A proposed model for assessing the CTO-performance relationship. Working Paper (Sabanci University) Available at https://www.researchgate.net/publication/232989464_Chief_technology_officer_roles_and_performance
Parker DP (2002) Title of subordinate document. In: The changing role of the chief technology officer. Parker and Associates Available via http://www.dpparker.com/article_cto_role.html
Petrikhin A (2017) Specifics and core functions of the CTO position and 'Hidden CTOs' in the technology management processes. Steinbeis University Berlin, 241, Master Thesis
Robb WL (1994) Selling technology to your CEO. Res Technol Manage J 37(5):43–45
Roberto M (2003) The stable core and dynamic periphery in top management teams. Manag Decis 41:120–131
Roberts F (2001) Benchmarking global strategic management of technology. Res Technol Manage J 44(2):25–36
Scott GM (2001) Strategic planning for technology products. R&D Manage J 31(1):15–26
Smith R (2011) The field grade CTO. Research-Technology Management 54(3), 60–61(2) doi: 10.5437/08953608X5403010.
Smith R (2002) Title of subordinate document. In: The role of the chief technology officer in strategic innovation, project execution, and mentoring Available via http://www.cs.princeton.edu/courses/archive/spring12/cos448/web/readings/smith.pdf
Smith R (2003) The chief technology officer: strategic responsibilities and relationships. Res Technol Manage 46(4):28
Thurlings, Bert, Debackere, Koenraad (1996) Trends in managing industrial innovation––first insights from a field survey. Res Technol Manage J 39(4):13–14
Tidd J (2005) Managing innovation: integrating technological, market and organizational change, 3rd edition
Uttal B, Kantrow A, Linden LH, Stock SB (1992) Building R&D leadership and credibility. Res Technol Manage 35(3):15
Wolff MF (1991) Are you credible with your CEO? Res Technol Manage J 34(2):9–1
Yin RK (1994) Case study research, design and methods (2nd edition). Sage Publications, Inc., London, pp 84–86