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The impact of metaverse for business model innovation: A review, novel insights and research directions

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ABSTRACT

Digital transformation is changing the way businesses operate. Emerging technologies have the ability to impact products, processes, value chains, networks, and business models. In this panorama, metaverse offers to businesses and consumers new ways to interact with each other, toward the establishment of new virtual and interconnected spaces. Although, business have rapidaly adopted metaverse technologies for several purposes, the metaverse research field is still in its infancy, and there is a lack of understanding of meanings, purposes, and opportunities. With the aim of providing an historical overview, this study examines the role of metaverse in business model innovation, unveiling the elements introduced by this emerging technology that can affect companies' business models, the changes that metaverse generates over time in value creation and value capture actions, and the sectors most involved in this transformation. A systematic literature review with a double layer of analysis was conducted (bibliometric and content analysis). Our results reveal that over time, metaverse generated three waves of impacts on companies' business models. For each wave, the actions of value creation and capture enabled by metaverse were identified and the sectors involved in this transformation over time were summarized. Results were discussed in order to debate the capability of metaverse to generate new actions of value creation according to radical, incremental, and exaptation paths of innovation and the consequent capability to capture value among several stakeholders. Salient research gaps emerged and future research directions were proposed.

1. Introduction

Digital transformation (DT) has become popular in recent years as it represents a path toward the integration of digital technologies into business processes (Liu et al., 2011). As a consequence, companies have undertaken various initiatives to explore new technologies and to capitalize the related benefits (Matt et al., 2015). This exploitation path allows a company to integrate products and services across functional, organizational, and geographical boundaries, thereby leading to relevant business transformation (Sebastian et al., 2017). Therefore, DT has changed the way that companies operate (Dal Mas et al., 2020) by introducing the paradigm of "Industry 4.0" (Lasi et al., 2014) and leveraging on artificial intelligence, distributed ledger technology, digital twin, augmented reality, metaverse, and other emerging digital technologies (Dimitris Mourtzis et al., 2022b). DT is also generating an evolutionary path in companies' business models (Priyono et al., 2020), reshaping value creation and value capture with unexplored possibilities (Teece, 2018).

In this panorama, the metaverse landscape has the potential to change products and services to offer businesses and consumers new ways to interact with each other toward the establishment of new virtual and interconnected spaces (Giang Barrera and Shah, 2023).

The term "metaverse", which was first introduced by (Stephenson, 1992) in the book *Snow Crash,* refers to the fusion of virtual and real life in a black spherical planet in which people can use avatars to move, interact, and communicate, hence extending the physical world (Kohler et al., 2009; Messinger et al., 2019). Avatars interact within real and simulated environments by leveraging augmented and virtual reality technologies (Dwivedi et al., 2022; Keeling et al., 2010). Enterprises will have the ability to expand and enhance their business models in

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unprecedented ways by moving from a digital business to a metaverse business (Kraus et al., 2022b). As declared by Marty Resnick, vice president at Gartner,[1] by 2026, 30 % of the organizations in the world will have products and services. The global metaverse market size was estimated at USD 38.85 billion in 2021 (Grand View Research, 2021). A survey by the SDA Bocconi School of Management on investments in companies in the digital sectors revealed that the investments in companies claiming to be involved in the metaverse had rapidly increased: +4.500 % from the third to the fourth quarters of 2021.[2] This trend was pushed by the COVID-19 pandemic, which sped the emergence of virtual communities as major lifestyle areas for locked-down users (Kraus et al., 2023; Zhan et al., 2022).

The worldwide technological giants have recently invested in metaverse: i) Facebook changed its name in Meta (López-Díez, 2021) and is investing millions of dollars in building a digital universe based on metaverse (Giang Barrera and Shah, 2023); ii) Microsoft is focusing on the development of work-based metaverse environments (i.e., Microsoft Mesh) with the aim of facilitating immersive collaboration in virtual space for teams that can also be accessed via mixed-reality glasses and virtual reality (VR) headsets (Dwivedi et al., 2022); iii) Google announced it was setting up a 39.5 billion dollars private equity firm to found metaverse projects (Winterhalter, 2023); and iv) Epic Games, in April 2022, is raised 2 billion dollars of investments of Sony Group Corporation and Lego group to build metaverse spaces where players cand have creative and involvement experiences (Jaung, 2022; Weking et al., 2023).

Several scientific studies also testify to the development of metaverse technologies in different industries, not only in the gaming world (Jung and Pawlowski, 2014; Rapp, 2020) but also for big fashion brands (J. Kim, 2021), agri-food (Cha, 2022), transport (Deveci et al., 2023; Pamucar et al., 2022), and medicine and healthcare (Zahedi et al., 2022), in which companies are becoming familiar with strategies based on metaverse to increase competitive advantage. Fields of application that are widely discussed in the international scientific scenario are marketing (Arghashi, 2022; Bhardwaj et al., 2023; Bloom, 2020), advertising (Fang et al., 2014; J. Kim, 2021; Q. Li et al., 2021), education (Kumar et al., 2008; Kye et al., 2021), and social studies (H. Choi and Kim, 2017; Falchuk et al., 2018). Following a value creation lens, Ferrigno et al. (2023) leveraged on a thematic analysis of 895 press releases published by LexisNexis between October 2021 and October 2022 and identified four relevant topics of value creation in the metaverse age: three primary enablers of value creation in metaverse (affordable design cost, decentralized database and cryptocurrency as a medium of exchange); five digital resources as value creation drivers (extended reality, VR, augmented reality, blockchain integration and non-fungible tokens [NFTs]); four different justifications for the creation of value in metaverse (social and business engagement, new entrepreneurial opportunities, DT intention, and return on investment); and five practices that support the creation of value in the metaverse (strategic initiatives, social media presence, interoperability, standardization, and product simulation).

Although, this evidence testifies to the increasing global attention and the rapid adoption of metaverse technologies by businesses for several purposes, the metaverse research field is still in its infancy and there is a lack of understanding about meanings, purposes, and opportunities (Giang Barrera and Shah, 2023), thereby opening the way to an interesting and unexplored research route. According to this perspective and to the best of the author's knowledge, Abbate et al. (2022), Schmitt (2022), Giang Barrera and Shah, (2023), and Ritterbusch and Teichmann, (2023) proposed literature reviews of the metaverse research field with the aim of systematizing the related knowledge, focusing, respectively, on: i) the key topics revolving around the metaverse research field; ii) the guidelines for implementing metaverse-based strategies; iii) the application of metaverse in the marketing field; and iv) the scientific definition of metaverse and its main characteristics (more details are in Section 2).

To complement the current literature reviews on metaverse, we are interested in providing an historical overview of the role of metaverse in business model innovation, unveiling the elements introduced by this emerging technology that can affect companies' business models, the changes that metaverse generate over time in value creation and value capture actions, and the sectors most involved in this transformation. Starting from this purpose statement, we seek to address the following research questions: a) *What are the elements introduced by metaverse that are capable of impacting companies' business models? b) What are the changes that metaverse generates over time on value creation and capture actions? c) What are the sectors most involved in business model innovation through metaverse?*

To address these questions, we conducted a systematic literature review with a double layer of analysis (bibliometric analysis and content analysis) of a sample of studies obtained from Scopus and Web of Science (WOS). Our results reveal that metaverse generated over time three waves of impacts on companies' business models, generating new actions of value creation and capture. We also identified 22 sectors involved in business model innovation through metaverse.

Results were discussed in order to provide an answer to the proposed research questions debating the capability of metaverse to generate new actions of value creation according to radical, incremental, and exaptation paths of innovation and the consequent capability to capture value among several stakeholders (e.g., suppliers, customers, and partners). From our discussion, salient research gaps emerged and future research directions were proposed.

The novelty of the current study consists of providing insights about the metaverse's ability to impact and change companies' business models over time, thus representing the first reflection point on this new path of business model innovation and laying the foundation for building the next wave of metaverse-based business model innovation.

2. Theoretical background

2.1. Metaverse: Key topics, guidelines, and applications

The metaverse is the next evolution of the Internet, called 3-D Internet, and it could radically innovate areas that have resisted the digital revolution (Dwivedi et al., 2022). Communication, social transactions, and human interaction have been modified and enriched by several digital innovations, and, metaverse represents an evolutionary milestone of the DT process that the global landscape is currently experiencing. As discussed in the Introduction section, metaverse has obtained increasing global attention and rapid adoption by businesses. Despite this, the metaverse research field is still in its infancy, and there is a lack of understanding of its meanings, purposes, and opportunities (Giang Barrera and Shah, 2023). To the best of the authors' knowledge, Abbate et al. (2022), Schmitt (2022), (Giang Barrera and Shah, 2023) and Ritterbusch and Teichmann, (2023) proposed qualitative studies with the aim of systematizing the metaverse knowledge, placing them in this research route.

Abbate et al. (2022) defined metaverse as a "new universe" and proposed a literature review to discover the key elements of metaverse. They found that the key novelty of metaverse is the possibility of increased online interactions and socialization in virtual communities, with the advantage of triggering a wider range of emotions. This broader range of emotions allows companies to exploit customer relationship strategies that could not previously be applied and thought. In this process, avatars play a strategic role, representing the human extension

[1] https://www.gartner.com/en/newsroom/press-releases/2022-02-07-gartner-predicts-25-percent-of-people-will-spend-at-least-one-hour-per-day-in-the-metaverse-by-2026

[2] https://www.sdabocconi.it/it/news/blockchain-e-metaverso-fanno-decollare-gli-investimenti-in-startup

and its impersonation in the virtual world, and they offer new experiences different from the ones offered by the hypertextual information or static media currently exploited in Web 3.0: interoperability and accessibility will drive the potential that the metaverse can offer.

Schmitt (2022) proposed a literature review to discover several guidelines for implementing metaverse-based strategies. The author defined the metaverse as a tool for innovation based on human ingenuity and creativity that is capable of leading to an innovation potential only limited by human imagination. He also discussed the disruptive potential of metaverse to shift the basis of competition and to open opportunities for the disruptive innovation in market and business models. Although metaverse could lead to the generation of new value and competitive advantages for businesses, the factors arising from the macroenvironment should not be overlooked. From an economic perspective, the metaverse represents the beginning of a single, global, virtual economy that transcends national borders. According to the geopolitical lens, companies are faced with approaches and interests that differ between countries and governments, which makes it vital to manage forces beyond the market. Regulations tend to have a strong impact on companies in certain jurisdictions and must be considered on the basis of geographical region. Disruptive metaverse technologies were the curtain that opened the scene to the new era of DT, by tracing the starting point to the 3-D Web. Currently, metaverse-based technological tools are at the antipodes and in the short term, are expected to become more powerful and affordable for many, if not all. The metaverse also shows social potential to drive global inclusion of emerging countries and to provide a virtual global economy in which all can compete, offering an unprecedented opportunity for value creation.

Turning our attention to marketing, which is a key element in business strategies, the metaverse meets the needs of the marketing 4.0 paradigm that considers the customer as co-creator of the product/service. Following this theoretical lens, Giang Barrera and Shah, (2023) proposed a literature review to analyze the current marketing applications based on metaverse~~,~~ since the applications in marketing are the most widespread in the current scenario. In the past, the use of the metaverse might have been distant and not within everyone's reach, but today, investors and pioneers of metaverse are riding the wave, thanks also to the maturity of digital technologies such as Blockchain and NFT. Giang Barrera and Shah, (2023) elaborated a framework that draws guidelines for the use of the metaverse in the user experience by placing a real bridge between the business and the consumer. However, there are several risks associated with the development of the metaverse related to (Giang Barrera and Shah, 2023; Schmitt, 2022): i) excluding consumers who lack the technological devices or skills for participation in metaverse experiences; ii) overreliance on metaverse, which could lead to the creation of a parallel reality and to divisions in society instead of cohesion, inclusion, and collaboration; and iii) the lack of technical standards capable of assuring an open and interoperable business environment in which everyone can compete and monopolies can be avoided.

Ritterbusch and Teichmann, (2023 p. 6) conducted a literature review to analyze and investigate scientific definitions of metaverse and the related main characteristics. This analysis led the authors to develop an overall and inclusive definition of metaverse: "a (decentralized) three-dimensional online environment that is persistent and immersive, in which users represented by avatars can participate socially and economically with each other in a creative and collaborative manner in virtual spaces decoupled from the real physical world."

These issues require researchers, practitioners, and companies to focus their efforts to address the current challenges of metaverse adoption by developing guidelines, suggestions, and policies related to the metaverse and its capacity to affect and transform the business models of companies.

2.2. Business model innovation: The role of digital technologies

The business model (BM) represents how a company creates and delivers value to customers, and it embraces mechanisms useful for capturing and sharing this value (Osterwalder and Pigneur, 2010; Sjödin et al., 2020; Teece, 2018). Through the development of a clear BM, a company can better understand the costs, revenues, and profit flows thanks to which it can achieve market stability over time (Teece, 2018).

Following a strategy-oriented lens, two elements are core in any BM: value creation and value capture. Value creation represents the company's capability to develop high-value products and/or services through which to satisfy for the better the lasting needs of customers (Rayna and Striukova, 2016). Value capture is the process of securing profits from the value creation and the distribution of those profits among the several stakeholders (Chesbrough, 2010; Osterwalder and Pigneur, 2010). Therefore, value can be distributed toward internal or external stakeholders, such as owners, managers, employees and customers, suppliers, investors, creditors, society, shareholders, and the government (Hall et al., 2023).

A critical point in the debate over BM design is not only the design of the value creation and capture processes but also ensuring they are adapted to and aligned with each other (Foss and Saebi, 2018; Ritter and Lettl, 2018; Sjödin et al., 2020). Thus, the BM does not represent the company strategy, but it is a tool that companies could use strategically. Doing this in the complex current business scenario~~,~~ requires that the company possess and leverage dynamic capabilities with the aim of strategically managing and making the most of the BM over time (Teece, 2018). For this reason, the BM must not represent an immutable work of art~~,~~ because if it did, it would lead the company into the red oceans of competitiveness and failure (Mauborgne, 2005).

BMs today are experiencing an evolutionary path driven by innovation and DT (Priyono et al., 2020), which leads to the business model innovation (BMI) theory: BMs evolve to take the company toward new blue oceans (Mauborgne, 2005), where value creation and value capture are shaped with unexplored possibilities deriving from both DT and company dynamic capabilities (Sabaruddin et al., 2023; Teece, 2018).

To better understand the transition from BM to BMI, we can refer to the fundamental theories of innovation. Schumpeter, the father of innovation theory, defined innovation by explaining its close connection to the processes capable of generating innovation as incremental or radical. Incremental innovation involves minor changes in existing practices, products, or services (Schumpeter, 2021); therefore, an incremental BMI implies a BM modification without making substantial changes in its structure. Radical innovation is the creation of new practices, products, and processes that are different from those previously existing (Schumpeter, 2021); therefore, a radical BMI implies the upheaval of an existing BM by making substantial modifications and sometimes completely changing it.

Another contribution to innovation theory comes from the exaptation theory (Cattani, 2006; Dew et al., 2004). Exaptation is a discontinuous evolutionary process that "identifies a third channel driving the emergence of novelty: a functional shift of an existing artifact that is not traceable to the discovery of new phenomena or the pull from clearly defined needs" (Andriani and Cattani, 2016, p. 116). Exaptation allows existing technologies to: (a) build new technological niches; (b) enter existing niches; or (c) transform internal components of current products by increasing their efficiency or extending their range of features without creating new products (Andriani and Carignani, 2014). Exaptation can help BMI ~~(Codini et al., 2023)~~change an existing BM through a soft and synergistic action between the internal and external environments (Andriani and Carignani, 2014; Dew et al., 2004; Codini et al., 2023).

BM innovation can have a different degree of radicality. Through the radicality factor, it is possible to establish whether the innovation of the BM is a radical or incremental innovation, and by analyzing scope and complexity factors, it could be possible to understand if the BMI

followed the exaptation path.

The emerging technologies' daughters of the fourth industrial revolution play a fundamental role in the innovation processes of the BMs since technological progress is an enabler of BMI (Teece, 2018). We can provide some examples showing the innovation of BMs driven by emerging technologies. The Web has caused a great wave of innovation that has led to the disintermediation of value creation, leading to companies moving their selling activities online (in part or entirely) and generating an incremental innovation of the existing BM (Armstrong, 2006). The advent of Internet of Things (IoT) is adding a layer of intelligence in physical objects (e.g., smartwatch, car, house), which become capable of collecting and communicating data related to customers and/or environments with the potential to change the usage model from onetime sale to rental and to greatly vary the value capture and generate radical innovations in BMs (Haaker et al., 2021). The advent of Blockchain technology has brought about a change of course in traceability processes, especially in the agri-food sector, leading to a change in the value proposition according to the servitization process. Therefore, companies offer a product accompanied by a set of information useful for guaranteeing its quality and safety, changing the BM and intercepting new targets of conscious consumers (Tiscini et al., 2020). Digital Platforms changed the way people seek information, purchase goods, consume news and media, travel, and move (Trabucchi et al., 2022). The value created is based not only on the platform's capability to reduce transaction costs and resolve frictions between two (or more) parties but also on four other factors useful to enhance and enrich the company's value proposition in innovating the related BM: environmental reliability, data-driven expansions, personalized services, and engagement mechanisms (Trabucchi and Buganza, 2023). The platform thinking revolution innovated BM leveraging on four different type of platforms: Product Platforms using a common core architecture that allowed to companies to customize their offer; Innovation Platforms offering a core product to third parties to develop complementary innovations based on the main platform; Transaction Platforms enabling transactions between different groups of actors; and Orthogonal Platforms leveraging on data to capture value connecting two unrelated customer segments (Trabucchi et al., 2022).

These examples testify to how change generated by technologies can be relevant to both value creation and value capture; in addition, the innovation of the companies' BMs can be obtained according to exaptation since a new product was not created but technology allowed the current product to be transformed by increasing its efficiency and extending its range of features.

The metaverse, configuring itself as an emerging and disruptive technology as was the case for the other technologies, has the potential to impact on the BMs of companies, opening to a new evolutionary path of BMI.

3. Materials and methods

3.1. Choosing the review methodology

We conducted a literature review as independent studies (Kraus et al., 2022a,b) to analyze the role of metaverse in BMI, unveiling the elements introduced by this emerging technology that can affect companies' BMs, the changes that metaverse creates over time in value creation and value capture actions, and the sectors most involved in this transformation. Literature reviews allow researchers to enhance their understanding of prior work in their field, enabling them to identify research gaps and future research routes (Kraus et al., 2022a,b; Rojon et al., 2021; Tang et al., 2023). This kind of study can be described among five fundamental elements (Fig. 1). Among the two *types of literature reviews*, this study used a systematic literature review (SLR) with the aim of enabling transparent disclosure and replicability by using a well-established protocol to guide data curation and analysis (Kraus et al., 2020; Lim et al., 2022). SLR allows the researcher to identify and critically analyze contributions to the research topic (Liberati et al., 2015; Sauer and Seuring, 2023), systematizing and sharing the results about a specific body of literature (Creswell and Creswell, 2017; Snyder, 2019; Tang et al., 2023).

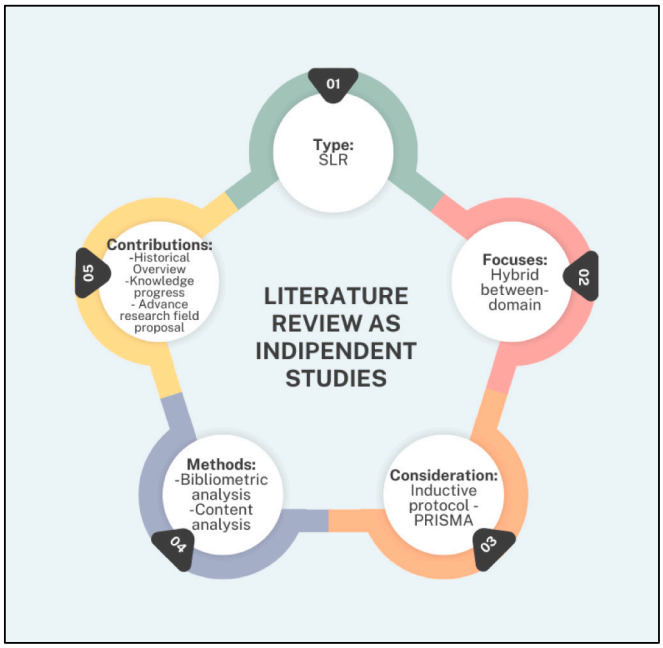

Fig. 1. Fundamental elements of this literature review as independent studies according (Kraus et al., 2022a,b).

This SLR is *domain-focused* and, specifically, a *between-domain hybrid* because it is focused on metaverse in BMI. Since the considerations required for literature reviews depend on their type, this SLR followed the *inductive reasoning approach* based on the PRISMA protocol to develop a corpus of scholarly documents to review (more details in Section 3.2). The retrieved sample of studies was synergistically analyzed using two *methods*: bibliometric and content analysis (more details in Section 3.3). The *contributions* emerging from this SLR are the following: i) provide an historical overview of the metaverse role in BMI; ii) provide the knowledge progression of the research field toward the description of the subsequent value creation and capture actions enabled by metaverse; iii) provide future research directions that could represent potential pathways for advancing the research domain, thereby laying the foundation for building the next wave of metaverse-based BMI.

3.2. Planning the SLR, considerations, and data collection

We adopted the PRISMA protocol to identify the corpus of scholarly documents to review (Page et al., 2021). According to this protocol, the search database, search scheme, and inclusion and exclusion criteria need to be defined. To avoid bias outcomes due to the scope covered by the selected database, we chose two databases (Scopus and Web of Science (WoS)) (Dabić et al., 2023). Search keywords were used to identify and carefully select the relevant literature by defining a well-structured query and combining representative keywords through Boolean operators (Kraus et al., 2022a,b). To improve the quality of our research scheme, we engaged in preliminary research to discover the search keywords more representative of the field of analysis (more information in Table 1).

After a procedure of samples merger and elimination of duplicates a sample of 34 studies was analyzed using Bibliometrix in Rstudio. Applying frequency analysis on title and abstract, we selected the 20 most recurring words representative of the metaverse technological field that we used in combination with keywords representative of BMI

Table 1
Details about preliminary data collection.

Scope of the data collection	Identify representative search keywords for the data collection procedure
Preliminary search scheme	("metavers*" AND ("value creation" OR "value capture" OR "business model")).
Database	Scopus and WoS
Search data	April 18, 2023
Search field	"article title, abstract, keywords"
Search period, subject area, publication stage, document type, source type	No limits
Language	English

("value creation", "value capture", "business model") to compose the search scheme. The details about the data collection procedure are summarized in Table 2.

As shown in Table 2, no limits were applied on subject area, publication stage, document type, and source type in order to guarantee a large sample of studies to analyze and to avoid missing potentially important contributions. The limit on English language was posed since it represents the academic lingua franca. Moreover, the search period was set until December 31, 2023, to have the analysis for the entire year.

After merging the sample coming from Scopus and WoS databases and eliminating duplicates, we obtained an initial sample of 724 studies. This sample was screened through the assessment of title and abstract with the aim of selecting the manuscripts that better reflect the scope of our study, leading to an intermediate sample of 551 studies. The intermediate sample was used to perform bibliometric analysis (more information in Section 3.3). Thanks to thematic longitudinal map analysis carried out in bibliometric analysis, it was possible to identify a cluster of 159 studies focused on the intersection between business models and augmented reality topics, which are the topics closest to our field of study among those highlighted by the analysis. The full text screening of these 159 documents allowed us to identify 76 studies focused on discussing the impact that metaverse has on business models. This final sample was analyzed using content analysis (more information in Section 3.3). The adopted screening process is summarized in Fig. 2.

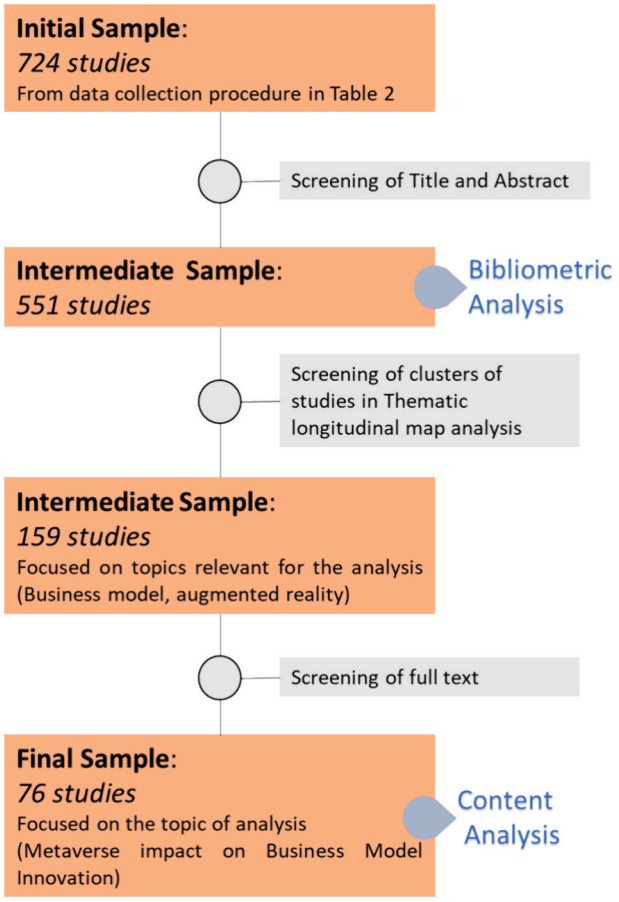

Fig. 2,. Screening process.

3.3. Data analysis methods

As previously introduced, two kinds of methods were used in this study to analyze the corpus of scholarly documents: bibliometric and content analysis.

Bibliometric analysis represents a methodology for analyzing research outputs, and it is born from library and information science fields (Rodríguez-Rojas et al., 2019). It allows scholars to objectively analyze a large corpus of studies using quantitative techniques (Donthu et al., 2021) and it combines two overarching categories of analysis: performance and science mapping (Kraus et al., 2022a,b). The first one, leverages word frequency analysis, citation analysis, and country publications analysis (Thelwall, 2008), and it is capable of assessing the productivity and impact of the literature of the analysis domain (Kraus et al., 2022a,b). The development of computer technologies makes this methodology an interesting option to evaluate the structures and networks science (Gaviria-Marin et al., 2019).Using Bibliometrix tools in Rstudio, we provided an overview of the research field (Section 3.3), assessing the following performance of the intermediate sample of 551 documents: main features of the sample; publications and citations trend; relevant authors, institutions and countries; country collaboration map; and trend topics. Science mapping allows the spatial representation of how scientific actors or topics are related to each other (Kasavan et al., 2021; Small, 1999). Science mapping supports scholars to map the literature in the analysis domain by leveraging on bibliographic data (e.g., bibliographic coupling, co-citation analysis, co-occurrence analysis) (Kraus et al., 2022a,b). Using Bibliometrix tools in Rstudio we performed the following science mapping analysis: co-occurrence network on authors keywords, thematic map; thematic longitudinal map; thematic map over time (Sections 4.1 and 4.2).

Content analysis was applied to the final sample (76 studies) to unveil the impact of metaverse on BMI. Content analysis is a "careful, detailed, systematic examination and interpretation of a particular body of material in an effort to identify patterns, themes, biases, and meanings" (Berg et al., 2012, p. 338). It is useful to analyze a small to medium corpus of studies using quantitative and qualitative techniques (Kraus et al., 2022a,b). Following the qualitative lens, we conducted a thematic analysis using a data extraction form designed to summarize useful data from the selected studies (Leonidou et al., 2020; Llorent-Bedmar et al., 2021; Nguyen et al., 2018; Vrontis and Christofi, 2019). A training phase for the researchers team was made in order to avoid differences in

Table 2
Details about data collection procedure.

Scope of the data collection	To identify the corpus of scholarly documents to review
Search scheme	(("metavers*" OR "augmented reality" OR "virtual reality" OR "extended reality" OR "virtual word" OR "mixed reality" OR "second life") AND ("value creation" OR "value capture" OR "business model")).
Database	Scopus and WoS
Search data	March 6, 2024
Search field	"article title, abstract, keywords"
Search period	Until December 31, 2023
subject area, publication stage, document type, source type	No limits
Language	English

coding and abstraction (Snyder, 2019), with the aim of minimizing human error and increasing the procedure's replicability (Leonidou et al., 2020; Nguyen et al., 2018). We traced the following themes: actions of value creation, actions of value capture, sector involved in metaverse transformation, and related technologies. Thanks to this analysis, we discovered three different waves of metaverse impacts on BMI, described in Section 4.3.

3.4. Overview of the research field

Thanks to the performance analysis, the main features of the intermediate sample (551 studies) were investigated and are summarized in Fig. 3. Covering a time span of 25 years, the role of metaverse in BMI has been studied by a wide and international network of authors demonstrating a document average per year of 7.74 and an annual growth rate of 13.74 %. (See Fig. 4.)

The analysis of the publication and citation trend over time evidences the increasing interest in the research topic with a publication rate doubled by almost 50 % from 2021 to 2023. The trend of citations is almost constant over time, confirming the continuity of interest of the scientific community in the topic.

With the aim of analyzing in depth the authors and the collaboration network, we selected the most productive authors and, leveraging on the three-fields plot, mapped them with the institutions and countries to which they belong (Fig. 5). Therefore, the Sankey diagram reveals the presence of a considerable network of authors belonging to several relevant institutions that are globally distributed. Specifically, the most productive authors are Kim, Mourtzis, Li, Liu, and Kara, belonged respectively to Kyung Hee University, University of Patras, National Institutes of Health, and Concordia University.

Fig. 6 shows the country collaboration map. The more productive countries (dark blue in color) are: China, Germany, United States, Italy and United Kingdom. Although some countries appear isolated (e.g., Peru, South Africa, and Norway), this analysis confirms the presence of an international and globally distributed research field.

The performance analysis continues with the trend topic graph (Fig. 7); which collects the recurrent keywords in the sample for each year. Some elements are noteworthy. Keywords representative of older manuscripts are related to the adoption of internet in BMs (e.g., Internet, electronic commerce, massively multiplayer online game [MMOG]). Although the terms related to virtual community and worlds born around 2006, their overlapping with the concept of BM starts in 2008. Moreover, several terms related to technologies emerged in the last years (e.g., augmented reality, artificial intelligence, Internet of Things, Industry 4.0, big data, machine learning, digital twin, metaverse), testifying to the trend of using technologies as an element of a BM. Specifically, metaverse appears as a relevant keyword in 2022.

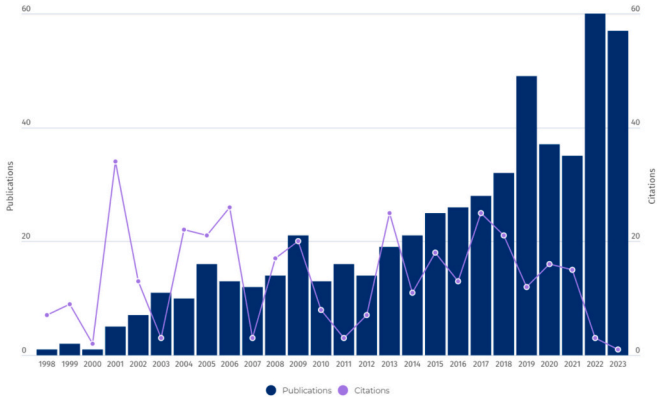

Fig. 4. Publications and citations trend.

4. Results

4.1. Thematic map of the research field

Applying a science map analysis, we discovered the thematic map of the research field. This analysis, which was performed on the keywords of the sample, revealed the presence of nine clusters of terms recurring with a total frequency (tf) of at least five (Fig. 8). It is interesting to note that among 1638 keywords proposed by the authors as representative of their studies, only 48 keywords occurred at last five times. Although, this set of keywords represents only 3 % of the entire sample, the minimum recurrence of terms ensures the relevance of these topics for the scientific field under analysis.

The cluster in the brown color, is composed of 16 terms, and it involves keywords related to the technological field, such as: Industry 4.0 (tf: 18), Internet of Things (tf: 16), digital transformation (tf: 15), artificial intelligence (tf: 12); blockchain (tf: 9); and big data (tf: 7). This thematic cluster of terms is representative of the technologies used in metaverse.

The cluster in the lilac color is composed of 12 terms, is the second largest cluster by size, and includes the terms with the highest total frequency, such as: augmented reality (tf: 53), business model (tf: 44), virtual reality (tf: 39), metaverse (tf: 25), innovation (tf: 16), and business models (tf: 15). This thematic cluster of terms is the most representative of the inquired research field since it collects manuscripts focused on the innovation of business models leveraging augmented reality, virtual reality, and metaverse.

The cluster in the blue color is composed of five terms: virtual worlds (tf: 15), second life (tf: 10), virtual world (tf: 7), MMOG (tf: 5), and social networks (tf: 5). Therefore, it emerges that this cluster collects studies related to the description of virtual worlds.

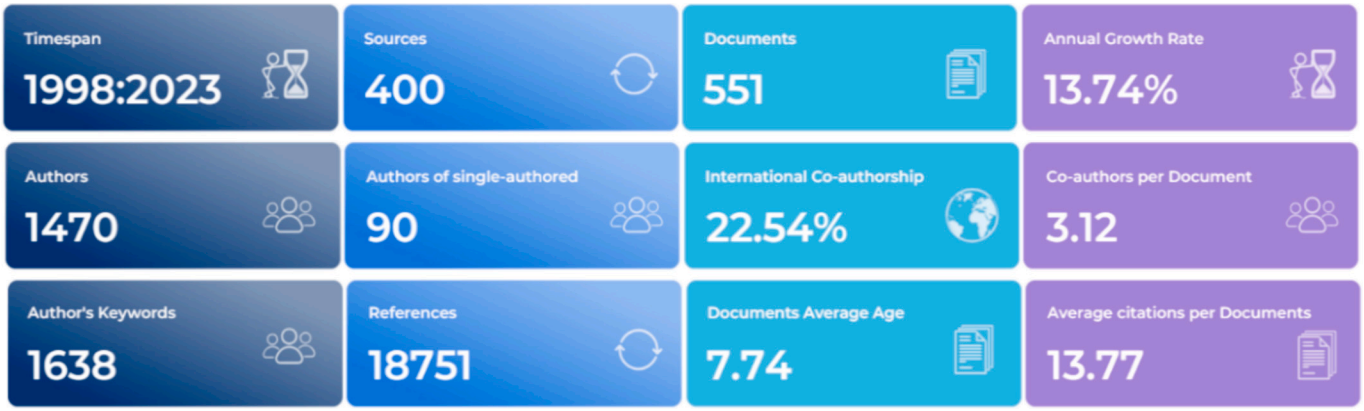

Fig. 3. Main features of the sample.

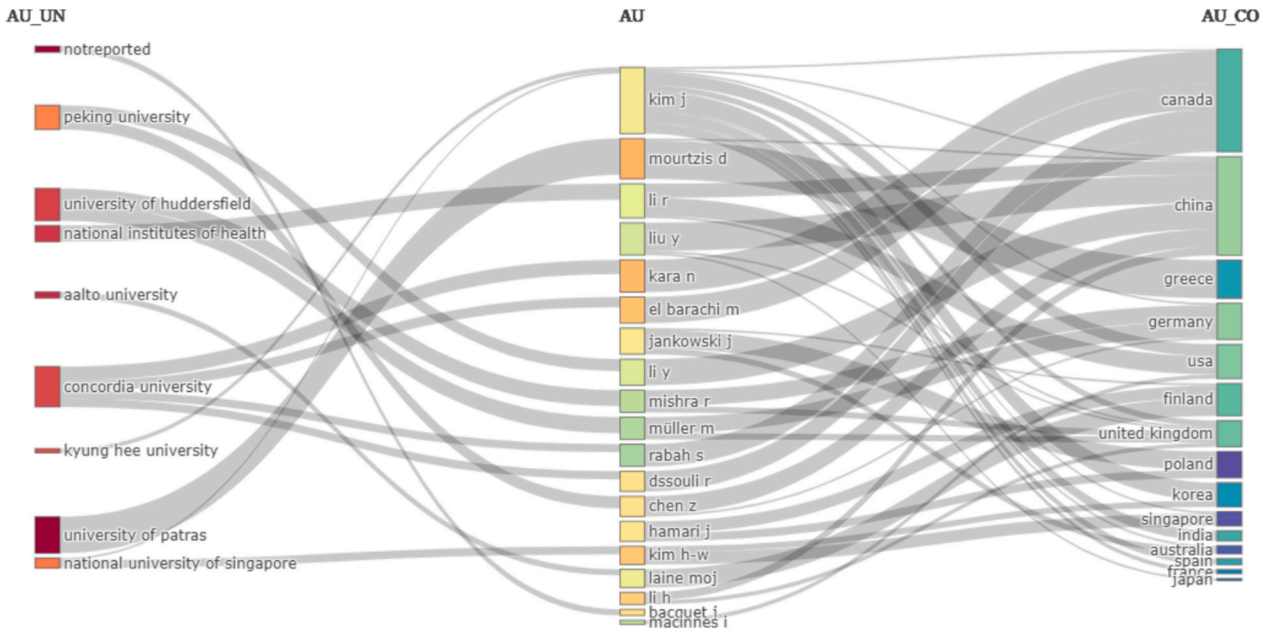

Fig. 5. Relevant authors, institutions, and countries.

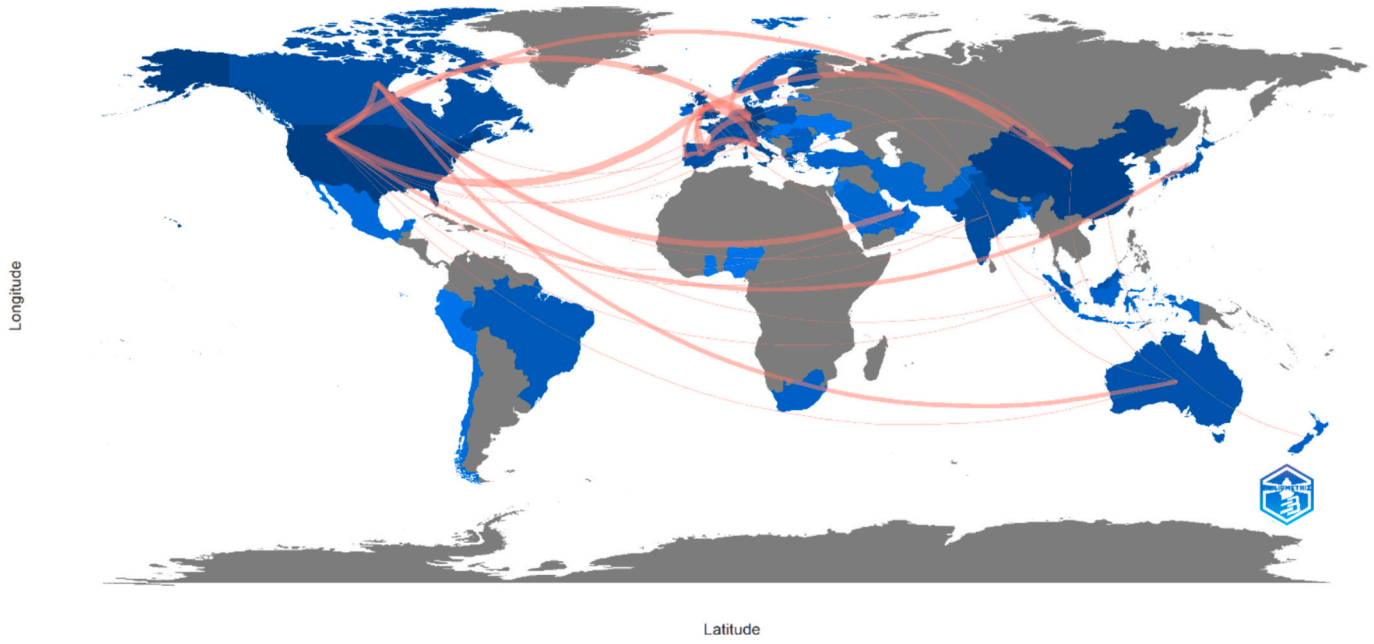

Fig. 6. Country collaboration map.

The cluster in the green color, is composed of five terms: virtualization (tf: 20), cloud computing (tf: 18), security network function (tf: 8), virtualization (tf: 6), and cloud (tf: 5). This thematic cluster of terms seems to be an addendum to the brown cluster, since it is focused on technologies. However, the green cluster regards the networking services technologies.

The cluster in the orange color is composed of five terms: virtual communities (tf: 20), value creation (tf: 13), e-commerce (tf: 5), online communities (tf: 5), and trust (tf: 5). Therefore, this cluster of terms collects studies focused on value creation in virtual communities, with specific reference to online communities and interest in strategies capable of fostering the trust of the members in the community. The last three clusters are less relevant than the others since they are composed, respectively, by only two terms. The cluster in the red color, composed of virtual community (tf: 13) and customer value (tf: 5), appears as a satellite of the orange cluster but it is more focused on the topic of customer valuer in virtual communities. The cluster in the purple color, composed of electronic commerce (tf: 5) and Internet (tf: 5), and the cluster in the grey color, composed of 5 g (tf: 6) and nfv (tf: 5), are satellites of the brown cluster focused on technologies used in metaverse but specifically focused on communication technologies.

Using the thematic map representation, the clusters of terms can be placed in four quadrants capable of describing the degree of relevance (centrality) and of development (density) of the topic representative of the inquired research field (Fig. 9). The *motor themes*, themes with high density and high centrality, belong to the first quadrant and represent well-developed themes with a strong internal and external tie. The cluster in the brown color, which is related to technologies used in

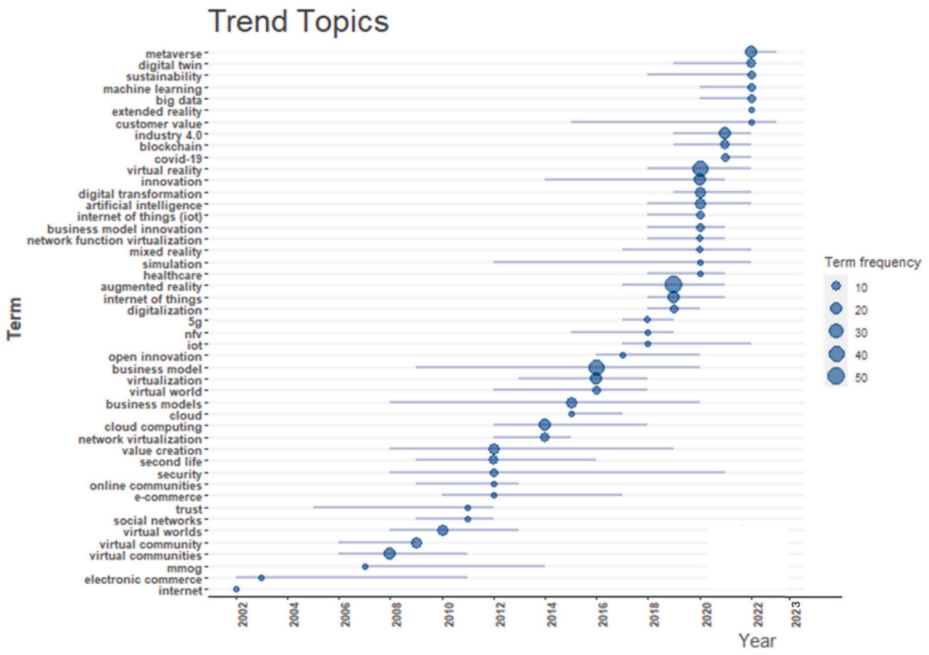

Fig. 7. Trend topics graph.

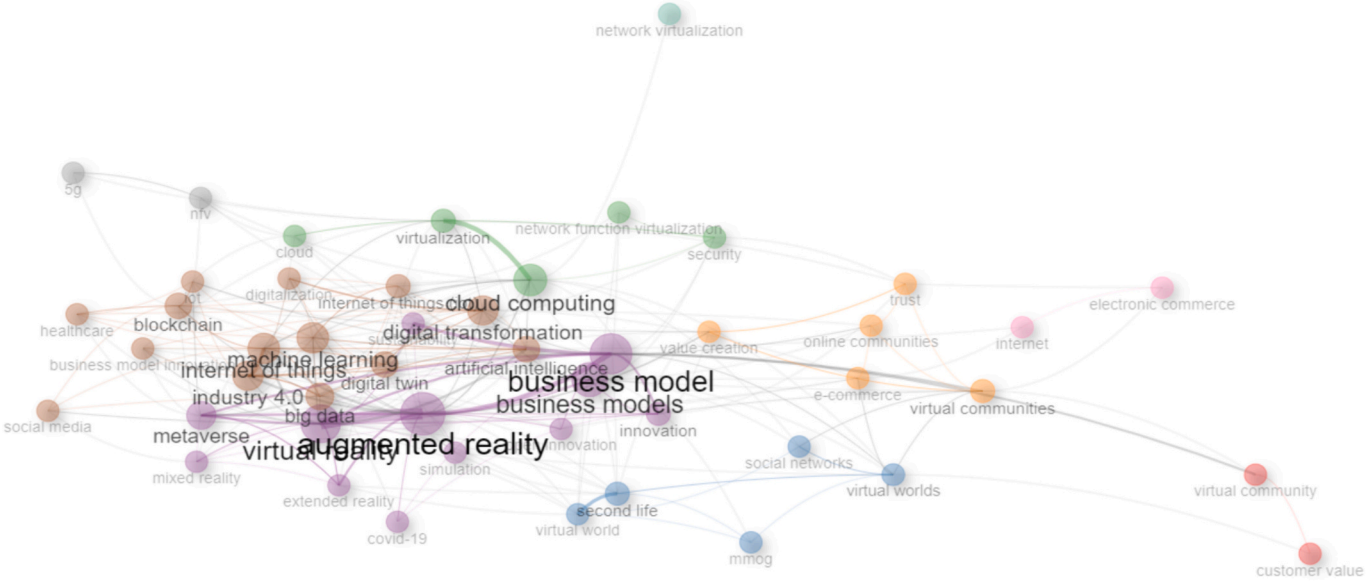

Fig. 8. Co-occurrence network on authors keywords.

metaverse, belongs to this quadrant. Themes placed in the upper-left quadrant are characterized by high centrality and low density and are considered as extremely developed and isolated or niche themes. The second quadrant, high density and low centrality, includes so-called niche themes that are considered highly-developed-and-isolated topics. Violet and grey clusters belong to this quadrant and are related to communication technologies: they are characterized by well-developed internal ties and marginally significant external ties. The emerging-or-declining themes fall under the third quadrant in which we found the red cluster: the low level of density and centrality reflects the weakness of their internal and external ties. Finally, the so-called basic themes are placed in the last quadrant encompassing the well-developed external ties and unimportant internal ties. We discover in this quadrant the green and the lilac clusters related, respectively, to the networking services technologies and the innovation of business models leveraging augmented reality, virtual reality, and metaverse. The blue and orange clusters are placed at the center of the map.

Fig. 10 summarizes the evolution of the most relevant topics over-time in a longitudinal map, that highlights how the themes flow into each other. Specifically, the entire timespan of the sample was divided into three ranges of equal length: 1998–2006, 2007–2014, 2015–2023. The graph shows the most important clusters of terms in each temporal range, with the cluster labelled with the most relevant term. (See Fig. 11.)

It is interesting to note that the "business model" topic compared as a relevant term for a cluster in the first two ranges. During the 2007–2014 temporal range, the business model topic inherited, totally or partially, the knowledge related to the following research topic of the first temporal range (1998–2006): business model, virtual communities, augmented reality, and innovation. Similarly, during the evolution

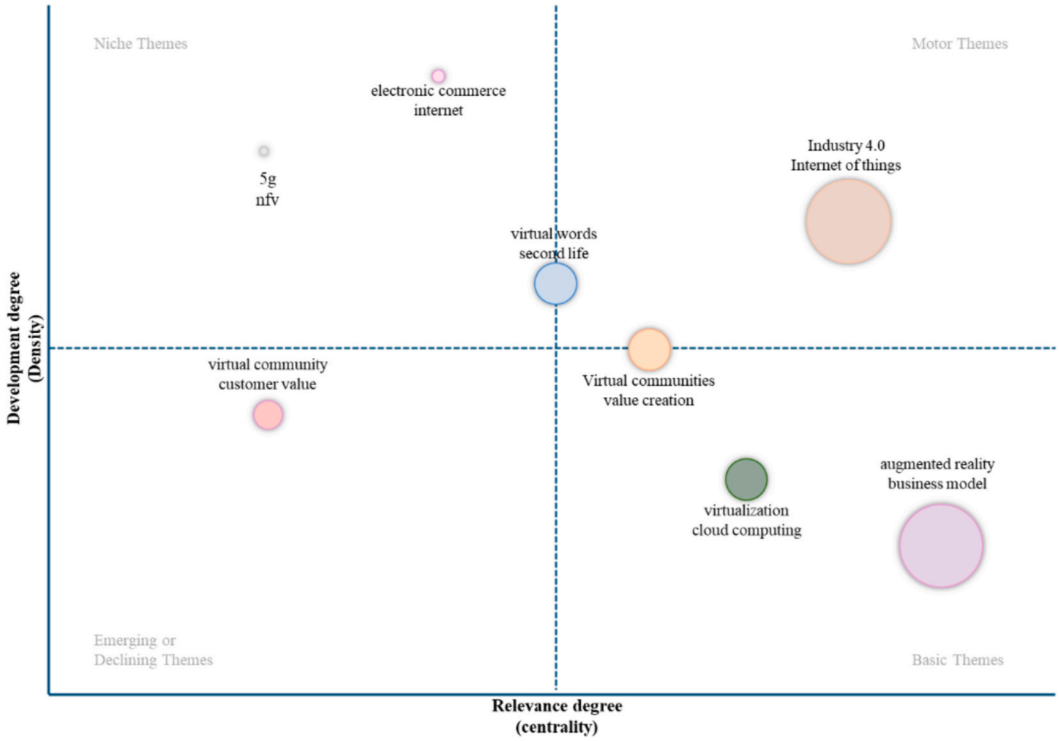

Fig. 9. Thematic map.

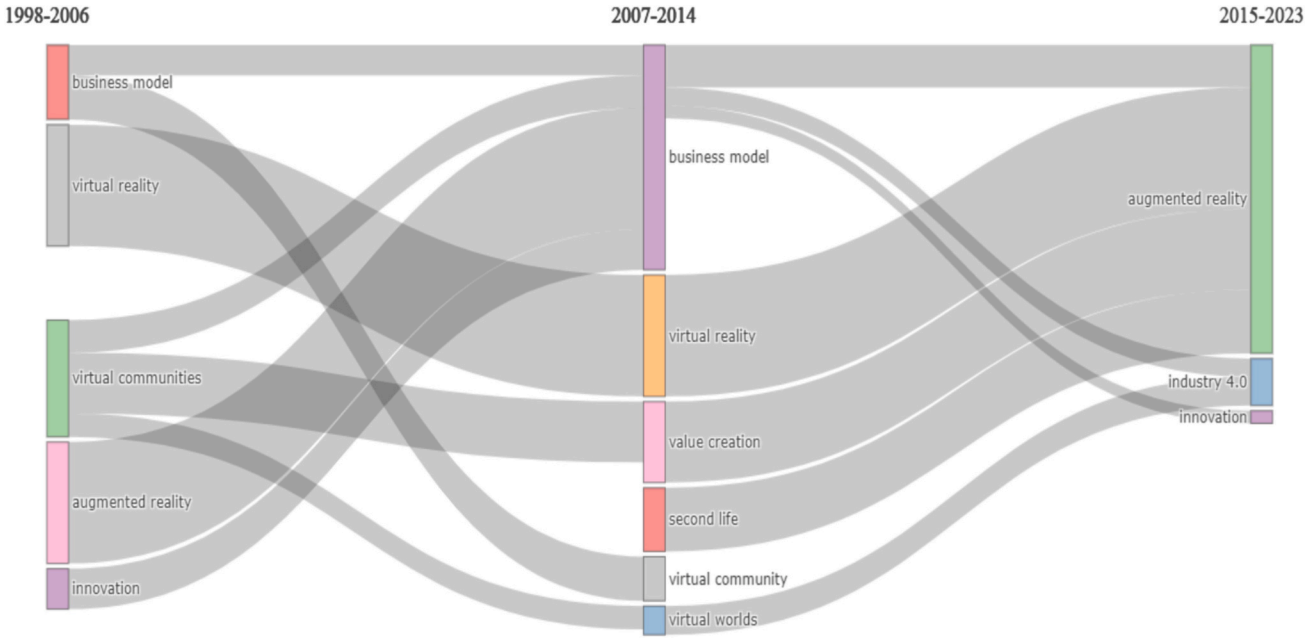

Fig. 10. Thematic evolution over time, longitudinal map.

between 2007 and 2014 and 2015–2023 temporal ranges, part of the business models topic evolved toward the augmented reality, Industry 4.0, and innovation topics. Moreover, the augmented reality topic embraced the topics related to: virtual reality, value creation, and second life.

The following picture provide a comparison of the thematic maps related to the selected three temporal ranges, giving information about the development and degree of relevance of the topics over time.

Focusing on the evolution of the business model topic, it is a niche theme in the range 1998–2006. It evolved as a basic theme during the range 2007–2014, testifying to an increase in the relevance degree (centrality) and a decrease in the development degree (density). This was probably favored by the fact that the business model cluster (range 2) incorporated part of the virtual communities' cluster (range 1), which was a motor theme in the first temporal range. Finally, in the last temporal range (2015–2023), the cluster related to augmented reality (which involves part of the knowledge related to the business model cluster of range 3) positions itself as a basic theme showing an increasing relevance degree from 1998 to 2006 to 2015–2023. This was probably favored by the fact that the augmented reality cluster (range 3)

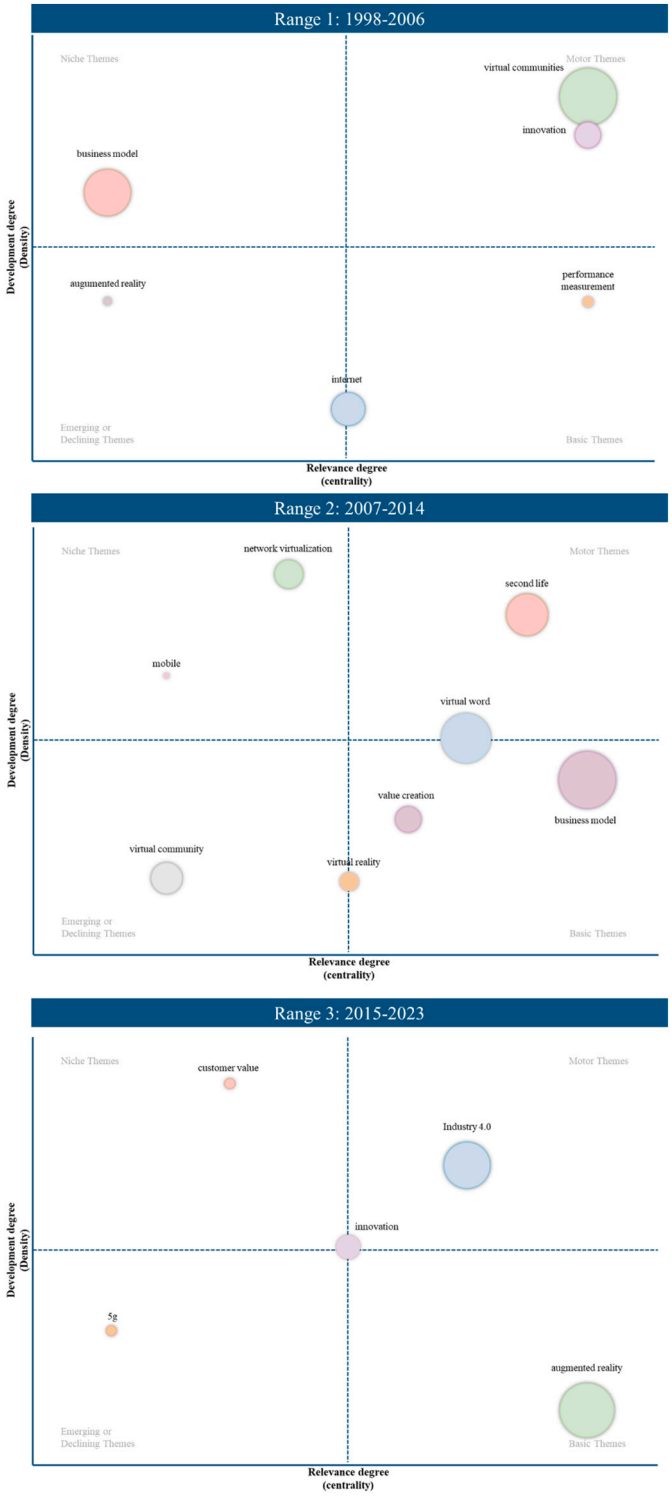

Fig. 11. Thematic map, evolution over time.

incorporated part of the virtual reality, value creation, and second life clusters, which were basic and motor themes in 2007–2014.

The results coming from the thematic analysis testify to the capability of virtual communities, augmented reality, and virtual reality to change business models. Therefore, to provide an answer to the posed research question we selected the studies belonging to business model (range 1), business model (range 2), augmented reality (range 3) clusters and analyzed them according to content analysis. The results of this third layer of analysis follow.

4.2. Unveiling the metaverse's impact on business models, three waves

As explained in the Methodology section, the final sample of our study was analyzed according to content analysis in order to unveil the metaverse's impact on BMs and the sectors involved in this transformation. From our analysis, three ~~3~~ different waves of impact emerged. Before discussing these waves and describing the actions of value creation and capture enabled by metaverse, it is interesting to highlight that the interest about this specific research topic has increased over time: the first wave encompassed six studies temporally identified between 1998 and 2006; the second wave included10 studies temporally identified between 2007 and 2014; and the last wave had 60 studies temporally identified between 2015 and 2023. The first wave was characterized by the ~~born~~ birth of the web virtual environment, and the element capable of impacting the BM was the virtual community. The evolution of virtual environments in the second wave was represented by virtual goods that were capable of generating change in the BM. Finally, the last wave was characterized by the explosion of metaverse technologies through which companies were capable of implementing innovative actions of value creation and value capture.

4.2.1. The first wave: BMI generated by virtual environment and communities - the father of metaverse

In the first wave of impact, we retrieved the use of different technologies (e.g., information technologies, integrated telecommunications networks, multi-model transportation systems) for the creation of virtual environment and communities capable of generating innovation in BMs (Manthou et al., 2004).

The transition from real to virtual environments emerges introducing changes in products and relationships moving the company's BM toward virtual networks. The virtual network model introduces the concept of virtual community, which refers to a group of people with shared values and interests. Specifically, our analysis reveals that these elements supported companies in the establishment of the following new *value creation actions*:

- Virtual marketplace. Virtual environments in which buyers and sellers trades information as a commodity (Jazayeri and Podnar, 2001). The industry most affected by this change was the music industry in which the birth of platforms created interaction processes between virtual networks and virtual communities leading to the shift in value creation from goods buying to goods sharing, from tangible products to intangible products (Volz, 2006).
- Virtual supply chain. Recognizing the power of the relationships, companies established virtual supply chains, moving their BMs toward virtual networks to enhance the success of the BMs. Technologies allowed the creation of the virtual value chain environment in which the several stakeholders can interact and collaborate, thereby improving the company's performance of agility, real time monitoring, and speed of response to the customer (Manthou et al., 2004).

Moreover, the virtual environment and community generated the following novelties in *value capture actions*:

- Trust in virtual communities. Virtual communities enabled companies to develop new Business to Consumer (B2C) BMs by leveraging on their capability to increase trust and commitment among the participants in the community (Gupta and Kim, 2004; Leimeister and Krcmar, 2004). The potential to build consumer trust and improve relationships was an excellent value capture mechanism in e-marketing and e-commerce platforms. Big players in this first wave (e.g., *E*-bay) have seen the power of reviews to increase the trust of new customers, an essential attitude to reduce the rate of abandonment of the cart at the time of checkout.
- Loyalty. Virtual communities allowed companies to increase their branding position, to develop a critical mass of consensus around a

product or service, to increase the level of consumer interest in the product or service portfolio, and to obtain marketing advantages from word of mouth. All these benefits turn into increased barriers to entry and into improved and more reactive customer relationship management (CRM) strategies. Among the different types of virtual community, a success case is represented by health communities in which the generated value consists ~~in~~ of marketing actions, quality assurance, after sales support, and co-innovation (Dannecker and Lechner, 2006).

4.2.2. The second wave: BMI generated by virtual objects - the early metaverse

Capitalizing the emerging trend of the first wave, the second wave showed the development of virtual objects (e.g., avatars, goods, currencies and tokens) (Lehdonvirta, 2009) that populated virtual environments, generating innovation in BMs. Leveraging on these virtual objects, this second wave saw the birth of the concept of metaverse; that is, the "metaverse based roadmap" was conceived, which was capable of guiding toward the future World Wide Web based on virtual reality technologies (e.g., 3D technologies) (Shoolapani and Jinka, 2011). Our analysis reveals that the virtual goods supported companies in the establishment of new *value creation actions*:

- Virtual goods and currencies. Selling virtual goods represents a major new source of revenues coming from online services, and it is useful to complement the existing advertising strategies based on usage fees or data and value selling (Yeh et al., 2013). Consequently, virtual currency develops rapidly, becoming an important part of the entire economy and a relevant element of people's daily lives.
- Devices for real-virtual interaction. Users need to adopt AR technologies to enhance the interaction between real and virtual using mobile and fixed devices. The advent of new devices capable of interacting with smart TV or during the screening of 3D films at the cinema represented a new way to generate value for consumers (B. S. Choi et al., 2013). This changed the value proposition of TV manufacturing companies and film producers. This evidences technology's impact on the value creation actions in virtual environments, which in this second wave, represented a well-established driver~~s~~ for new value creation actions in the electronic device industry (Wu et al., 2008).
- Virtual bank and retail. The application of early metaverse in bank and retail showed the possibility to create virtual branches of banks or retail chains through which traditional activities could be virtualized. These changed the nature of the selling experience and led to an increase in customer experience, improvement in brand quality, reduction in operational costs, and increased revenues (Shoolapani & Jinka, (2011).

From our analysis, it also emerged that the virtual goods are capable of supporting companies in the establishment of new *value capture actions* for:

- Information security and privacy. In a scenario in which the value generation happened thanks to virtual goods and communities, the security of information is an element capable of changing BM (Yassine and Shirmohammadi, 2009). New professional careers were born that played the role of virtual intermediary to guarantee the privacy of customers' data and negotiate the cost of the goods based on this.
- Trust and loyalty. As had already emerged in the first wave, encompassing a virtual community in a BM represented a strategy to obtain more customers trust and loyalty, reducing the uncertainty related to the purchase decision process (Li and Lai, 2008; Porter et al., 2013). Also in this wave, technologies confirmed the ability to change the way in which consumers satisfy their relational needs (e.g., need for inclusion, need for control, and need for affection) (H. Li and Lai, 2007) virtualizing what traditionally happened through physical human~~s~~ contact. This virtual relationship path is established with content-based websites that incorporate social functionalities (e.g., customer reviews) and avatars that make the virtual experience more real. These types of services increased users' engagement and trust and enhanced user's sense of belonging to the community as well as their willingness to pay more (Zalmanson and Östreicher-Singer, 2014).

4.2.3. The third wave: BMI generated by metaverse-enabling ~~s~~ technologies – the consolidated metaverse

The last wave is the one in which the metaverse concept is established, and authors widely discuss the advent of metaverse-enabling technologies (technologies that allows the creation of products or services based on metaverse) and how these change BMs.

Our analysis reveals that metaverse-enabling technologies support companies in the establishment of new *value creation actions*:

- Sustainable meta-product and service. Metaverse-enabling technologies were used to create new concepts of product and service that were useful in guaranteeing to stakeholders economic, social, and environmental sustainability. For example, in the fashion industry, *digital twins* allowed the virtualization of the testing phase of new clothes, with the outcomes of reducing costs, avoiding the waste of resources, and to increasing stakeholder involvement, thereby offering the company the opportunity to address the path of sustainable development of the business (Wagner and Kabalska, 2023). In the accounting sector, *augmented reality* connecting digital and physical information can offer the possibility to improve training, to speed up repetitive tasks, and to conceive new work procedures to address accountability of the sustainable development goals (SDGs) (Al-Htaybat et al., 2019; Wagner and Kabalska, 2023). Moreover, in the energy sector, *IT* platforms enable the virtual early testing of complex value chains to obtain simulations of efficiency and operational cost before the real-world implementation (Ma, 2023);
- Meta-solutions for virtual-based design and production. Metaverse-enabling technologies were applied in the development of solutions useful in the design or production processes of new products or services. For example, in manufacturing, fashion, and retailing, *augmented reality* has increased information sharing along the several business units and between partners, bringing advantages in collaborative processes (Casciani et al., 2022; Ginters et al., 2020; Hagl and Duane, 2018; Kshetri, 2023; D. Mourtzis et al., 2019; Dimitris Mourtzis et al., 2022a; Dimitris Mourtzis et al., 2018; Stecken et al., 2019). In food & beverage, *MAR (mobile augmented reality) technology* allowed a new way to share product information among the several actors in the supply chain, bringing advantages in food traceability and risk management (Penco et al., 2021). In the technological provider sector, *augmented reality* has generated innovative mobile and web applications and devices with innovative functionalities (e.g., an augmented reality app for information sharing in business to business context, chat bot avatar) (Hagl and Duane, 2018; Royo-Vela and Velasquez Serrano, 2021) capable of innovating the users' involvement processes by leveraging co-creation actions (King and Grobbelaar, 2020; Mancuso et al., 2023);
- Meta-solution for education and training. Metaverse-enabling technologies were used to create innovative solutions for the fruition of knowledge. The industry that mainly used these actions was healthcare, in which technologies of *augmented reality*, *virtual reality*, and *IT platforms* are used to train doctors in non-simulated operations (Gruson et al., 2023; Kulkov et al., 2021), to test the safety of innovative crops in swamp farming (Rowan et al., 2022), and more generally, to train employees (Galloro et al., 2020; H.-J. Kim and Kim, 2018);
- Meta-solution for marketing and selling. Metaverse-enabling technologies were applied to create new solutions for marketing and

selling. For example, in retailing, *augmented reality* allows simplification of open innovation actions to create a virtual environment in which several stakeholders collaborate in the creation of customized products (Alam et al., 2021; Y. Wang and Xu, 2021). In the food & beverage sector, the application of *virtual technologies* in smart labelling allows companies to share more product and process information with the consumer (Penco et al., 2021). In the game industry, consumers were encouraged to buy physical objects (also in physical stores) that were already visualized in the virtual world (*virtual and augmented reality*), triggering indirect buying/selling mechanisms (Pieskä et al., 2019). In the fashion industry, *augmented reality* allows virtual interaction with the consumers with the aim of analyzing their responses to a new product and predicting their future buying behavior (Naik and Bhardwaj, 2024). In the marketing field, *3D technologies* changed the relationship between company and consumer, decreasing information asymmetry and positively affecting selling (Alves and Ferreira, 2008; Dwivedi et al., 2023; Elradi et al., 2017; Studen and Tiberius, 2020);

- Cultural meta-product and service. Metaverse-enabling technologies were used to create new applications or platforms to make physical cultural attractions and experiences usable virtually. For example, in cultural and creative industries, the development of platforms based on *augmented reality* allowed consumers to virtually visit museums or observe archaeological heritage (Alvaro-Tordesillas et al., 2019; Yoon et al., 2022). In the tourism sector, mobile applications based on *augmented reality* were developed to give consumers the opportunity to live virtual experiences such as surfing in tourist villages (Cranmer et al., 2021).
- Meta-goods and currencies. Confirming the trend started in the second wave, virtual goods and currencies were used as value creation actions in the metaverse consolidation phase. Specifically, *blockchain technologies* were used to create new virtual goods. In the banking sector, NFT leads to the birth of cryptocurrencies (Balaji et al., 2023; Sahay et al., 2022; Surakka, 2009; C. Wang et al., 2023). In the gaming sector, NFT is used as exchange currency and to evaluate interactions (C. Wang et al., 2023).

Moreover, it emerged from our analysis that metaverse-enabling technologies are capable of supporting companies in the establishment of new *value capture actions*:

- Meta-experience. Metaverse-enabling technologies were used to improve customer-company interactions as well as the use of the product/service. Several industries benefit from these actions: i) marketing and banking, in which the *blockchain* NFT (Non-fungible token) linked physical to virtual goods to attract consumers to buy a product since it is described as unique and unrepeatable (Dwivedi et al., 2023; Hennig-Thurau et al., 2023); ii) healthcare, in which mobile application based on *augmented reality* allows a better interaction between doctor and patient, which can provide/obtain assistance in a remote way, with relevant impacts on social care, risk management and cost control (Arlati et al., 2019); iii) tourism, in which mobile applications based on *augmented reality* allowed the possibility of attracting more young visitors, improving consumer targeting activities and transforming museums into nonconventional experiences (Cranmer, 2019; Cranmer et al., 2021; Yoon et al., 2022); iv) manufacturing, aerospace and shipbuilding, in which the interaction between engineers and final consumers that is allowed by *extended and virtual reality* tools allowed improvements in product design and development processes leading to quality products: the use of a product *digital twin* allowed early product testing by users, generating feedback before the product's launch on the market (Dimitris Mourtzis, Angelopoulos, et al., 2022; Müller et al., 2023; Ohlig et al., 2023; Pasquinelli et al., 2018; Stecken et al., 2019) ; v) gaming, in which *augmented reality* enables consumers to collaborate with companies by testing and observing the virtual products before they are transformed into real ones to sell in physical stores (Balaji et al., 2023; Pieskä et al., 2019); and vi) retail, in which *IT platforms* increased the interaction between consumers and products, enabling a virtual path of presale (Y. Wang and Xu, 2021);
- Purchasing processes support. Metaverse-enabling technologies were applied to create solutions capable of analyzing and affecting consumer behaviors and choice. *Augmented reality* was used to create holograms that help consumers during the purchasing process in physical stores (Manolova et al., 2021). A smart mirror based on the use of *augmented reality* was used in the fashion industry to provide support to the final consumer in choosing the best outfit (Casciani et al., 2022). In the marketing sector, *augmented reality* is applied to customize products, services and, more generally, solutions (King and Grobbelaar, 2020; Manolova et al., 2021; D. Mourtzis et al., 2019; Shah Kazmi et al., 2021);
- Loyalty. Metaverse-enabling technologies were used to improve consumer conversion and loyalty. This action was implemented in mobility, food and beverage, materials production, and automotive sectors in which *augmented reality* allows consumers to interact with the company after product purchase and consumption, triggering a mechanism of attachment to the brand (Brunner and Wolfartsberger, 2020). In the consulting section, *augmented reality* is used to show company reputation and transparency (Nissen and Seifert, 2016). *Augmented reality* is also used in the fashion industry to realize a direct link between company and stakeholder, enabling the real-time assessment of needs and product customization (Wagner and Kabalska, 2023). *IT platforms* were used in the retail industry to implement virtual experiences for the selling of products, allowing the company to benefit from the establishment of continuous relationships with the consumers (Nasr and El-Deeb, 2023; Y. Wang and Xu, 2021). Marketing uses *augmented reality* and *3D technology* to create virtual agents capable of increasing the interactions between consumers. The possibility of receiving assistance in all phases of the purchasing process increases the customer's positive experience. The customer feels pampered, which encourages the buying experience to be repeated in the future (Elradi et al., 2017; King and Grobbelaar, 2020; Mancuso et al., 2023);
- Cost leadership. Metaverse-enabling technologies were used to monitor costs and develop strategies of market leadership. Consulting used *augmented reality* to forecast purchasing decisions based on costs leveraging in the analysis of consumer faces during the interaction with avatars (Nissen and Seifert, 2016);
- Differentiation and Focus. Metaverse-enabling technologies were used to discover the latent needs of market niches. For example, *augmented reality* was used in the healthcare sector to develop medical simulation apps that attract the professionals with specific backgrounds (Mancuso et al., 2023; Yang et al., 2019).

4.3. Sectors and technologies involved in metaverse transformation

Thanks to the content analysis of the study belonging to the third wave, we were able to determine that 22 different sectors are currently involved in the adoption of metaverse-enabling technologies. Marketing (frequency 7), Fashion (frequency 5), Manufacturing (frequency 5), Technology providers (frequency 4), Tourism (frequency 3), and Education (frequency 3), Retail industry (frequency 3) were the sectors most debated in our sample. The analysis has allowed us to identify nine typologies of metaverse-enabling technology families: Augmented Reality (AR), Virtual Reality (VR), Extended Reality (XR), Mixed Reality (MR), Digital Twins (DT), IT Platforms, Blockchain, 3D Technologies and MAR Technology. Among these technologies, the most applied in the metaverse revolution are: VR (frequency 16), AR (frequency 11) and Blockchain (frequency 4). Fig. 12 shows the metaverse-enabling technologies used by the several sectors: the bigger the bubble, the more technologies are used by the sector. Manufacturing (5 technologies), Marketing (4 technologies), Fashion (5 technologies), Retail (3 technologies) and

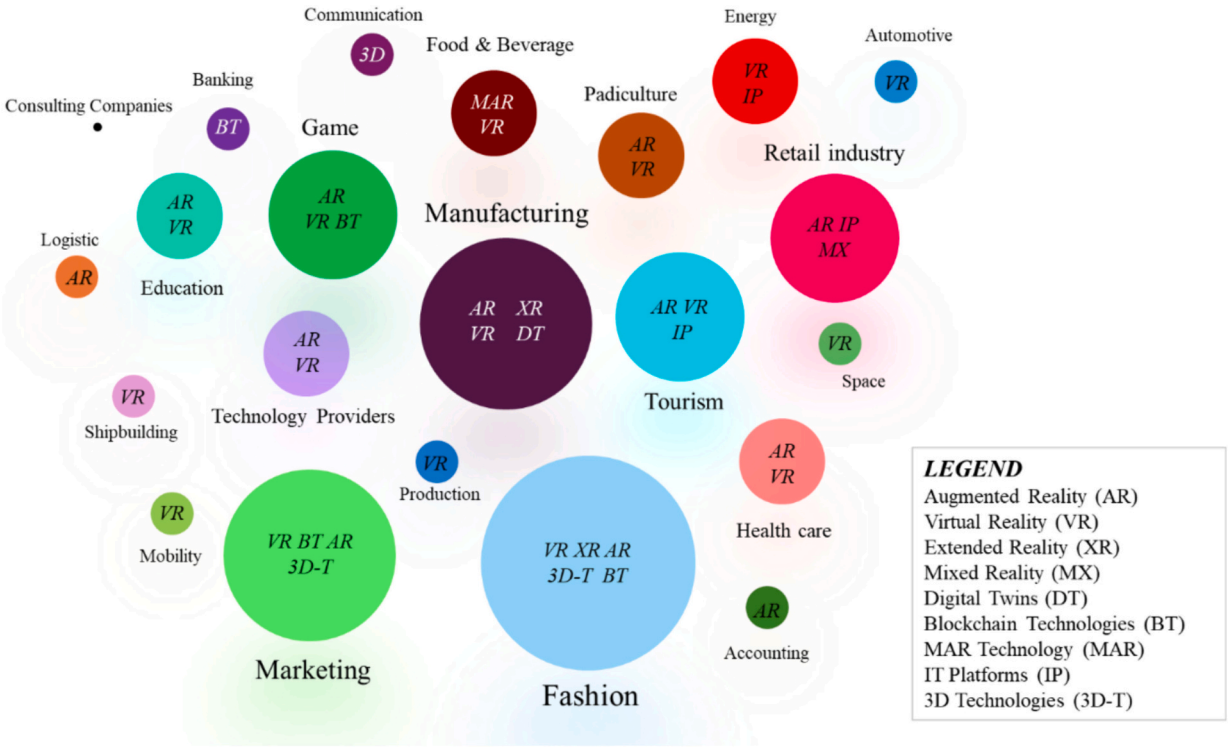

Fig. 12. Main sectors involved in the use of metaverse-enabling technologies.

Tourism (3 technologies) were the sectors that used a greater number of technologies.

5. Discussion

The paper contributes to the BM literature and examines the role of metaverse in BMI; specifically, it unveils the elements of this emerging technology capable of affecting companies' BMs, the changes that metaverse creates in value creation and value capture actions, and the sectors and technologies most involved ~~by~~ in this transformation. Following a temporal logic, we identified three evolutionary waves in which these types of technologies introduced new actions for value creation and capture, thereby innovating companies' BMs. Our waves are the testimony that companies are experiencing an evolutionary path driven by metaverse transformation, which leads to evolving their BMs toward new blue oceans (Mauborgne, 2005), where value creation and value capture are shaped according to unexplored possibilities (Sabaruddin et al., 2023; Teece, 2018) enabled by the new metaverse-based technologies. To better understand the impact generated by metaverse on BMI, the next subsections are focused on: i) the capability of metaverse to innovate value capture according to radical, incremental and exaptation approaches (Schumpeter, 2021; Cattani, 2006; Dew et al., 2004), and ii) the capability of metaverse to innovate value capture by delivering value among the several stakeholders (e.g., suppliers, customers, partners) (Chesbrough, 2010; Osterwalder and Pigneur, 2010).

5.1. How metaverse innovated value creation

Over time, metaverse-based technologies change a company's capability to develop high-value products and services that satisfy the needs of customers (Rayna and Striukova, 2016). At the beginning, the transition from the real to the virtual environment represented a radical innovation (Schumpeter, 2021). The virtual environment and virtual communities were new and different creations of previously real environments and relationships (Manthou et al., 2004). Therefore, they were capable of generating a radical BMI, introducing substantial modifications to the previous BM and sometimes completely changing it: the disruptive potential of metaverse debated by Schmitt (2022) was confirmed. Both new value creation actions (virtual market-place and virtual supply chain) introduced a change in BMs toward virtual networks in which virtual communities interact.

Virtualization transformed the physical stores into virtual marketplaces that allowed companies to sell products and services according to a new perspective, thereby reaching new consumers and increasing visibility in a global market (Armstrong, 2006). This represented a big opportunity for small businesses that could leverage the services provided by a marketplace platform and pay a respective fee to benefit from easy transactions (selling-buying) and the trust that these platforms have been able to develop with their audiences over time: their virtual community. The online interactions and socialization triggered a wider range of emotions, allowing companies to exploit new customer relationship strategies (Abbate et al., 2022). The years of the first evolutionary wave were (1998–2006), when Amazon or eBay established themselves as marketplaces on the international scene. Recognizing the power of the virtual relationship, companies enlarged the virtualization effect along the entire supply chain in which, thanks to technologies, stakeholders could interact and collaborate (Manthou et al., 2004), improving their capability to manage information and flows of good. Supply chain in a virtual environment uses several technological applications running on different computer systems, networks, and protocols. Thanks to these technologies, virtual supply chains utilized information and knowledge as a substitute for inventory, competed on agility and speed, and viewed partner/customer collaboration as a competitive strategic asset. Therefore, the virtualization of the supply chain increased the performance of agility, allowed flows of goods and information to be monitored in real time, and provided a faster response to the customer. As for the marketplace, the virtual environment for a supply chain changed the partners' BMs, their organizational and technical coordination, and their agreements, which created new roles and collaborative capabilities for each partner in the establishment of a virtual community among the supply chain stakeholders.

Once the virtual environments and communities were established,

the second wave paved the way for a series of innovations of an incremental nature (Schumpeter, 2021). Virtual objects were new elements of value creation capable of introducing interesting minor changes in the existing BMs based on making more immersive virtual environments and communities (Ritterbusch and Teichmann, 2023), which generated a BM modification without making substantial changes in its structure. Virtual environments were populated by the introduction of goods, currencies, and tokens and have led to the consolidation of online sales as a source of revenue. This facilitated the creation of virtual banking and retail: once the customer became familiar with virtual environments and placed trust in virtual communities, it was natural to virtualize more and more environments. The selling experience changed and banks and retailers evolved their BMs, adding virtual branches that earned benefits in brand quality, operational cost, and revenue (Shoolapani and Jinka, 2011). The introduction of avatars in marketplaces and platforms added a personification level to the virtual community, adding a benefit in the related value capture mechanisms and confirming the strategic role of avatars discussed by Abbate et al. (2022).

To reduce the gap between the real and the virtual, devices for augmented reality increased the offered value of different industries by improving the way in which the virtual experience was provided (e.g., 3D film production) and, therefore, changing the BMs (e.g., establishing partnerships with the producers of 3D devices) (B. S. Choi et al., 2013; Wu et al., 2008).

In the last and current wave in which metaverse finds its consolidation, BMI followed the discontinuous evolutionary process of exaptation. New actions of value creation were born that were unrelated to a new phenomenon or the pull from clearly defined needs (Andriani and Cattani, 2016). In some cases, the existing metaverse-based technologies built new technological niches, as for the sustainable meta-product and service, meta-solution for education and training, and cultural meta-product and service. Sustainable meta-product and services support a company toward the economically, environmentally and socially sustainable production and the achievement of the SDGs: traditional BMs evolving toward sustainable ones by incorporating principles of waste reduction or stakeholder involvement (Al-Htaybat et al., 2019; Ma, 2023; Wagner and Kabalska, 2023). Meta-solutions for education and training represent an innovation for the niche of people who need to increase their skills and knowledge toward the virtual environment (e.g., training of doctors, specialized employees) (Gruson et al., 2023; Kulkov et al., 2021; Galloro et al., 2020; H.-J. Kim and Kim, 2018), and which represent drivers to innovate the BMs of the related companies by introducing partnership with providers and adopting the culture of continuous change in resource management. Cultural meta-products and services represents an innovation for the niche of people who need to enjoy virtual cultural experiences, opening a new branch of offer capable to reach new target of markets otherwise unattainable, for example, the involvement of a disabled person in an extreme tourist experience.

In other cases, the existing metaverse-based technologies allow enter into existing niches, as in the cases of meta-solutions for virtual-based design and production and for marketing and selling. Meta-solutions for virtual-based design and production allowed designers and producers to improve information sharing, collaborative processes among partners, risk management, and co-creation actions. Meta-solutions for marketing and selling allowed companies to produce a customized product, to share product and process information, to obtain real-time feedback from consumers, to reduce information asymmetry, or to change the selling logic triggering indirect buying/selling mechanisms (Pieskä et al., 2019; Alves and Ferreira, 2008; Dwivedi et al., 2023; Elradi et al., 2017; Studen and Tiberius, 2020), generating a layer of useful information similar to that generated by innovation based on IoT (Haaker et al., 2021). Therefore, metaverse allows a company to implement a servitization process capable of enriching the value proposition (Tiscini et al., 2020) and that has the potential to act as an orthogonal platform, thanks its ability to generate value from data collected by digital services (Trabucchi et al., 2022; Trabucchi and Buganza, 2023).

In other cases, the existing metaverse-based technologies allow an increase in efficiency or in the range of features of current products, such as in the case of meta-goods and currencies that have been improved through the use of emerging technologies like the blockchain (Balaji et al., 2023; Sahay et al., 2022; Surakka, 2009; C. Wang et al., 2023, Tiscini et al., 2020).

It is expected that in the next stage of affirmation and exploitation of the metaverse, the innovation process will continue to follow the exaptation trend and build new technological niches in many industries, entering into other existing niches, and transforming the current features of products or services by increasing their efficiency or extending their range of features (Andriani and Carignani, 2014).

5.2. How metaverse innovated value capture

Innovation generated by metaverse in value capture was aligned with the innovation in value creation (Foss and Saebi, 2018; Ritter and Lettl, 2018; Sjödin et al., 2020), confirming the role of BM as a tool that companies could strategically employ. Metaverse triggered over time a process of securing profits from value creation and the distribution of those profits among different internal and external stakeholders (Hall et al., 2023). However, its ability to bring value to each category of stakeholder has evolved over time. At the beginning, thanks to the establishment of virtual communities, value capture that leveraged actions capable of creating and increasing trust were mainly aimed at the possibility of generating value for consumers. B2C BMs in virtual environments (e.g., market-place, e-commerce or e-marketing platforms) leveraged several mechanism to increase trust and commitment among the participants of the community (Gupta and Kim, 2004; Leimeister and Krcmar, 2004), such as the customers reviews that were and still are an essential element to reduce the rate of abandonment during virtual purchasing. Moreover, acting on loyalty actions in the virtual communities, companies increased their branding position and generated a critical mass of consensus around a product or services, shifting the mechanisms already successfully tested in real business to the virtual environment, such as the word of mouth, marketing actions, co-innovation, or after-sales support (Dannecker and Lechner, 2006), which become more effective due to the network effect immediately generated by Internet technologies. Even if, we did not find in the first wave a specific action aimed at bringing value to the other supply chain actors (e.g., suppliers, partners), the value creation action related to the virtual supply chain suggests that there have also been significant shifts toward these categories (e.g., efficiency in risk management; reduction of information errors, waste, and rework), even if the scientific panorama has not explored them in depth.

Trust and loyalty as value capture actions persisted even during the second and third waves. In the second waves, they were related to the introduction of new virtual objects in the virtual environments: avatars, reviews, and chat satisfied the relational needs of consumers increasing their perception of inclusion in the community, the affection received, and the perception of virtual environment control (H. Li and Lai, 2007) that translated into consumer willingness to pay more (Zalmanson and Östreicher-Singer, 2014). This action was complemented by information security and privacy value capture actions to assure privacy and security during the information sharing processes (Yassine and Shirmohammadi, 2009). Also in this wave, value capture actions were mainly aimed at consumer, leaving the other categories of stakeholders lesser explored.

In the third waves, the action of trust disappears and only that of loyalty remains. This probably happened because companies no longer needed to leverage new tools to increase trust in virtual environments and communities since the consumer has now become expert in these technologies and has gained a certain experience in the virtual world that leads him or her to perceive it as normal. However, companies continued to benefit from loyalty value capture actions leveraging

metaverse-based technologies, such as augmented reality, to provide interactions with the company (e.g., virtual agents, chatbot) to show reputation and transparency, to offer customization activities triggering more attachment to the brand (Brunner and Wolfartsberger, 2020; Nissen and Seifert, 2016), and encouraging costumers to repeat the buying experience over time (Elradi et al., 2017; King and Grobbelaar, 2020; Mancuso et al., 2023). BMs changed: the consumer no longer buys a product or service but buys an experience. Companies leveraged metaverse-enabling technologies to create meta-experiences in which the customer-company interaction and the experience of using the product and service changed with the effect of generating revenues in many sectors: blockchain NFT linking physical to virtual goods increases selling in marketing and banking (Dwivedi et al., 2023; Hennig-Thurau et al., 2023); augmented reality devices changes the relationship between patients and doctors, allowing medical services to also be provided in difficult and risky situations, such as that generated by the COVID-19 pandemic (Arlati et al., 2019); augmented reality makes younger and more interesting tourism attractions (e.g., museums), allowing companies to reach new market targets (e.g., young people, disabled people) (Cranmer, 2019; Cranmer et al., 2021; Yoon et al., 2022), extended and virtual reality increase the operability (e.g., design, production, requirement analysis) among the partners of complex supply chains (e.g., aerospace, manufacturing), and augmented reality and IT platforms allowed the gaming industry and retail to testing early and offer presale (Alves and Ferreira, 2008; Balaji et al., 2023; Pieskä et al., 2019; Y. Wang and Xu, 2021). The adoption of technologies allowed companies to generate value capture actions along purchasing processes that enabled mechanisms capable of analyzing and affecting consumer behavior and choice: some examples retrieved in our sample are holograms of virtual shopping assistants and smart mirrors in physical stores (Manolova et al., 2021; Casciani et al., 2022), and product customization programs using augmented reality (King and Grobbelaar, 2020; Manolova et al., 2021; D. Mourtzis et al., 2019; Shah Kazmi et al., 2021). To these we can add the use of sponsored content on platforms, mechanisms for promoting similar products and services based on the history of searches or purchases made, the promotion of commercial activities close to the places visited, and so on. Finally, the use of metaverse-enabling technologies generated value capture actions linked to the differentiation strategies: the possibility to monitor cost inside the company and along the supply chain; the possibility to forecast purchasing decisions that allow the company to adopt strategies of cost leadership (Nissen and Seifert, 2016); the possibility to discover latent market needs and quickly analyze changes in consumers' needs that allowed to the company to adopt strategies of differentiation and focus (Mancuso et al., 2023; Yang et al., 2019). Only in this third wave did the actions of value capture based on the metaverse open toward all categories of stakeholders: consumers remain the biggest beneficiaries of the value capture actions, but benefits of value delivery also involved suppliers, partners, managers and employees, and society. Continuing this emerging trend, we expect that in the future evolutionary wave, the value capture mechanisms generated by the metaverse will be able to reach more and more categories of stakeholders (e.g., owners, investors, creditors, government).

Fig. 13 summarizes the innovation generated by the metaverse in BMs, highlighting for each of the three evolutionary waves the value creation actions and the types of BMI, and the value capture actions with the involved stakeholder categories.

6. Conclusions and future research directions

Our literature review combining bibliometric and content analysis brings us to give an answer to the posed research questions:

What are the metaverse elements capable of impacting companies' business models?

Metaverse generates overtime three waves of impacts on companies' business models. The elements capable of changing the company BMs were: virtual environments and communities, virtual objects, and metaverse-enabling technologies. Metaverse-enabling technologies were the current engine theme of the entire research topic.

What are the changes that metaverse generates in the business models?

Metaverse has the capability of changing value creation and capture actions. Specifically, the three elements of virtual environments and communities, virtual objects, and metaverse-enabling technologies were used over time to create new value, thereby helping companies in the development of virtual marketplaces and supply chains, virtual goods

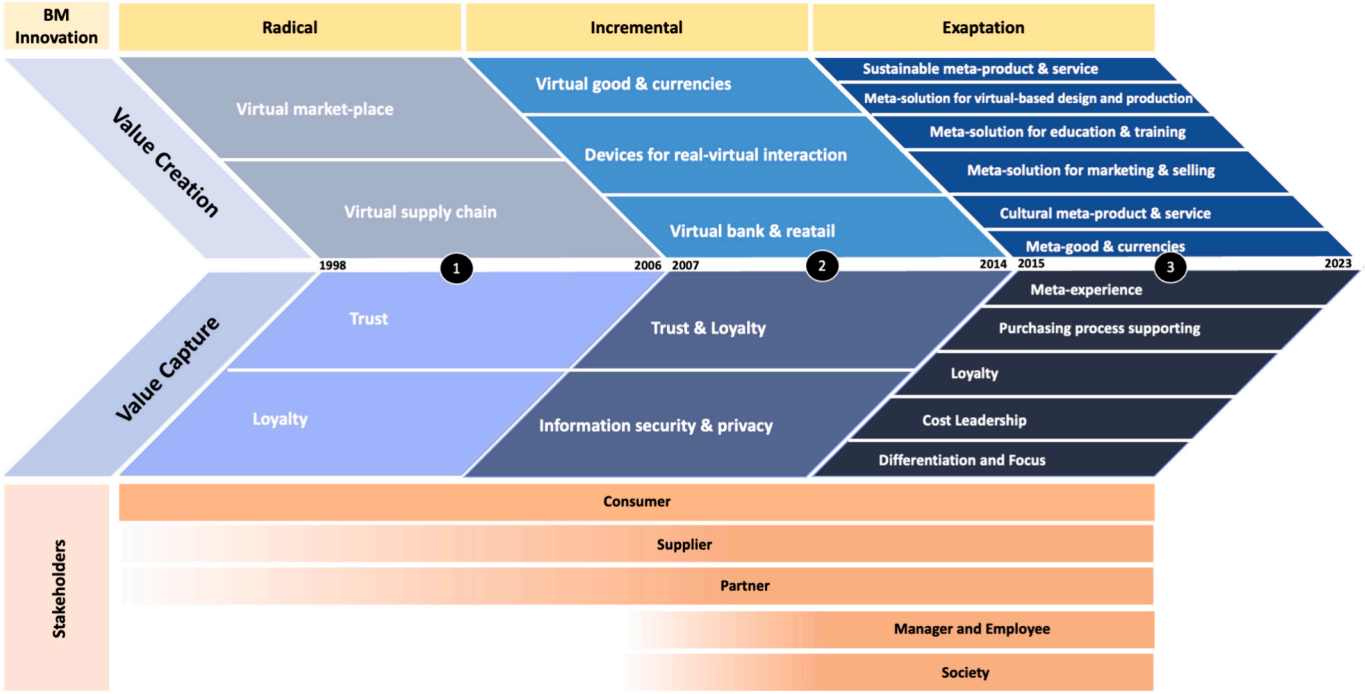

Fig. 13. Evolution of the impacts generated by metaverse in business model.

and currencies, virtual devices for real-virtual interactions, virtual banking and retail, sustainable meta-products and services, meta-solutions for virtual-based design and production, meta-solutions for education and training, meta-solutions for marketing and selling, cultural meta-products and services, and meta-goods and currencies. Technologies were capable over time of supporting companies in the establishment of new value capture actions leveraging trust, loyalty, information security and privacy, meta-experiences, purchasing process support, cost leadership, and differentiation and focus.

What are the sectors most involved in business model innovation through metaverse?

Metaverse was applied in 22 several sectors: Accounting, Banking, Communication, Consulting, Education, Energy, Fashion, Food & Beverage, Game, Health Care, Logistic, Manufacturing, Marketing, Materials production, Mobility, Automotive, Paludiculture, Retail, Space, Shipbuilding, Technological Providers, and Tourism. The driving sectors in this development process are Marketing, Manufacturing, Tourism, and Fashion.

6.1. Emerging gaps and future research directions

Covering a time span of 25 years, an international and globally distributed network of authors has been studying the impact that metaverse generates on BMI, starting from the adoption of the Internet in BMs to the virtual environment, communities, and objects. Therefore, this study confirmed that metaverse represents the natural evolution of the Internet (Dwivedi et al., 2022). Currently, metaverse-enabling technologies have the role of motor themes in the research field, bringing to light the high interest of academia in exploring the potentiality of technologies in business model innovation. A situation of uncertainty was instead found for the themes that were the driving forces of the first and second waves: virtual worlds (environment and objects) and virtual communities.

In our opinion, the virtual worlds research topic is moving from the emerging theme section to the engine theme section due to the possibility given by technologies to enrich and change the virtual world over time. The virtual communities cluster is following the opposite path, moving from the motor theme section to the declining theme section, which represents an opportunity for academics to envisage future research routes, since more efforts could be expended to understand how the virtual communities research field can evolve in the future.

Although in the first wave (1998–2006), BMs appeared divided from virtual reality (see Fig. 10), virtual communities, and innovation, in the second wave (2007–2014) the BM topic encompassed virtual communities, augmented reality, and innovation topics, and then it merged into the augmented reality cluster in the subsequent time frame (2015–2023), showing an increasing of degree of relevance over time. This result confirms the capability of technologies to innovate BMs (Haaker et al., 2021; Teece, 2018; Tiscini et al., 2020; Trabucchi and Buganza, 2023) and opens an interesting research route focused on an in-depth analysis of the impact that the several emerging technologies will generate on companies' BMs (e.g., artificial intelligence).

We extensively discussed in the previous section the capability of technologies (information and communication technologies at the beginning and metaverse-enabling technologies overtime) to change BMs by implementing BM evolutionary paths driven by DT, as debated by (Priyono et al., 2020). Putting our study in this line of research, our results revealed three waves of impact. In the first wave (1998–2006), virtual environments and communities changed the BMs of companies, allowing the virtualization of market, supply chain, network, and relationships (Manthou et al., 2004) and enhancing trust and loyalty (Gupta and Kim, 2004; Leimeister and Krcmar, 2004). The positive effects generated by this change were related to brand positioning and to customer relationship management.

The second wave was characterized by the presence of virtual goods (e.g., avatars, objects, currencies, tokens, virtual meeting places) and their sale in virtual environments represents a high source of revenues (Lehdonvirta, 2009; Yeh et al., 2013). It is evident that this mechanism was born and successful because it is placed in a context in which virtual communities are already established and functioning well. The concept of metaverse was born in this wave and the first experiences of pervasion between the real and the virtual occurred, with physical objects that allowed interactions in the virtual world (e.g., 3D devices) (B. S. Choi et al., 2013; Shoolapani and Jinka, 2011). This result confirms those proposed by Abbate et al. (2022), according to which the key novelty of metaverse is the possibility of increased online interactions and socialization in virtual communities, with the advantage of triggering a wider range of emotions. It could be interesting for academics to proceed with a validation process for these results through the use of qualitative and quantitative methods, such as case studies or surveys to evaluate the perception of companies referring to the three metaverse elements capable of impacting BMs. Case studies can provide empirical evidences about the use of these metaverse elements in BMI, and surveys can help to discover the presence of new elements not considered in our study.

The connection between real and virtual elements emerging in the second wave finds a wide development in the third wave where a series of technologies enabling the metaverse (e.g., digital twins, augmented reality, MAR technology, virtual reality, IT platforms, 3D technologies, blockchain technologies, and extended reality) to change the mechanisms of value creation and capture, confirming this ability of the metaverse (Schmitt, 2022). Specifically, we found that metaverse-enabling technologies can be used to create new value and help companies in the development of new sustainable products and services, of solutions useful in the products/services development process, of education and training products/services, of marketing and selling products/services, of cultural product/service, and of virtual goods and currencies. This led to several advantages for companies, such as cost reduction, waste avoidance, an increase in stakeholder involvement, operational efficiency, information sharing inside and outside company boundaries, co-creation actions with consumers and stakeholders, improved customer experience, increase in brand attraction, and expansion of the product portfolio. These results enrich the knowledge of the research field according to which metaverse improves customer relationship strategies (Abbate et al., 2022) and creates product/service co-creation processes (Giang Barrera and Shah, 2023).

Moreover, metaverse-enabling technologies are capable of supporting companies in the establishment of new value capture actions for consumer involvement, purchasing processes support, loyalty, cost leadership, and creation of new market segments. This led to several advantages for companies, such as the attraction of more consumers, improvement in the quality of the relationship between consumer and company, improvement in the levels of quality and customization for products and services, effects on consumer behavior and choice, improvement of trust, loyalty, and reputation, improvement of cost leadership, and the discovery of the latent needs of market niches. These results are capable of enriching the current research field of BMI, providing a list of concrete actions in which metaverse-enabling technologies are used to change BMs. Therefore, our study confirms the capability of metaverse to change both value creation and capture generating BMI according to exaptation since this technology allows the transformation of the current products or services by increasing their efficiency and extending their range of features (Codini et al., 2023). This observation opens the way to an interesting research route focused on empirically analyzing the capability of metaverse to act as exaptation agent in the future waves.

It is reasonable to consider our results as a first attempt at systematization that will in the future require more effort to open the way to a research route focused to study new mechanisms of value creation and capture enabled by the metaverse. Case studies could also bring new empirical evidence and surveys could help to discover new mechanisms of value creation and capture enabled by the metaverse. Finally, it could be interesting to replicate this study to discover the capability of other

emerging technologies to generate new mechanisms of value creation and capture.

Our results testified that metaverse was applied in a high number of sectors, confirming the confirming cross-sector diffusion. Marketing, Manufacturing, Tourism, and Fashion are the driving sectors in this development process. This result advances the knowledge in the research field by shedding light on the recent interest of Manufacturing and Tourism in this technology and confirming the previous results in Marketing (Arghashi, 2022; Bhardwaj et al., 2023; Bloom, 2020) and Fashion (J. Kim, 2021).

However, despite the little evidence found, the presence of metaverse applications in 22 sectors testifies to the potentiality of this approach to improve business results in anticipation of a global adoption trend that will certainly come in the future. This result highlighted a gap in the current research file that suggest to the academia the need to pay more attention to different sectors, such as Logistics, Mobility, Banking, Energy, Space, or Automotive. It could also be interesting to study the transferability of technological and best practices from the from the most developed sectors to the least developed ones and to understand how the specific characteristics of a sector can affect companies along the path of change in BMs by the metaverse, whether positively or not.

Table 3 summarizes the emerging gap and the proposed future directions.

6.2. Limitations

Despite the research methodology being well established, thereby assuring the replicability of the research procedures and analysis, this study presents some limitations. First, the choice of keywords and search scheme affected the results of our review: other keywords and search scheme could lead to different results. To minimize this bias, we conducted a preliminary data collection with the aim of identifying the representative search keywords for the data collection procedure. Second, although Scopus and WoS databases are recognized as complete and quality scientific databases, they might have missed relevant studies relevant for the analysis topic. The sample for analysis could be enlarged using other databases (e.g., Science Direct). Third, bibliometric analysis can be performed using other indicators or other software (e.g., VOSViewer), leading to complement and confirm our results. Finally, the content analysis generates a limitation related to the interpretation of the contents by the researchers. To minimize this bias, we followed a rigorous methodology based on reference check and numerous comparisons among the researcher team to harmonize the interpretation of results to guarantee the quality of the findings. However, our analysis could be enriched with other types of analysis useful to in-depth investigation of the semantic of the textual dataset (e.g., semantic analysis). Therefore, these limitations could represent follow ups to our study: i) enlarge the search scheme encompassing other relevant keywords and consider other data bases to enlarge the sample of analysis; ii) enlarge the set of analysis in order to validate and complement the results of our study; iii) conducting the analysis again in a future timeframe can give information about the evolution of the metaverse-based BMI in the next wave. Moreover, it could be interesting to validate these results by leveraging on qualitative analysis. For example, conducting a survey on a sample of companies that adopted metaverse technologies in their value proposition could be useful to understand if the evidence coming from this literature review about the innovation actions in value creation and capture are also present in real empirical cases.

Table 3
The emerging gap and the proposed future directions.

Emerging gaps	Proposed future directions
Emerging uncertainty was instead found for the themes that were the driving forces of the first and second waves: virtual worlds (environment and objects) and virtual communities.	Understand how the virtual communities' research field can evolve in the future.
The merging the possibility of technologies to change business models by implementing evolutionary paths of business models guided by digital transformation	- Analyze the impact that the several emerging technologies generate on companies' business models. - Provide empirical evidences of the use of these metaverse elements in business model innovation.
Emergence of the metaverse concept and the first experiences of pervasion between real and virtual occurred, with physical objects allowing interaction in the virtual world	Discover the presence of new elements not considered in our study.
Emerging the connection between real and virtual elements finds extensive development across a number of metaverse-enabling technologies and a change is noticeable in the mechanisms of value creation and capture, confirming this ability of the metaverse.	- Provide empirical evidences about new mechanisms of value creation and capture enabled by the metaverse. - Discover new mechanisms of value creation and capture enabled by the metaverse. - Discover the capability of other emerging technologies to generates new mechanisms of value creation and capture.
Emerging application of metaverse in a high number of sectors, confirming the confirming cross-sector diffusion Marketing, Manufacturing, Tourism, and Fashion are the driving sectors in this development process. But despite the little evidence found, the presence of metaverse applications in 22 sectors testifies to the potentiality of this approach in improving business results anticipating a global adoption trend that will certainly come in the future.	- Enhance research in least developed sectors (e.g., Logistics, Mobility, Banking, Energy, Space, Automotive). - Study technological and best practices transferability from the most developed sectors to the least developed ones. - Assess how the specific characteristic of the sector can affect, whether positively or not, the path of change in business models by the metaverse.

CRediT authorship contribution statement

Maria Elena Latino: Conceptualization, Data Curation, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – review and editing. **Maria Chiara De Lorenzi:** Data curation, Formal analysis, Software, Visualization, Writing – original draft, Writing – review and editing. **Angelo Corallo:** Funding acquisition, Supervision. **Antonio Messeni Petruzzelli:** Conceptualization, Methodology, Supervision, Validation, Visualization, Writing – original draft, Writing – review and editing.

Declaration of competing interest

None.

Data availability

Data will be made available on request.

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