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## Article

# Digital transformation in commercial banks: Unraveling the flow of Industry 4.0

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# Digital transformation in commercial banks: Unraveling the flow of Industry 4.0

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## ABSTRACT

This study investigates the strategies employed by commercial banks during their digital transformation, particularly regarding the integration of Industry 4.0 technologies. A systematic literature review of 287 articles was conducted to identify strategies at micro, *meso*, and macro levels. At the micro level, three key strategies emerged: value co-creation, security, and inclusion, aiming to enhance customer experience, secure data, and improve digital accessibility. At the meso level, banks adopt agile organisational structures, automation, and expand digital platforms to optimise internal processes and foster external collaborations. At the macro level, strategies include establishing fully digital banks, incorporating digital features into traditional operations, or collaborating with other stakeholders to innovate business models. A conceptual framework is presented to illustrate the dynamic interaction between these levels, emphasising the importance of a holistic approach for successful digital transformation. The research connects its findings to theories of general-purpose technology and dynamic capabilities. Implications highlight the need for overcoming challenges such as legacy systems, regulatory complexities, and internal resistance. These findings offer valuable insights for banks implementing Industry 4.0 technologies, with a focus on strategic alignment, organisational readiness, and technological innovation.

## 1. Introduction

Historically, the banking sector has been recognised as one of the pioneers in adopting technologies to support business diversification, as seen in the 1980s with the introduction of automated teller machines (ATMs), which revolutionised the industry and enabled direct interactions with customers (Filotto et al., 2021; Shang & Chiu, 2023). Similarly, the transition from the 1990s to the 2000s brought the profound impact of the Internet and mobile devices on commercial banks,<sup>1,2</sup> leading to new perspectives and paradigms, with new communication channels (Gul et al., 2021).

However, the trajectory of these technological advancements has not been uniform but heterogeneous, with varied economic impacts that

may be specific to each commercial bank or its regulatory environment (Bekar et al., 2018; Heikkilä & Wikström, 2021; Teubner, 2021). For example, while larger multinational banks quickly adopted technologies to improve operational efficiency and customer personalisation, smaller regional banks often faced challenges due to limited resources and stricter regulatory constraints, resulting in slower adoption rates and different technological strategies (Rysin et al., 2023).

After the global financial crisis in 2008, there was a decline in the legitimacy of commercial banks, combined with the widespread use of smartphones, generating a major transformation in banking services (Vasiljeva & Lukanova, 2016). Furthermore, throughout the 2010s, two factors made innovation in banking business models evident. The first consisted of the emergence of FinTechs, described by Gomber et al.

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<sup>1</sup> The academic literature occasionally designates commercial banks as either traditional banks or retail banks; however, it is important to note that these terms denote identical institutional entities.

(2017) as a fusion of 'financial' and 'technology,' representing innovators in the financial industry that harness the power of internet-based technologies to transform traditional financial services like lending and transaction banking. The second was the digital transformation (DT), which affected the balance of the banking sector in different ways, leading to significant changes in competitive dynamics and the way products and services are delivered to customers (Baiyere et al., 2023; Verhoef et al., 2021).

Commercial banks have had a greater challenge in the DT process due to the complexities of their logic, institutional structures, and regulations (Saputra et al., 2022). As stated by Lipsey et al. (2005), the institutional structure influences the capacity to absorb and adjust to emerging technologies. Intricate and inflexible banking regulations also have a direct impact on how financial institutions embrace and implement technological innovations. In this context, the dynamic capabilities framework, as proposed by Teece (2007), emphasizes that it is the dynamic capacity of banks to reconfigure and adapt their existing resources that will enable them to thrive in a rapidly changing technological landscape. As commercial banks face increasing pressure to innovate and compete with FinTechs, their ability to develop and deploy these dynamic capabilities, such as organisational learning, technological integration, and strategic flexibility, becomes crucial (Barroso & Laborda, 2022; Heubeck, 2023).

Consequently, new business models have emerged driven by disruptive technologies that integrate physical and digital elements - such as big data, artificial intelligence (AI), cloud, and blockchain - marking the beginning of the Fourth Industrial Revolution, or Industry 4.0 (I4.0) (Cividino et al., 2019). This revolution aimed to offer more efficient, customised, and accessible services to customers, leading to increased competition in the banking sector (Gomber et al., 2017).

Moreover, I4.0 technologies can be related to the general-purpose technology (GPT) framework established by Lipsey et al. (2005). The GPT framework refers to a class of technologies that have the potential to drastically transform economies, industries, and societies due to their widespread applications, versatility, and ability to spur further innovations. These technologies are not confined to a specific industry but instead influence a wide range of sectors and enable new technological developments, resulting in long-term economic growth and structural changes (Carlaw & Lipsey, 2006; Lipsey et al., 2005).

Since the emergence of FinTechs and the spread of I4.0 technologies, much research on banking services has been dedicated to investigating the innovations and technological disruptions that these players have introduced into their business models, such as digital banks, which operate exclusively online (Bradford, 2020). However, there is a lack of a more comprehensive analysis that serves to understand the changing paradigms of commercial banks and an agenda to support their DT development (Vives, 2019). Consequently, this article investigates: *In the context of I4.0, what are the main strategies that commercial banks are developing to adapt to DT, remain competitive, and create value?* As an auxiliary objective for this question, this study also intends to investigate which specific I4.0 technologies hold the most potential to transform the banking sector.

In addressing the research question, this paper employed a systematic literature review (SLR) to investigate the impacts of digital technologies stemming from I4.0, which are reshaping the business models of commercial banks. By scrutinising three comprehensive databases, ABI/INFORM, EBSCO Host Business Source Elite, and Scopus, a total of 287 articles were meticulously chosen, and an inductive coding approach was applied to pinpoint the primary themes and insights (Xiao & Watson, 2019). As a result, we developed a conceptual framework, encompassing three levels, which depicts the dynamic interaction between customers, technology, and banking networks, highlighting the need for a comprehensive, systems-oriented approach to achieve successful DT.

From this SLR, three significant implications emerge. Firstly, it sheds light on the convergence of terminology revolving around 'digital

transformation' within the banking sector. This encompasses concepts such as 'digitisation' and 'digitalisation,' particularly within the realm of I4.0 technologies. Consequently, it introduces clarity on the concept of DT, its multifaceted nature and the various dimensions it encompasses, which is critical to advancing the field. Secondly, it explains the different ways commercial banks implement their strategies to drive DT and identifies which strategies fit each area, helping to build a conceptual framework. This framework highlights how strategies interact within each area, creating value for both banks and their customers, as well as highlighting the key I4.0 technologies involved in this process. Thirdly, it underlines the importance of aligning the DT process within commercial banks with established theories such as GPT (Lipsey et al., 2005) and dynamic capabilities frameworks (Teece, 2007). This alignment not only fosters coherence but also facilitates the consolidation of the core principles of such theories. This, in turn, propels the advancement of research on the capabilities of commercial banks within the overarching context of I4.0.

Finally, this SLR suggests diverse avenues for future research to further deepen our comprehension of the predominant trends pertaining to the services rendered by commercial banks vis-à-vis the I4.0 technologies. Moreover, it underlines the necessity of exploring the evolving customer profile, which is increasingly engaged with digital services, thus highlighting the imperative for banks to adapt and innovate in tandem with these shifting dynamics.

## 2. Background

### 2.1. Commercial banks' evolution to Industry 4.0

The banking sector has been at the forefront of early technological adoption (Bons et al., 2012). Looking at the evolution of the banking industry throughout the 1990s and 2000s, most commercial banks began offering internet-based platforms, allowing customers access to their accounts and varying degrees of functionality to initiate transactions, update personal information, and perform similar activities (Ojeniyi et al., 2019). Mobile banking naturally followed, extending this trend with the advent of smartphones and a diverse range of user-friendly applications (Sampaio et al., 2017). The terms 'mobile banking' and 'internet banking' (via personal computers) emerged as complementary additions to a bank's suite of communication channels (Stafford & Gillenson, 2003). Notably, the global financial crisis of 2008 and the rise of FinTechs in the 2010s marked a shift towards prioritising internet access and smartphone use for digital services (Filotto et al., 2021).

Throughout the 2010s, the banking sector underwent significant transformations with the emergence of I4.0 technologies and the introduction of 'Open Banking' regulation (Xie & Hu, 2024). Concerning I4.0, its concept was introduced in Germany in 2011, referring to the fourth cycle of the Industrial Revolution<sup>2</sup> (Vogel-Heuser & Hess, 2016). The I4.0 technologies such as AI, big data, machine learning, blockchain, cybersecurity, cloud, and Internet of Things (IoT) possess the capacity to foster substantial innovation and competitive expansion while concurrently enhancing the sustainability of the existing industrial system (Bai et al., 2020; Chang et al., 2021; Müller et al., 2018). These disruptive technologies have enhanced the quality of services and products and have significantly influenced organisational performance, introducing new paradigms and opportunities across various industries, including banking (Kamble et al., 2018).

In relation to Open Banking, it involves the establishment of digital interfaces that allow customers to share their banking details with third

<sup>2</sup> The first cycle was driven by the steam engine, railways, and steel; the second by electricity and chemicals; the third by automobiles, the petrochemical industry, and computers; and the fourth by information technology and digital networks (Ademmer et al., 2017).

parties (Xie & Hu, 2024). This development significantly accelerated the creation of applications with advanced financial functionalities (Frattini Passi, 2022). This milestone represents a major shift and adaptation to the evolving consumer behaviour landscape (De Venn, 2023). However, not all banks were quick to adapt to Open Banking, as it required new security mechanisms, such as strong authentication, encryption, and continuous monitoring, posing a challenge for commercial banks that needed to balance innovation with protection against fraud and cyber-attacks without compromising the customer experience (Gozman & Willcocks, 2019; Premchand & Choudhry, 2018; Xie & Hu, 2024).

For commercial banks, since the inception of Open Banking and the implementation of I4.0 technologies in subsequent years, the goal for the coming years is to enhance the customer experience through digital transactions and personalised services (Chauhan et al., 2022). Meanwhile, many commercial banks are still in the early stages of introducing I4.0 technologies and searching for solutions to adapt to this new context, such as improving the speed and efficiency of transactions for their customers while ensuring compliance with regulations (Mehdiabadi et al., 2020; Wewege et al., 2020). For instance, banks are striving to provide customers with the option to make financial decisions using AI-powered robo-advisors, which offer financial analysis and suggestions based on the customer's profile while comparing services from other banks. At the same time, banks need to pay attention to ethical and regulatory issues regarding the impacts of these technologies on consumer behaviour (Korherr et al., 2022; Malali & Gopalakrishnan, 2020).

Indeed, I4.0 technologies are rapidly reshaping the banking industry. Indicators of this transformation include the reduction of physical branches in favour of digital service channels, as well as investments in employee training and partnerships with technology companies to accelerate the adoption of I4.0 technologies (Riikkinen & Pihlajamaa, 2022). By investing in intangible resources, such as strategic collaborations and cybersecurity training, for example, these banks can achieve a sustainable competitive advantage over competitors who do not have these resources (Úbeda et al., 2022). Therefore, while there are complexities introduced by this transformation, some banks are adopting these changes gradually, beginning with specific departments, such as real estate or insurance, and gradually expanding to broader portfolios. This approach highlights that implementing I4.0 technologies are closely linked to GPT theory (Martinelli et al., 2021; Sia et al., 2021). Like previous GPTs, such as electricity or steam power, I4.0 technologies are pervasive, enabling new forms of value creation while simultaneously rendering existing infrastructures obsolete (Clausen, 2023; Corradini et al., 2021).

Nonetheless, the theory of GPTs posits that, although their transformative potential is immense, they often face a paradox similar to the Solow Paradox (Triplett, 1999), where productivity gains from new technologies are not immediately observable. In the case of I4.0, the speed of adoption and the extent to which organisations can adapt to the changing technological landscape will determine the realisation of their full economic benefits (Tortorella et al., 2021). For instance, the widespread implementation of these I4.0 technologies challenges existing organisational structures, operational models, and regulatory frameworks, creating a need for rapid innovation and flexibility (Cañas et al., 2021). These frictions are particularly evident in sectors like banking, where traditional business models must coexist with the digitalised new business models (Broby, 2021; Vives, 2019). As with earlier GPTs, the transition to I4.0 requires overcoming initial resistance, but once deeply embedded, it can fuel long-term growth and innovation across industries (Teece, 2018).

## 2.2. Digital transformation: concepts and mechanisms

The concept of DT is often mistaken for simply implementing the latest technology. In academic circles, there are various interpretations of DT across different fields and disciplines (Vial, 2021). Some

definitions are broad, emphasising the skills and capabilities needed for effective operations, while others are more focused, highlighting specific aspects like strategic change, performance, or culture (Kane et al., 2019). Despite the emphasis on technology in the term 'digital,' research suggests that there is not always a direct correlation between DT and technology adoption (Furr & Shipilov, 2019).

Moreover, DT is frequently conflated with terms such as 'digitisation' or 'digitalisation'. To offer clarity, Verhoef et al. (2021) delineated these terms into three distinct stages for DT: digitisation, digitalisation, and transformation. Digitisation refers to the transition from analog to digital tasks or the incorporation of IT into existing processes. The subsequent stage, digitalisation, entails leveraging digital technologies to alter established business practices. The last stage is the transformation, as the most extensive stage, denotes a comprehensive organisational overhaul leading to the creation of new business models, which may be novel within the company or the industry at large (Lydiana et al., 2022). When a company reaches this third stage, it normally has the necessary technological infrastructure and a certain level of technological maturity. However, such steps may not occur linearly. Following the same logic as GPT theory, companies must persist in a gradual DT process, which is also related to the gradual adoption of I4.0 technologies to increase their productivity and competitive advantage (Lipsey et al., 2005; Parra-Sánchez et al., 2021) and understand the impact of such transformations.

Regarding the main mechanisms that assist in a successful DT process, the literature indicates innovation and integration (Hanelt et al., 2021). In the innovation mechanisms approach, DT encompasses novelty in both strategic and operational dimensions, involving activities such as formulating digital business strategies, mobilising and accelerating transformation at the strategic level, and exploring digital capabilities for the development of innovative products, processes, and business models, with a particular emphasis on human-machine interaction for sustainable synergies (Heubeck, 2023; Hinings et al., 2018).

On the other hand, integration mechanisms play a pivotal role in aligning new elements with existing ones within an organisation during DT. This requires the formulation of a comprehensive strategy serving as the central concept for coordination, prioritisation, and implementation (Hanelt et al., 2021). These activities encompass unlocking organisational potential, fostering technological flexibility, and achieving physical-digital harmonisation through cross-functional cooperation and coordination mechanisms (Larkin, 2017). Integration mechanisms also facilitate alterations in the value-generation trajectories of an organisation, manifesting in four key dimensions: adoption of technologies, shifts in value creation strategies or business model adaptability, modifications in organisational structure, and financial aspects (Buck et al., 2023).

The effectiveness of such mechanisms can be related to the dynamic capabilities' theory (Teece, 2007). Both the innovation and integration mechanisms require banks to demonstrate flexibility to reconfigure their resources and capabilities (Haki et al., 2024; Heubeck, 2023). This flexibility is essential in the context of DT, since as it is a gradual process, commercial banks also need to develop internal capabilities to identify opportunities that allow both the innovation and integration mechanisms to operate in the most agile way possible so that DT can occur with greater efficiency (Ghosh et al., 2022).

Leveraging digital technologies presents substantial opportunities for organisations to enhance their competitive advantage, enabling them to cultivate and augment their digital capabilities (Grover et al., 2018; Heubeck, 2023). In essence, DT can be conceptualised as the gradual process through which a company innovates, communicates, and leverages value creation as an entrepreneurial endeavor (Buck et al., 2023). Moreover, and as previously explained, I4.0 is an important enabler of business model transformation (Toth-Peter et al., 2023).

### 3. Methodology

In this study, we employed an SLR to explore specific aspects of a significant phenomenon, following established procedures and guidelines commonly used by researchers, scholars, and practitioners to identify, evaluate, and synthesise existing research (Okoli, 2015). The SLR process involves three main stages: planning, conducting, and reporting (Xiao & Watson, 2019). In the planning stage, the review scope, a review protocol, and a well-defined research question are established (Tranfield et al., 2003). The conducting stage includes developing a search strategy, applying eligibility criteria, and conducting evaluations, coding, analysis, and synthesis. The reporting stage involves writing the review report and disseminating findings.

For the search strategy in this SLR, three widely recognised electronic databases that specialise in business-oriented journals were selected: ABI/INFORM, EBSCO Host Business Source Elite, and Scopus. These databases were chosen due to their comprehensive coverage of business and technology-related literature, as well as their focus on high-quality, peer-reviewed academic journals (Gusenbauer, 2022). In particular, ABI/INFORM is known for its strong collection of finance, business, and management articles, while EBSCO Host Business Source Elite provides access to a wide range of industry-specific research (King, 2020; Tucker, 2006). Scopus, one of the largest abstract and citation databases, ensures a broad and up-to-date selection of relevant articles across multiple disciplines (Schotten et al., 2017), making it particularly suitable for research on DT and I4.0 technologies in the banking sector.

The keywords and search terms used in these databases were developed based on the research question as suggested by Tranfield et al. (2003) and were carefully evaluated by the research team, with particular focus on the banking sector. These terms included essential concepts such as 'commercial bank,' 'fintech,' 'Industry 4.0,' and 'digital transformation.' To ensure comprehensive coverage, the search terms were expanded to include synonyms and related terms such as 'traditional bank,' 'digi\*ation,' 'digitali\*ation,' and 'digital business.'

The study selection process followed predetermined eligibility criteria to refine the list of articles for review (Ahmed et al., 2019). The selection of studies for this review did not impose any restrictions on the periods and publication dates considered, given the novelty of the I4.0 and DT concepts. The research team considered six main criteria for excluding articles: (1) languages other than English, (2) no peer review, (3) different research fields, such as manufacturing and health, (4) only the reference list mention keywords and search terms, (5) duplicate articles, and (6) not directly related with the banking sector, I4.0 or DT.

The search was conducted in January 2024, and after applying criteria from fields closely related to the banking sector, such as management, accounting, finance, marketing, information systems, and information technology, 1513 articles were identified. Subsequently, articles that merely referenced the search terms were excluded, and duplicate articles were also removed, leaving 808 articles for analysis. During the screening process, the evaluation focused on titles, abstracts, and keywords, including articles centred on the financial sector and emphasising the role of DT and I4.0. Articles investigating DT across various sectors or addressing banks without considering digital technologies were excluded. Following the independent screening by two researchers, who analysed abstracts and, if necessary, full texts for relevance, 287 articles were selected in the final review. Fig. 1 outlines the process of identifying and selecting the articles.

For the analysis of the 287 articles in the SLR, an inductive coding approach was employed. Accordingly, this analytical method does not rely on pre-established concepts or theories regarding the topics or codes, allowing for a more open and flexible investigation of the data (Chandra et al., 2019). Inductive coding involves a careful and systematic examination of raw textual data, where the researcher develops concepts, themes, or process models based on their interpretation of the data (Thomas, 2006). This approach proved essential, as it allowed patterns and new insights to emerge directly from the data, free from the influence of pre-existing theories or frameworks (Mayring, 2015), providing a clearer and more in-depth view of the practices and challenges faced by financial institutions. Fig. 2 presents the steps of the inductive coding process.

Following the first three steps, the 287 articles underwent a thorough assessment involving a full-text analysis encompassing detailed data analysis and synthesis. During this process, relevant information was extracted and carefully documented in a comprehensive literature grid table using Excel. This meticulous record-keeping of all the articles was implemented to ensure accuracy and facilitate easy reference, ultimately resulting to the identification of 16 codes (Ahmed et al., 2019).

In steps four and five, the identified codes were categorised and organised into three clusters based on their respective topics and dimensions (Xiao & Watson, 2019). Before proceeding with data analysis and reporting, the entire research team underwent a detailed review of the emergent themes from the inductive coding and the draft of the review. This step was crucial for ensuring the validity and reliability of the coding process, as the team worked collaboratively to ensure that the codes were applied consistently and accurately reflected the data extracted from the literature. To assess and ensure inter-coder

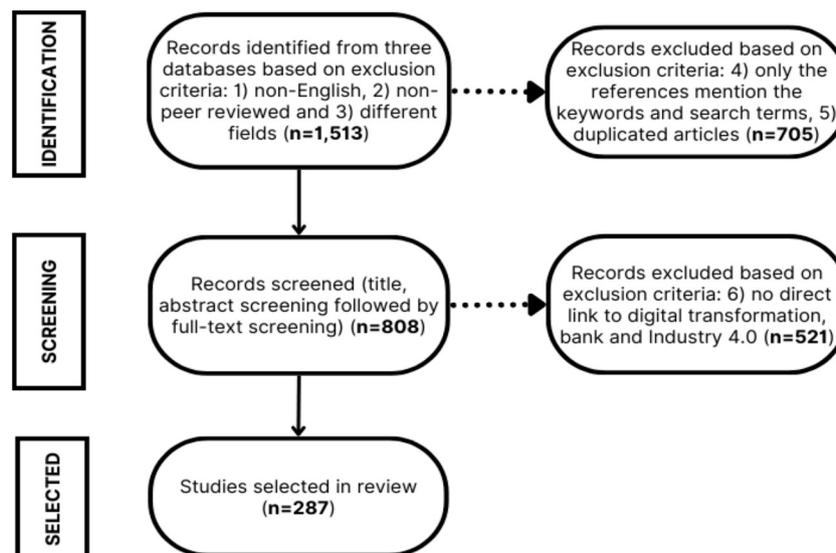


Fig. 1. Overview of literature search and study selection.

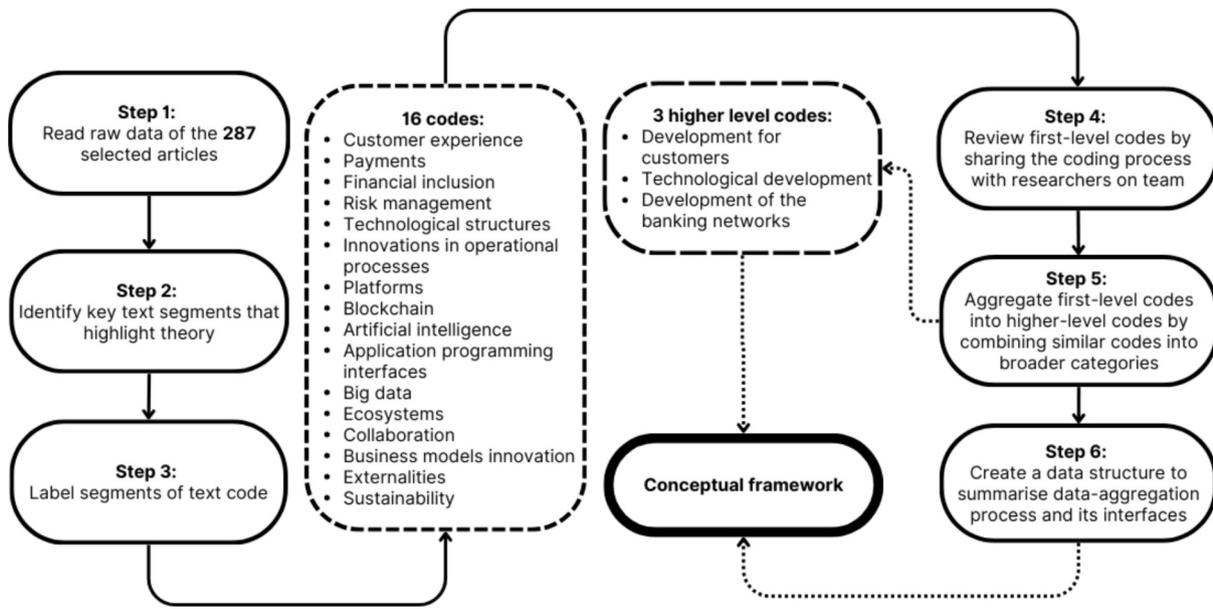


Fig. 2. Inductive coding process.

Note: Figure adapted from *Inductive coding*, by Y. Chandra and L. Shang, 2019, *Qualitative Research Using R: A Systematic Approach*, 91–106. Copyright 2019 by Y. Chandra & L. Shang.

reliability, we employed a systematic approach where multiple team members independently coded a subset of articles and then compared their results (Chandra et al., 2019). Any discrepancies in the application of codes were discussed and resolved through consensus, with team members providing clarifications and justifications for their coding decisions. This iterative process helped to align the coding approach across the team and to enhance the consistency of the applied themes (Thomas, 2006).

Additionally, after the initial coding, the team revisited the three higher-level themes and conducted further discussions to confirm their alignment with the underlying data. This process of verification and adjustment among the team members ensured that the interpretations were reliable, that the codes rigorously reflected the patterns within the analysed literature, and that the higher-level themes accurately represented the emerging insights (Birkel & Müller, 2021; Okoli, 2015).

Subsequently, the review outcomes were discussed from a descriptive and content perspective. This discussion entailed providing a

narrative account of the findings, resulting in step six and culminating in the development of the conceptual framework. The descriptive perspective allows for a comprehensive overview of the identified information, while the content perspective delves into the analysis and interpretation of the data within a theoretical framework.

## 4. Results

### 4.1. Distribution of articles per year

After reviewing the final articles, we realised that the articles spanned from 2010 to the 2023, showcasing consistent growth in publications starting from 2018, with a notable peak of 85 articles in 2023, as stated by Fig. 3. The combination of commercial banking and I4.0 represents a relatively new research area, which explains the surge in publications in recent years and the scarcity of papers before 2018.

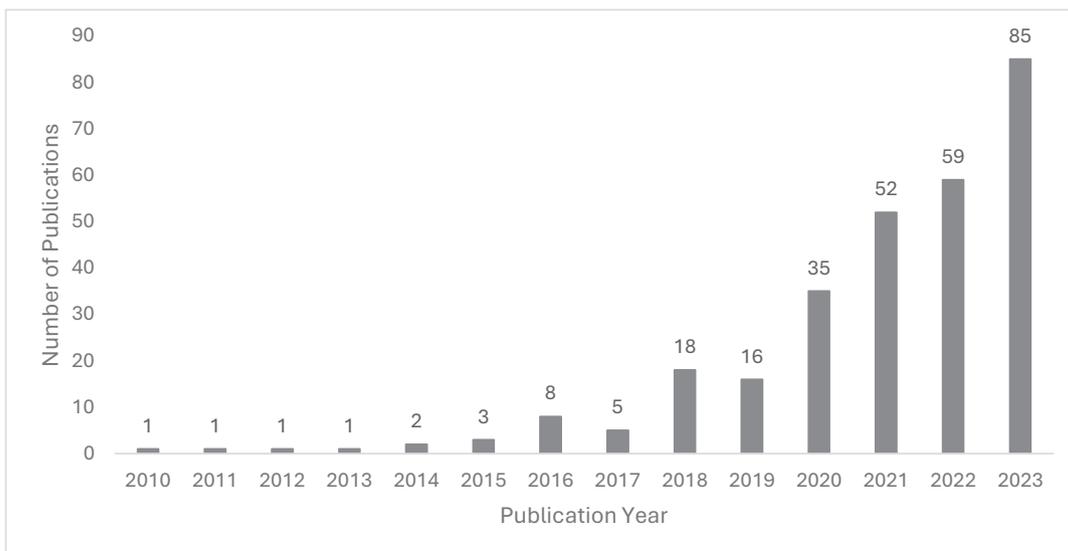


Fig. 3. Distribution of articles by year.

4.2. Methodological approaches

A substantial majority of the studies encompassed within the review are characterised as empirical, comprising 62 % of the total, which amounts to 179 out of the 287 studies under consideration. Among these 179 articles, 96 were identified with quantitative methodologies, 64 qualitative and 19 mixed methods.

Regarding the 96 studies with quantitative methods, surveys are frequently used, with 34 studies using cross-sectional surveys and 13 using longitudinal surveys. In some cases, researchers used modelling techniques; for example, 23 studies used hypothesis testing, 13 studies applied econometric methods, and eight studies employed regression analysis. Concerning the 64 qualitative studies, case study is the predominant research method, found in 36 of the studies, and ethnographic is the second most common qualitative approach, observed in 13 studies. Furthermore, regarding the 19 studies with a mixed method approach, generally combined case studies with a quantitative method, such as surveys, to provide a more comprehensive understanding of the research topic.

4.3. Digital transformation approaches in banking sector

After applying the first-level code approach it was possible to classify each article with a specific topic. The 287 articles were coded into 16 topics, which represent the main themes being investigated in the field of DT in the banking sector.

Thus, to identify the main study trends, the 16 topics were aggregated into three higher-level cluster by combining similar topics into broader categories, in other words, according to the relevance and emphasis of each article. Table 1 shows the quantitative distribution of the topics among the clusters that were named: ‘development for customers’ (88 articles), ‘technological development’ (88 articles), and ‘development of the banking networks’ (111 articles).

The most common topic within the three clusters was ‘customer experience’, with 47 articles. These articles consider several aspects related to the consumer, such as service personalisation, trust, omnichannel, co-creation, and behaviour. It is also important to note that this topic includes companies and governments as corporate customers. The second most common topic, with 39 articles, was the analysis of the progressive transformation of the banking ecosystem involving local, regional, or global contexts. The research in these articles takes a more holistic and high-level approach to the banking sector, with the impacts of DT considering aspects such as complexity, value chain, and regulation. For this reason, the name chosen for this topic was ‘ecosystems’.

Regarding the three clusters, it is important to highlight the approach applied to the ‘technological development’ cluster. The 88 articles that make up this cluster presented different approaches to technology, exemplifying two main attributes: the advancement of a fundamental technological infrastructure or a meticulous scrutiny of a specific technology and its corresponding application. To exemplify the first attribute, we can present the topic ‘technological structure’, which

**Table 1**  
Distribution of articles in three clusters and 16 topics.

Development for customers: 88	Technological development: 88	Development of the banking networks: 111
Customer experience: 47	Artificial intelligence: 17	Ecosystems: 39
Payments: 19	Technological structures: 16	Business models innovation: 27
Risk management: 13	Innovation in operational processes: 15	Collaboration: 18
Financial inclusion: 9	Blockchain: 15	Externalities: 15
	Platforms: 12	Sustainability: 9
	Application programming interfaces: 8	
	Big data: 5	

in 16 articles is addressed in a generic way, or digital platforms (12 articles) considering different aspects of conducting DT. Concerning the second attribute could be preset as ‘core I4.0 technologies’, because in these articles it is possible to identify an emphasis on a specific type of I4.0 technologies, such as AI (17 articles), blockchain (15 articles) and the interconnectivity represented by application programming interfaces (API) (8 articles). In the following topics, more details will be presented on each of the topics allocated, as well as tables with summaries and references.

4.4. First higher-level code: development for customers

Development for customers represents the category of studies with an emphasis on internal aspects of commercial banks, comprising articles coded as customer experience, payments, risk management, and financial inclusion. Table 2 presents a summary of the 4 codes and their respective references.

As presented previously, customer experience is the most investigated topic in the articles selected for this SLR. The analysis of the articles in this topic showed that I4.0 technologies have been essential for identifying and meeting customer needs. For example, technologies such as AI and big data are capable of understanding customer behavioural trends and granting banks the possibility of offering more convenient and customised services (Benbya et al., 2021; Hosseini et al., 2022). On the other hand, the use of technology is still a barrier for many consumers due to regulatory limitations, mistrust, and insecurity, or even a lack of knowledge in the use of electronic devices (Iwashita, 2022).

To reduce customer distrust regarding the use of technology, commercial banks have developed strategies to ensure greater security when making payments, in addition to risk management, which are two other topics in this group (Andaregie et al., 2024). According to Antwi and Kong (2023), the use of smartphones was essential to consolidate the use of digital payments, whether with real-time transfers or the use of virtual cards. Due to the COVID-19 pandemic, technologies such as face recognition, biometry and blockchain began to be used not only to offer greater efficiency in payments but also greater security, fraud prevention, and compliance with regulations established for the protection and use of customer data (Mróz-Gorgoń et al., 2022).

The fourth theme in this group is financial inclusion, which is interconnected with the other higher-level themes. In relation to the higher level of technological development, research carried out in developing countries shows that the use of I4.0 technologies has been essential for the banking inclusion of customers living in rural or low-income areas (Gupta & Kanungo, 2022; Sodokin et al., 2022). Through banking applications, these customers began to be included in bank portfolios and had access not only to banking services but also to a series of benefits and specific products for microcredit or agribusiness

**Table 2**  
Development for customers codes description.

Development for customers codes	Academic articles
<ul style="list-style-type: none"> <li>• <b>Customer experience:</b> considers customer-centric initiatives and the critical aspects for customers in relation to digital banking, including loyalty, trust, omnichannel, co-creation, and behaviour.</li> </ul>	Dehnert and Schumann (2022)
<ul style="list-style-type: none"> <li>• <b>Payments:</b> the reduction in the circulation of money and the establishment of new and fast payment technologies, including the use of electronic devices instead of cards, as well as new forms of instant transfers and e-wallets using QR codes.</li> </ul>	Zhao et al. (2023)
<ul style="list-style-type: none"> <li>• <b>Financial inclusion and microfinance:</b> focuses on access to banking services for populations in rural or low-income areas, in addition to programs for digital literacy.</li> </ul>	Benami and Carter (2021)
<ul style="list-style-type: none"> <li>• <b>Risk management:</b> also related to cybersecurity, it considers the elements that affect customer confidence in the use of digital technologies, whether in relation to fraud prevention or data security.</li> </ul>	Fang et al. (2023)

(Dorfleitner et al., 2022). Regarding the development of banking networks, the digital banking inclusion of low-income customers has been a safe way of guaranteeing the payment of social benefits by governments, as it allows data to be crossed between government records and those of the bank, making the process more secure (Sohag et al., 2022).

Therefore, this cluster demonstrated how the development of a positive customer experience occurs in an integrated way with I4.0 technologies, which are essential for offering personalised service, ease and speed in payments and transfers, security and reliability of their platforms, and disseminating a digital culture that helps customers mature in the use of these technologies.

#### 4.5. Second higher-level code: technological development

The technological development cluster is made up of studies that focus on topics related to technology and that were coded as technological structures, innovations in operational processes, platforms, blockchain, AI, API, and big data. The emphasis in research on technological development in banks occurs in different ways, and we see two trends, one focusing on customers and the other on processes and employees. In addition, we also found that the first stream is focused on establishing digital technological structures and platforms that provide a series of improvements in the work of teams and the design of bank processes. The second stream is made up of studies on a specific type of I4.0 technologies, such as AI, big data, or blockchain, and explores, in depth, the application and effects of such technologies in commercial banks. Table 3 presents a summary of the seven codes and their respective references.

The articles coded as technological structures present analyses of the dynamics of the technological systems already existing in the banks, as demonstrated by Lauterbach et al. (2020), in which the existing system receives and interprets the tasks, and then they are attended to. Technological structures are associated with the concept of digitalisation

**Table 3**  
Technological development codes description.

Technological development codes	Academic articles
<ul style="list-style-type: none"> <li>• <b>Technological structures:</b> explores DT as a process that leads banks to acquire digital maturity, expanding their customer service capabilities, service delivery, and mechanisms for disseminating a digital culture.</li> </ul>	Al-Busaidi and Al-Muharrami (2021)
<ul style="list-style-type: none"> <li>• <b>Innovations in operational processes:</b> considers aspects of corporate learning, talent management, or training that contribute to a digital culture and creative environment, in addition to changes and adjustments in internal processes, with the aim of adapting to technological services.</li> </ul>	Gfrerer et al. (2021)
<ul style="list-style-type: none"> <li>• <b>Platforms:</b> loans, payments or opening accounts can now be done through platforms or apps, which has changed the way of relating to clients and has made banking processes more efficient and conducive to innovation.</li> </ul>	Westermeier (2020)
<ul style="list-style-type: none"> <li>• <b>Blockchain:</b> incentivises tokenisation of assets and is one of the best features of I4.0. It originates from cryptocurrencies and is considered a safe and fast way to make transfers or payments, preventing or minimising fraud.</li> </ul>	Elrefae and Nuseir (2021)
<ul style="list-style-type: none"> <li>• <b>Artificial intelligence:</b> as one of the pillars of I4.0 and having a high capacity to provide fast and accurate support to different types of customers in different contexts, AI has drawn the attention of researchers and is the main topic in 17 articles of this SLR.</li> </ul>	Dhanya and Ramya (2023)
<ul style="list-style-type: none"> <li>• <b>Application programming interfaces:</b> this is another I4.0 technology, which is primarily responsible for the DT in the way customers and banks interact, providing a secure interface for sharing data.</li> </ul>	Rastogi et al. (2023)
<ul style="list-style-type: none"> <li>• <b>Big data:</b> has contributed to innovation in banking services as it identifies factors relevant to the creation of new value propositions, such as automation and hyperconnectivity.</li> </ul>	Sohag et al. (2022)

(Verhoef et al., 2021), as they generally refer to technologies established in banks, which will be digitally transformed using I4.0 technologies. Another example of a technological structure identified was information and communications technology (ICT), which is responsible for increasing the competitiveness of banks by carrying out analyses and issuing reports to support investments (Al-Busaidi & Al-Muharrami, 2021).

An example of the development of these technological structures consists of digital platforms, which allow banks to provide services to customers with greater efficiency, customisation, and interactivity (Rastogi et al., 2023). The platforms use technology capable of generating management support reports, whether collecting data on employee activities or the resources most used by customers, who, over the years, have prioritised the use of applications to perform banking services (Westermeier, 2020).

The perspective of using platforms to generate management support reports is directly related to the topic of innovation in operational processes. This topic explored by the articles includes banks' initiatives and strategies to disseminate a digital culture among employees to gain maturity in terms of the technological context, providing training and incentives for the specialisation of work teams in the use and application of I4.0 technologies, impacting how operational processes are carried out (Gfrerer et al., 2021; Ofosu-Ampong & Acheampong, 2022).

The remaining topics assigned to this cluster comprise four specific I4.0 technologies: API, blockchain, AI and big data, while other technologies, such as machine learning and the Internet of Things, were mentioned in some articles but not with the same prominence. It is necessary to highlight that the use of these technologies represents a sequence of the technological development of commercial banks based on the digitalisation of the existing technological structure, establishment of digital platforms, and team training, which illustrates well the integrative role of this cluster with the others (Mhlanga, 2020).

For example, API can be considered the core of DT in banks in terms of interconnectivity, as it was the technology that changed the way people interact with banks due to the possibility of sharing data with other financial institutions (Rastogi et al., 2023). This technology is closely associated with Open Banking, which is a way of sharing customer data securely and allows for a multitude of new business opportunities (Bahri & Lobo, 2020). This interconnectivity technology also allows banks to incorporate financial services and products from non-bank companies, including social networks, with the diversity of payment options being one of the main advantages, thus offering greater convenience to their customers (Heshmatisafa & Seppänen, 2023).

Another I4.0 technology directly associated with improving payment services is blockchain. The use of blockchain technology has been highlighted in numerous academic investigations (e.g., Chang et al., 2021; Choi, 2020; Elrefae & Nuseir, 2021) into digital currencies and cryptocurrencies and is also equally applicable to a wide spectrum of financial transactions (Adhami et al., 2018; Upadhyay, 2024). Research on the effects of blockchain shows how this technology has changed the payment and negotiation chain, as it is considered a safe, fast, traceable, and flexible technology for the use of different types of currencies and is also compatible with different applications (Choi, 2020). Furthermore, there is a strong relationship between blockchain and cybersecurity. This is directly related to legal uncertainties since there are countries where the regulatory framework for blockchain transactions is not yet consolidated (Torres de Oliveira et al., 2020).

Further, AI is the I4.0 technology most investigated by researchers (17 articles in this SLR) and is often applied alongside other technologies, such as machine learning (e.g., Milojević & Redzepagic, 2021) and big data (e.g., Fares et al., 2023). Among the various applications of this technology, we highlight its importance for the perception of credit risk management, document analysis, transaction processing, banking inclusion, and customer service (Lyu, 2022).

Finally, big data is the fourth I4.0 technology included in this cluster and has impacted the development of new knowledge, such as data

science applied to banks, to develop algorithms and statistical models to analyse the variety of this data (Sohag et al., 2022). The flexible and reprogrammable nature of big data technologies assists in developing capabilities to store, recognise, and predict events, behaviour, rule-based actions, and visualisation that enable the automation of human-to-material service practices and services (Lehrer et al., 2018).

4.6. Third higher-level code: development of the banking networks

Development of banking networks is a cluster that includes studies on DT from the external point of view of commercial banks. Therefore, it is the category that encompasses studies on banking ecosystems, whether of countries or regions, cooperation and collaboration with other players, such as FinTechs or startups, the emergence of new banking business models, the effects of externalities such as financial crises or regulations, and sustainability. Table 4 presents a summary of the five codes and their respective references.

The studies coded as ecosystems have a great diversity, including everything from analysis of the banking context of a country to general analyses of the progress of I4.0 technologies and regulations for the financial system (Poloz, 2021). Longitudinal studies that analyse historical contexts, such as the 2008 global crisis, or studies on technological evolution in financial services were also considered (Busquets, 2018).

The themes of externalities and sustainability could have been included in the ecosystems theme, but we noticed a significant number of studies that addressed these themes. The externalities code includes regulatory changes, financial crises and specific events, such as the disruptions generated by the COVID-19 pandemic, that are capable of causing changes in the pace of DT in commercial banks (Malali & Gopalakrishnan, 2020). This also indirectly affects the customer experience, which, due to social isolation, requires more digital resources for banking services, for example (Spencer, 2021).

Regarding sustainability, since the 2008 global financial crisis, the risks associated with trust and the loss of legitimacy and reputation have become critical factors for the survival of commercial banks (Englert et al., 2020). The incorporation of sustainable practices in the use of I4.0 technologies not only responds to customer expectations but also strengthens the resilience of financial institutions, contributing to a more ethical, transparent and responsible system (Forcadell et al.,

**Table 4**  
Development of the banking networks codes description.

Development of the banking networks codes	Academic articles
<ul style="list-style-type: none"> <li>• <b>Ecosystems:</b> explores the growth and progressive transformation of the banking landscape in local, regional or global contexts, considering aspects such as complexity, value chain, and the emergence of new players.</li> </ul>	Mogaji (2023)
<ul style="list-style-type: none"> <li>• <b>Collaboration:</b> how commercial banks and FinTechs are related, being able to act competitively or collaboratively, especially when sharing technology or platforms, with the possibility of incorporating FinTechs by commercial banks.</li> </ul>	Bellardini et al. (2022)
<ul style="list-style-type: none"> <li>• <b>Business model innovation:</b> technological changes and pressure from FinTechs alter the strategy and design of the business model of commercial banks, redefining paradigms and new pillars of productivity for banks.</li> </ul>	Mala et al. (2023)
<ul style="list-style-type: none"> <li>• <b>Externalities:</b> studies on how regulations or financial crises such as the COVID-19 pandemic affected banks to accelerate innovations and DTs.</li> </ul>	Malali and Gopalakrishnan (2020); Spencer (2021)
<ul style="list-style-type: none"> <li>• <b>Sustainability:</b> considers the challenges of the banking system to invest in new technologies in a sustainable way amid the intense demand for rapid modernisation and reconciliation with the regulatory environment.</li> </ul>	Siddik et al. (2023)

2020).

Collaboration is a topic of interest in several studies, such as Bellardini et al. (2022). For example, when commercial banks and FinTechs work together, this makes the banking environment more innovative and conducive to the dissemination of I4.0 technologies. FinTechs are known for their agility and innovation in financial services, while banks have experience, resources, and an established customer base (Wu et al., 2023). Such a partnership allows for combining knowledge and capabilities, resulting in more diversified and accessible financial products and services (Ngau et al., 2023). As a result, banks with a more complex structure can benefit from the agility of FinTechs, while FinTechs can take advantage of banks' infrastructure and credibility to expand their business and innovations (Drasch et al., 2018).

In addition to collaborating with FinTechs, the external influence generated by competitiveness and the emergence of I4.0 technologies forced commercial banks to innovate their business models, prioritising DT in more relevant areas in a gradual movement instead of applying the I4.0 in all areas of the bank (Quatrochi et al., 2023; Sanga & Aziakpono, 2023). This progressive transformation of business models, which highlights the strengths of each bank, means that many customers have applications from different banks for different services. For example, an application for managing their mortgage or for international transfers and exchanges, another that offers more rewards for electronic payments and purchases, and another for keeping resources in investments and savings that yield better rates. However, since a few years ago, customers enjoyed all these services from the same financial institution (Hanif & Lallie, 2021; Reaves et al., 2017).

5. Discussion

Based on the results, we suggest a conceptual framework illustrated by Fig. 4, with the representation of the multilevel structure of the banking context, presenting the main strategies developed by commercial banks at each of the levels and their interactions. The small arrows across the levels indicate the cyclical feedback loop aspect of these interfaces, which helps to illustrate the dynamic process and the integration between the levels. The two opposing arrows in the bottom illustrates the progression of I4.0 technologies as facilitators and conditioners of DT, permeating all levels and culminating in value creation.

This framework highlights the significant impact of DT on banking technology infrastructure, driving substantial structural changes (Baiyere et al., 2020; Wessel et al., 2021). According to Salmela et al. (2022), these changes arise from the dynamic nature of digital technologies, the convergence of digital markets, and fluid organisational boundaries. Our analysis finds that the concept of 'fluid organisational boundaries', referring to collaborative efforts among firms to capitalize on I4.0 technologies, best represents the DT process in commercial banks (Baskerville et al., 2020).

Starting from the external layer, the macro level encompasses elements from the banking networks cluster, including factors beyond the control of banks, such as I4.0 technologies, financial crises, and regulatory frameworks. These factors trigger changes in the banking landscape, prompting commercial banks to develop adaptation strategies. From a theoretical perspective, the macro level illustrates the impact of GPTs, with I4.0 technologies acting as pervasive enablers that reshape both the economic landscape and the logic of the banking industry (Cañas et al., 2021; Heikkilä & Wikström, 2021).

The flow reaches the meso level when I4.0 technologies are integrated into the bank's existing technological infrastructure. This intermediate level serves as a bridge between the macro and micro layers, where strategies from the macro level are implemented, including innovations in internal processes, employee training, and organisational restructuring to enhance operational efficiency and address micro-level needs. This aligns with the dynamic capabilities framework (Haki et al., 2024), reflecting banks' ability to sense external changes, seize technological opportunities, and reconfigure resources. At the meso level,

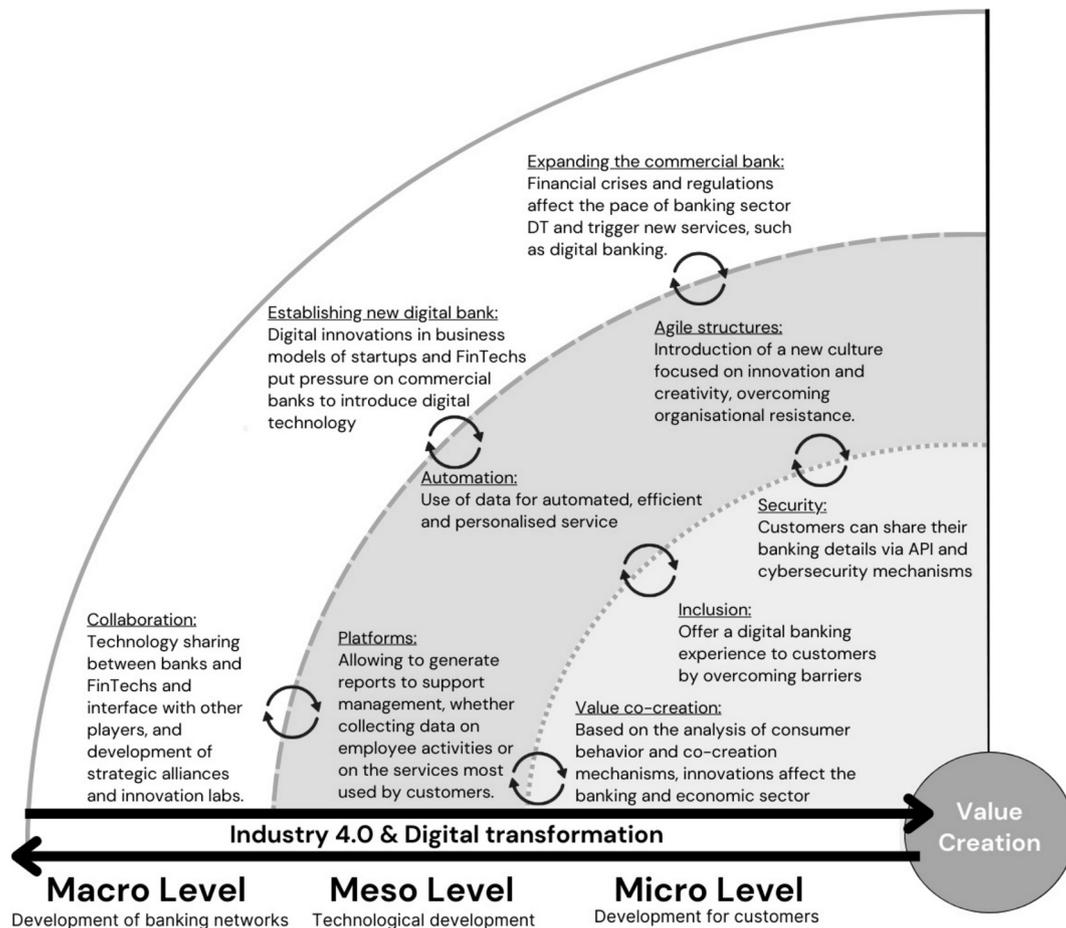


Fig. 4. Conceptual framework.

Note: This conceptual framework illustrates the multi-level structure of DT in commercial banks, highlighting the main strategies at the macro, *meso* and micro levels, and their dynamic interactions. The small arrows represent the feedback loops between the levels, while the two opposing arrows at the base indicate the bidirectional flow of I4.0 technologies as enablers of DT and value creation.

dynamic capabilities are activated to transform GPTs into value-creating innovations, driving DT across all levels (Abdurrahman, 2025).

At the micro level, customer-driven internal demands align with I4.0 technologies integrated at previous levels, enabling enhanced banking services such as improved security, data protection, service efficiency, and overall convenience. The activation of dynamic capabilities is particularly evident in banks' ability to align technological changes with evolving customer expectations (Khan et al., 2021).

Therefore, this multilevel integration shows that DT creates value through an I4.0 technological flow. This flow can be analysed from any direction, according to the arrows represented in the framework. For example, it can be considered from the macro level banking network development cluster, which represents the technological innovations resulting from I4.0, changing the banking context and bringing the digital perspective to the customer in this sector (Dehner & Schumann, 2022; Korherr et al., 2022). This illustrates the nature of I4.0 technologies as GPTs, whose pervasive influence transcends organisational boundaries and initiates structural changes across multiple levels (Birkel & Müller, 2021; Tortorella et al., 2021).

Another way of understanding the flow is based on the micro level, where the customer cluster significantly contributes to the advancement of DT by influencing the banking network through the analysis of customer behaviours, preferences, and perceptions. Banks leverage these insights to develop new and customised solutions, services, and products, driving the evolution of banking networks (Hosseini et al., 2022; Malar et al., 2019; Menrad, 2020). This feedback-driven flow exemplifies dynamic capabilities, as banks continuously adapt to

customer expectations, seizing emerging opportunities and reconfiguring offerings and internal processes, creating a recursive innovation cycle that reshapes institutional strategies and fuels technological evolution (Faro, Abedin, Cetindamar, & Daneshgar, 2024).

It is crucial to emphasize the interconnectivity of all framework elements, as banks must consider all three levels during DT processes. For example, a customer experience-focused strategy at the micro level, as customers gain digital service knowledge, creates new demands (Ngu et al., 2023). This drives banks to invest in new technologies (Kaur et al., 2021), influencing business models, regulations, and the local banking ecosystem, ultimately impacting other levels of the framework and contributing to value creation.

However, it is important to acknowledge that several barriers can impede the flow of DT through I4.0 technology adoption. Internal factors such as a bank's structural complexities, organisational inertia, technological capabilities, and learning processes can either accelerate or slow the transformation (Heubeck, 2023). Contextual elements like the regulatory environment, financial inclusion levels, and customer digital literacy also present obstacles, creating disparities in digital development across banks (Ayllon, 2020). This analysis aligns with GPT theory (Sodokin et al., 2022), which suggests that DT in banking requires a significant period for organisational restructuring (Hilbert, 2020). According to GPT theory, there is typically a lag between initial investments and productivity gains, compounded by institutional and organisational resistance (Lipsej et al., 2005).

In this way, our framework considers the context, the industry, the technologies, and the essential structures for establishing strategies

capable of withstanding the pressures and demands that may arise from any level to achieve DT in commercial banks (Sund et al., 2021). Although there are still operational barriers, challenges, and limitations to be considered, I4.0 technologies have brought several opportunities for commercial banks to expand their structure and be more competitive (Rodrigues et al., 2022; Seran & Bez, 2021; Úbeda et al., 2022).

### 5.1. Micro level strategies

In the customer development cluster, three main strategies emerge: value co-creation, security, and inclusion. Value co-creation involves strategically using customer data, with AI and big data as key technologies to understand behaviour, anticipate trends, and deliver personalised services (Hosseini et al., 2022; Malar et al., 2019; Salmela et al., 2022). From a GPT theory perspective, deploying these technologies effectively allows banks to leverage dynamic capabilities that foster adaptability and continuous value creation.

Manser Payne et al. (2021) highlight co-creation through AI-powered virtual financial assistants, which go beyond basic chatbot functions by offering personalised, real-time support in areas such as investment planning, insurance, and debt consolidation. However, the effectiveness of such tools may be limited by data quality and availability, as privacy concerns, regulatory constraints, and customer hesitation to share information can reduce the accuracy of AI-generated insights.

Security strategies aim to protect data, manage account access, and enable secure transactions, including cryptocurrency use, in line with regional regulations (Elrefae & Nuseir, 2021). Saeed et al. (2023) note that banks in regions like Bahrain face threats such as identity theft, system breaches, and hacking. For instance, during the COVID-19 pandemic, ING Bank observed a surge in phishing attacks exploiting the crisis to send deceptive emails posing as health-related updates, tricking customers into clicking malicious links or sharing sensitive data. These incidents underscored the growing need for strong cybersecurity defences (Cristea, 2021).

Cybersecurity mechanisms and blockchain technology are key strategic tools that strengthen banks' asset protection and customer security (Mróz-Gorgoń et al., 2022). However, their implementation demands significant financial and technological investment, often beyond the reach of smaller or regional banks. Despite robust security efforts, Saeed et al. (2023) found that customers in Iraq and Bangladesh still exhibit scepticism towards online banking, partly due to past high-profile data breaches (Khan et al., 2022). This highlights the need for banks to continuously enhance dynamic capabilities to adapt cybersecurity systems, especially for detecting money laundering, which poses risks to economic development.

The third micro-level strategy centres on customer inclusion, leveraging connectivity to extend digital banking to those hindered by barriers such as limited internet access, low technological literacy, or distrust in digital services (Sohag et al., 2022). These challenges often affect disadvantaged groups, particularly in rural or low-income areas, highlighting the potential of community partnerships and digital literacy programs to bridge the gap (Irfan et al., 2022).

The customer inclusion strategy highlights how financial inclusion contributes to both risk stabilisation for banks and improved credit access for disadvantaged groups and small businesses (Ahamed & Mallick, 2019). Yang and Masron (2023) illustrate this through mobile financial services that enhance identity verification, data management, and timely notifications, reducing transaction errors and indirectly boosting bank profitability.

### 5.2. Meso level strategies

The technological development cluster includes three key strategies: agile organisational structures, automation, and platforms. Agile structures aim to cultivate a digital culture by encouraging teams to work in

squad formats, adapt quickly, and embrace creativity and learning from failure (Furr & Shipilov, 2019; Guinan et al., 2019). This approach represents a dynamic capability that enables organisations to harness emerging technologies such as AI and automation by promoting flexibility, experimentation, and continuous learning. However, transitioning from traditional hierarchies to agile models may face resistance, challenging the development of a digital culture and innovation readiness - an area that could benefit from further exploration of how leadership, organisational culture, and market dynamics affect such transformations (Pacheco-Cubillos et al., 2024).

The second meso-level strategy, also team-oriented, focuses on robotic process automation technology. This technology, supported by AI, can be viewed as a GPT that enables banks to enhance operational efficiency and reduce costs across multiple functions, minimising human intervention in tasks such as risk assessment, detection and prevention of payment fraud and improvement of anti-money laundering processes. This applies to both middle office functions and back-office tasks such as transaction processing, wire transfers, account openings, and fund transfers (Khams, 2022).

Although robotic process automation enhances efficiency and lowers costs, its integration depends on legacy system compatibility and demands significant AI infrastructure investment. Automating routine compliance tasks helps banks meet regulatory demands more efficiently, freeing staff for strategic roles (Adewumi et al., 2024). However, if not properly secured, automated systems may be exploited by cybercriminals. Studies stress the need for robust cybersecurity from the outset, as breaches can erode trust, trigger regulatory sanctions, and hinder digital transformation (Ghelani et al., 2022; Villar & Khan, 2021).

This process aligns with the GPT perspective and the Solow Paradox, which argues that despite automation and AI's potential to boost efficiency, productivity gains may be delayed (Brynjolfsson et al., 2019). In banking, realising these gains requires complementary investments in workforce upskilling, system integration, process redesign, and robust cybersecurity strategies - often causing short-term slowdowns before benefits emerge (Ononiwu et al., 2024).

The third meso-level strategy focuses on enhancing digital platforms for better usability and efficiency, enabling third-party development via APIs. This fosters competition and enhances customer relevance in payment and information services, exceeding regulatory requirements (Karine, 2023). Diamond et al. (2019) highlight that banks are adopting open and cloud-native technologies to create strategic platforms that facilitate intelligent processes addressing common issues across the ecosystem.

The adoption of cloud-based platforms enables banks to scale operations efficiently and offer consistent services across channels, improving accessibility and reliability (Murinde et al., 2022). However, platform expansion requires strong API governance, cybersecurity measures, and data protection compliance, which can complicate third-party interoperability. These challenges demonstrate that meso-level strategies need careful organisational adaptation, technological readiness, and regulatory alignment to achieve sustainable DT in banking (Diener & Špaček, 2021). This also reflects the Solow Paradox, where significant digital investments may not lead to immediate productivity gains (Prakash et al., 2024). Ultimately, the success of these strategies relies on both technological readiness and the gradual adaptation of organisational structures and regulatory frameworks to realise the full potential of DT (Hanelt et al., 2021).

### 5.3. Macro level strategies

The development of banking networks focuses on three primary strategies for business model innovation: establishing a new bank, expanding an existing bank, and collaborating with other players. The first macro-level strategy involves creating a fully digital bank offering services exclusively through its website and mobile applications, without physical branches. This bank may specialise in areas such as

insurance, real estate, or investments, with insights from the digital banking process gradually integrated into commercial banking (Musaev et al., 2021).

However, establishing a fully digital bank can face significant challenges, including building customer trust, ensuring regulatory compliance, and developing robust digital infrastructure, all of which require substantial initial investment and clear market positioning (Melnyk, 2024; Wewege et al., 2020). An example is Suncorp Bank, which began its digital transformation by focusing on unsecured loans, with plans to later expand into secured loans (Hawes & Chitra, 2016).

Digital banks may face challenges in gaining the trust of underserved communities with historical barriers to banking, emphasising the need for targeted outreach and education to tackle digital inequality (Toyon, 2023). These challenges underscore the dynamic capabilities required to adapt to the evolving digital banking landscape, including managing customer perceptions, digital infrastructure, and building trust while leveraging emerging technologies (Abdurrahman, 2025).

The second macro-level strategy focuses on a commercial bank's gradual establishment of a digital bank, progressing by product or service type until it encompasses all sectors (Krasnikolakis et al., 2020). From a GPT perspective, this strategy represents the incremental adoption of foundational technologies across various banking sectors, aiding the transition to more digital-focused business models (Carlaw & Lipsey, 2006). However, legacy systems, internal resistance to change, and challenges in aligning digital initiatives with traditional banking operations may constrain this strategy (Gozman & Willcocks, 2019).

An example of a mechanism driving this strategy is Open Banking, which, through interfaces with other institutions, has expanded banks' digital business models. However, inconsistent regulations across jurisdictions may hinder effective implementation (Ziegler, 2021). Additionally, banks may adopt varying strategies in Open Banking, which could lead to reduced screening efforts to prevent competitors from benefiting or selective information sharing to maintain a competitive edge (Xie & Hu, 2024). Thus, integrating legacy systems with new digital innovations and adapting to regulatory changes requires organisational capabilities to navigate external challenges and internal shifts, enabling banks to leverage the potential of GPTs like Open Banking and APIs.

The third macro-level strategy highlights collaboration with Big-Techs or FinTechs as key to DT, involving the integration of FinTechs or startups to enhance customer interfaces, digitise processes, analyse data, and expand product offerings (Bellardini et al., 2022). For example, banks have partnered with tech giants like Google, Amazon, and Microsoft to improve efficiency and customer experience using cloud computing and AI, while innovation labs foster creativity and competitiveness within the sector (Sund et al., 2021).

Collaborations and strategic alliances with FinTechs also introduce risks related to data security, regulatory inconsistencies, and challenges in integrating FinTech solutions into the bank's existing systems, along with increasing dependence on FinTechs for technological development (Harasim, 2021). This aligns with the dynamic capabilities theory, where FinTechs provide valuable knowledge and technology in these partnerships (Abdurrahman et al., 2024).

## 6. Theoretical implications

This study is a SLR aimed at understanding, in the context of I4.0, the main strategies that commercial banks are developing to adapt to DT, remain competitive, and create value. Building on this foundation, an initial theoretical implication of this study was the conceptual exploration of DT in banking, including key concepts such as digitisation, digitalisation, and the transformation itself, which directly ties into I4.0 technologies and the innovation strategies of commercial banks. DT seeks to establish a new operational framework by integrating technology and leveraging each bank's core competencies to gain a competitive edge, leading to technological advancements, structural and

cultural shifts within banks, and ultimately resulting in value creation (Abdurrahman et al., 2024).

In contrast, DT does not occur continuously but depends on banks perfecting various operational and organisational capabilities to maintain an appropriate pace for the DT process and mitigate their organisational inertia (Faro, Abedin, Cetindamar, & Daneshgar, 2024; Konopik et al., 2022). This implication aligns with the GPT theory proposed by Lipsey et al. (2005), which suggests a time lag between technological investments and productivity gains, characterised by an inevitable transition phase. This involves system integration, staff training, organisational adjustments, and the optimisation of operational processes. An example can be found in the journey of DBS Bank in Singapore. In their case study, Sia et al. (2016) analysed the bank's DT and proposed that the pursuit of a digital business strategy is not merely a project, nor the sole responsibility of a specific digital department or division. Rather, it is a fundamental belief that must be embraced throughout the entire organisation. In doing so, the bank would be better equipped to overcome internal resistance and obstacles, ensuring the success of the DT process.

Secondly, this study facilitated an examination of I4.0 technologies as novel digital resources assimilated by commercial banks in diverse manners, predominantly through the innovation mechanisms of their business models and system integration. The technologies most prominent in the articles were big data, blockchain, AI, and API. These organisational changes lead to another theoretical implication, which relates to the dynamic capabilities theory (Heubeck, 2023; Teece, 2007). As banks strive to continuously adapt to emerging innovations in response to market demands, they demonstrate the dynamic reconfiguration of their resources and capabilities. The complexity of this process leads many banks to gradually transform their business models, with the coexistence of more traditional business models and those that are more modern and aligned with I4.0 technologies being common. An interesting example is the coexistence of banking services involving both traditional and digital currencies, which will significantly impact the payment system, both domestically and internationally, reflecting not only a global trend but also the inevitable outcome of the digitalisation of financial and non-financial services (Galazova, 2023).

Finally, this study presented a conceptual framework emphasising the flow of I4.0 technologies in the banking sector through the DT process, highlighting the integration between three levels of development: customers, technology, and banking networks. This framework is novel in its approach, offering a systemic view of how I4.0 technologies interconnect these critical elements, and expands on previous research (e.g., Mehdiabadi et al., 2020; Poloz, 2021) by providing a high-level, integrative perspective that is not limited to individual banks or isolated studies. It contributes to the understanding of how I4.0 has opened new possibilities for banking services, fostering a continuous dissemination of these technologies across multiple dimensions of the banking sector. In doing so, the conceptual framework goes beyond the existing literature, such as specific analysis of a single bank or group of banks but integrates multiple studies to address critical factors that are both external: increased competitiveness, regulatory barriers, financial crises; and internal: organisational learning levels, engagement, and internal resistance.

Given this, the successful management of these factors becomes crucial, as the DT process can experience slowdowns or discontinuities if not properly addressed (Hughes et al., 2023). For instance, the COVID-19 pandemic underlined both the opportunities and the necessity for adaptable banking organisational structures, as regulatory measures like lockdowns and restricted in-person interactions have driven the rapid adoption of digital collaboration tools (e.g., Zoom), service delivery innovations (e.g., AI and robotic process automation), and customer relationship management via digital channels (Hanelt et al., 2021).

## 7. Managerial implications

This study highlights essential managerial strategies for banks undergoing DT, particularly addressing internal and external pressures. A phased approach to digital initiatives allows gradual adoption of new technologies, preventing overload on operational resources. For example, AI-powered virtual financial assistants can enhance customer engagement by offering personalised services like investment planning and debt consolidation, while partnerships with financial technology firms help banks access advanced solutions without significant internal investment (Manser Payne et al., 2021).

Security and compliance remain top priorities in the digital era. Banks must strengthen cybersecurity frameworks to mitigate risks such as identity theft and hacking, while regulatory technology tools streamline compliance processes (Saeed et al., 2023). Cloud-based platforms provide cost-effective solutions for securing data and ensuring consistency across digital channels, which is particularly beneficial for banks with limited resources. These strategies are crucial for maintaining operational efficiency and meeting regulatory obligations in a rapidly evolving environment (Murinde et al., 2022).

Lastly, promoting financial inclusion is an effective strategy for expanding banking services while managing resource constraints. Mobile-first solutions, which improve identity verification and communication, reduce transaction errors and enhance customer satisfaction, leading to long-term profitability (Yang & Masron, 2023). However, overcoming organisational resistance to DT requires strong leadership to guide cultural shifts and ensure alignment with market demands and regulatory frameworks. These approaches directly influence a bank's competitiveness and market position in an increasingly digital financial landscape.

## 8. Limitations

This article presents several limitations, which also open up avenues for future research. First, we are limited by the fact that the DT process in commercial banks is analysed solely within the context of I4.0 technologies. Future research should examine the DT process through alternative theoretical perspectives, offering complementary insights into how organisations adapt and integrate transformative technologies over time. Furthermore, adopting different methodological approaches could further enrich the understanding of DT in the banking sector by exploring more in-depth organisational, institutional, and ecosystem factors.

Additionally, the research relies exclusively on a SLR of 287 peer-reviewed academic articles. While this approach provides a strong theoretical basis, it may not fully capture the practical applications or immediate industry trends that are often documented in sources outside of the academic peer-reviewed literature, such as official banking reports or grey literature. As these types of documents are frequently used by practitioners to track real-time developments, and their exclusion may lead to an incomplete understanding of how these technologies are currently being implemented in the banking sector, future research should consider incorporating them to provide a more holistic and contemporary perspective.

## 9. Future research

In addition to the future research avenues identified through our study's limitations, we now present further areas for investigation that emerged from our findings.

### 9.1. Comparative studies between commercial banks by region

Due to legal, social, and cultural differences, customer demands for banking services vary significantly across regions. Given that banks typically publish comprehensive annual reports, future research could

adopt a comparative longitudinal methodology - employing both quantitative and qualitative approaches - to examine these variations. Such an approach could yield deeper and more nuanced insights into the appropriate DT agendas for both developed and developing economies or different business systems (Whitley, 1999). From a theoretical standpoint, frameworks such as institutional theory (e.g. Scott, 1995) or diffusion of innovation theory (Rogers et al., 2014) could be employed to investigate how regional factors influence the adoption of DT in commercial banks and to identify the most suitable strategies accordingly. Furthermore, it would be valuable to compare private and public commercial banks, analysing which technologies each prioritises in their DT processes. Ethnographic and case study approaches would be particularly relevant to uncover the organisational dynamics, decision-making rationales, and stakeholder interactions that shape DT implementation. These methods could offer rich contextual insights into how institutional pressures, governance structures, and customer expectations influence the trajectory of digital transformation across different banking models and regions.

### 9.2. Comparative studies with other sectors

Another opportunity for future research would be to conduct comparative studies using large datasets to conduct longitudinal cross-industry analysis (Jain et al., 2017) between the banking sector and other economic sectors, such as retail, manufacturing, healthcare, and education, regarding the implementation of I4.0 technologies through DT. Such studies could highlight the similarities and differences in the adoption and impact of emerging technologies in different contexts, helping to better understand the role of factors such as regulation, market structure, and consumer needs in the DT process. Moreover, such longitudinal analysis would be particularly important to observe changes over time in different sectors, comparing the pace and forms of adoption of I4.0 technologies and their impact on organisational performance and customer experience. Theoretical lenses such as resource-based view (Barney, 2001) or stakeholder theory (Freeman et al., 2010) could provide valuable perspectives on how organisations in various sectors utilise I4.0 technologies to create competitive advantage or meet stakeholder expectations.

### 9.3. Investigate other Industry 4.0 technologies

A third opportunity for future research would be a more thorough investigation into other I4.0 technologies mentioned in this SLR, such as machine learning, cloud computing, and IoT. Case studies and documentary research using bank reports or interviews can be applied to explore the application of these technologies, which are essential for banking services (Kariuki et al., 2024). The reason for their under-utilisation may be database limitations, and conducting detailed research could help clarify how these technologies can be better leveraged in the DT of banks. Further investigations specifically focusing on these technologies are crucial to understand if there are new possibilities for advancing the DT process in banks, or if there are other barriers preventing the adoption of certain digital tools (Pacheco & Iwaszczenko, 2024).

### 9.4. New business models

DT entrepreneurs are developing new business models aimed at boosting the growth of their companies to a level where they can pursue acquisition agreements with established companies (Supe et al., 2019). After the emergence of FinTechs, other types of startups linked to financial services are arising in the economic context, such as 'InsurTechs' related to insurance, 'PropTechs' associated with the real estate market, and those focused on crowdfunding (Cruz Rambaud & López Pascual, 2023). These movements, driven by DT, indicate a tendency for the emergence of new startups. These startups may not necessarily

become competitors of banks, but they can provide complementary services and gain significant relevance in the future. Thus, the third suggestion for future research would be to explore the new business models emerging in the banking sector and examine which I4.0 technologies these new companies are applying. This approach can be further developed using quantitative or qualitative methods, with case studies serving as an interesting alternative to gain a deeper understanding of these innovations in business models.

### 9.5. Other methodological alternatives

Our analysis indicates a surge in academic articles on this topic since 2020, reflecting heightened interest within the research community. Given the valuable insights gleaned from these studies regarding relevant strategies and mechanisms, we advocate for deeper exploration using quantitative and qualitative methodologies. These approaches hold promise for facilitating a more nuanced understanding of the complex interactions among the 16 topics we identified as driving DT in commercial banks. Furthermore, rigorous regression analysis can unveil the relative influence of these topics on the DT process. Additionally, applying theoretical frameworks such as absorptive capacity perspective (Cohen & Levinthal, 1990) could help examine how commercial banks develop the ability to integrate and apply new I4.0 technologies within their business models. These studies can identify unique attributes and evolutionary paths among organisations operating in diverse contexts, including regional or national disparities.

Finally, the focus of such investigations should extend beyond technological aspects alone to encompass the customer-centric dimension. Our research underscores the critical significance of customer experience, which emerged as the most explored topic with 47 selected articles. Therefore, qualitative research is warranted to uncover the underlying mechanisms and drivers within a comprehensive framework. Consequently, ethnographic research assumes particular importance in understanding the roles of customers and stakeholders in shaping DT in the commercial banking sector. In alignment with this, given the prominence of customer experiences, the use of experiments becomes particularly pertinent. Those different perspectives will be essential in understanding how commercial banks approach the increasing consolidation of customer-centric practices in a holistic way.

### CRedit authorship contribution statement

**Thiago Felipe:** Writing – review & editing, Writing – original draft, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Rui Torres de Oliveira:** Writing – review & editing, Visualization, Validation, Supervision, Project administration, Methodology, Conceptualization. **Agnes Toth-Peter:** Writing – review & editing, Software, Resources, Data curation. **Shane Mathews:** Supervision. **Uwe Dulleck:** Supervision.

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### Data availability

Data will be made available on request.

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