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Green and sustainable business models: historical roots, growth trajectory, conceptual architecture and an agenda for future research—A bibliometric review of green and sustainable business models

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Abstract
Over the last two decades, green and sustainable business models (GnSBMs) have become a prominent topic of discussion among scholars, practitioners and policymakers. Preponderance of research and an increasing global pressure to adopt GnSBMs necessitate a comprehensive understanding of the state of research on GnSBMs. Towards this end, we extracted 851 publications on GnSBMs from the Scopus database and employed a series of bibliometrical techniques to: (1) explore the historical roots and sleeping beauties, (2) assess the life cycle, (3) map the conceptual evolution and (4) propose a research agenda for this growing field. Our analysis revealed that research on GnSBMs is moving from a multidisciplinary to an interdisciplinary domain. Its historical roots can be traced to the pioneering works on business strategy in the 1950s, environmental science in the early 1960s and stakeholder theory in the 1980s. Life cycle analysis indicated that research on GnSBM went through an introductory stage from 2002 to 2013 and then began to rapidly grow in 2014, and this growth is forecast to continue until circa 2040. The conceptual structures from 2002 to 2013 and 2014 to 2020 were mapped and an agenda for future research was proposed.

Keywords Co-word analysis · Life cycle analysis · Reference publication year spectroscopy · Green business models · Sustainable business models · Circular business models · Sharing business models · Social business models

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Introduction

Few topics have received as much attention from researchers and practitioners as business sustainability (Barbieri & Santos, 2020; Curtis & Mont, 2020; Dyllick & Muff, 2015; Gao & Bansal, 2013), and at its core, green and sustainable business models (hereafter GnSBMs) (Agrawal & Bellos, 2017; Foss & Saebi, 2017; Franceschini & Pansera, 2015). It is common sense that every sustainable business has a GnSBM (Dentchev et al., 2018; Lüdeke-Freund, 2020; Yip & Bocken, 2018) which 'helps describing, analysing, managing and communicating (1) its sustainable value proposition to its customers, and all other stakeholders, (2) how it creates and delivers this value, (3) and how it captures economic value while maintaining or regenerating natural, social and economic capital beyond its organizational boundaries' (Schaltegger et al., 2016b, p. 268). Achieving a true business sustainability, hence, requires an understanding of GnSBMs and how they differ from usual BMs (Dyllick & Muff, 2015).

Given the role of GnSBMs in the discourse of business sustainability, it is essential to have a panoramic and up-to-date understanding of the state of research in this field. Although several literature reviews (e.g. Martin Geissdoerfer et al., 2020; Lemus-Aguilar et al., 2019; Schaltegger et al., 2016a, 2016b), taxonomies (Fraccascia et al., 2019; Nosratabadi et al., 2019a, 2019b) and typologies (Ciulli & Kolk, 2019; Henry et al., 2020) have contributed to this end, there are still several unanswered questions which deserve more attention. For instance, there have been no attempts to exclusively assess the history and evolution of scientific research on GnSBMs. This void is an impediment to theoretical development and cumulative knowledge production in such a potent filed. In this study we aim to fill this void by presenting the first systematized assessment of the history and evolution of research on GnSBMs. To do so, we depart from the tradition of conventional systematic reviews and adopt a multimethod bibliometric approach which addresses three specific research questions: (1) What are the historical roots of research on GnSBMs? (2) At which stage of its life cycle is the current body of knowledge on GnSBMs? and (3) What themes have been central or peripheral, developed or underdeveloped in this field? We use reference publication year spectroscopy (RPYS) (Marx et al., 2014) to address the first research question. Next, we employ life cycle analysis (LCA) (Meyer et al., 1999) to answer the second question. Finally, we perform a series of coword analyses (Callon et al., 1983) to address the last question. By addressing these questions, we make three contributions to the literature on GnSBMs. First, we offer an up-to-date systematization of the literature in this field. Second, we extend the literature by tracing the evolution and identifying seminal works across disciplines which laid the foundation of knowledge in this domain. Third, we detect and discuss central and peripheral areas of research in the literature on GnSBMs and set out an agenda for future research.

The remainder of this paper is organized in three sections. First, we present an overview of the literature on GnSBMs. We next outline the design of our analysis and elaborate our findings. We then conclude by discussing the implications of our findings, proposing an agenda for future research and highlighting limitations of our study.

Background literature

The business model concept and its building blocks

Although the business model (BM) concept is not new (Bellman et al., 1957), the foundations of our current understanding of it were developed in the early 2000s when it was used to explain how e-commerce ventures create value (Alt & Zimmerman, 2001; Amit & Zott, 2001) and how new technologies were commercialized (Chesbrough & Rosenbloom, 2002).

The BM concept has evolved into an influential concept which describes how any business creates, delivers and captures value (Foss & Saebi, 2017; Teece, 2010). Every business has a BM which not only shows how it fits into an ecosystem (Magretta, 2002; Teece, 2010), but also allows it to gain legitimacy (Amit et al., 2020) and position itself in product markets (Zott et al., 2011). In fact, every business starts by choosing a BM by which it would like to compete (Casadesus-Masanell & Ricart, 2010).

Prior studies offer multiple conceptualizations of the building blocks of a BM. Magretta (2002, p. 88) posits that, 'all business models have two parts: Part one includes all the activities associated with making something: designing it, purchasing raw materials, manufacturing and so on. Part two includes all the activities associated with selling something: finding and reaching customers, transacting a sale, distributing the product, or delivering the service'. To Morris et al. (2005), a BM has six components: (1) the offering; (2) the market; (3) the competencies of the firm; (4) competitive strategy; (5) economic factors; and (6) personal factors of the entrepreneur or investors. Similarly, Johnson et al. (2008) contend that a BM is made up of four interlocking elements: (1) a value proposition; (2) resources; (3) the processes to convert inputs to finished products or services; and (4) the profit formula to achieve an attractive return. Further, Osterwalder (Osterwalder, 2004; Osterwalder & Pigneur, 2010; Osterwalder et al., 2005) identifies nine components of a BM grouped in four factors, namely: (1) the product factor containing 'customer segments', 'channels' and customer relationships, (2) the value propositions factor, (3) the infrastructure management factor that includes 'key resources', 'key activities' and 'key partners' and (4) the financial factor that encompasses the 'revenue streams' and 'cost structure'. Finally, Zott and Amit (2010) describe a BM in terms of the content, structure and governance of activities which it performs.

From the BM concept to GnSBMs

The BM concept entered the sustainability literature over a decade ago (Stubbs & Cocklin, 2008). Early studies focussed on the conceptualizations of GnSBMs (Birkin et al., 2009; Høgevold & Svensson, 2012; Hutchinson et al., 2012; Massa & Tucci, 2013; Stubbs & Cocklin, 2008) and demonstrated how they combine economic, social and environmental values in their value propositions (Biloslavo et al., 2018; Boons & Lüdeke-Freund, 2013; Kleine & von Hauff, 2009). Despite these attempts, literature lacks a clear definition of GnSBMs. As such, we define it as an architecture of socio-environmental and economic value that creates delivering and capturing mechanisms used by a business.

While some studies (e.g., Joyce & Paquin, 2016; Lüdeke-Freund et al., 2018; Ritala et al., 2018; Shakeel et al., 2020) show that any BM can be transformed into GnSBMs by incorporating socio-environmental values into its operational designs, others studies have highlighted failure of such BM transformations owing to organizational tensions (e.g., van Bommel, 2018; Yang et al., 2017) or inherent operational complexities (Bocken et al., 2019; Morioka et al., 2018).

As shown, GnSBMs have become a prolific topic. Two perspectives explain proliferation of scholarly interest in GnSBMs. First, the institutional view suggests that political, regulatory and environmental factors pressure businesses globally to adopt GnSBMs (García-Muiña et al., 2020; Svensson et al., 2016a, 2016b; Wit & Pylak, 2020) to alleviate concerns such as stakeholders' need for sustainability (Chiappetta Jabbour et al., 2020), social inequalities (Yunus et al., 2010a, 2010b) and inadequate value co-creation (Porter & Kramer, 2011).

Second, the technological view suggests that new technologies such as blockchain (Tiscini et al., 2020), digital sharing platforms (Cocquyt et al., 2020; Sposato et al., 2017) and renewable energies (Huenteler et al., 2016; Reinhardt et al., 2019; Secinaro et al., 2020) have facilitated design of new GnSBMs or transformation of existing BMs into green and sustainable ones (Gao & Li, 2020; García-Muiña et al., 2020; Sposato et al., 2017; Tirabeni et al., 2019).

Preponderance of research in this field calls for systematization of the literature. We thus identified five themes which represent the core of research on GnSBMs: (1) Industry 4.0, (2) product service systems, (3) circular economy, (4) sharing economy and (5) social BMs. By using these themes, we offer a more systematic and focussed picture of research on GnSBMs and set the stage for our bibliometric analysis.

GnSBM and industry 4.0

Industry 4.0 refers to a set of technologies such as Internet of Things (IoT), blockchain (BC), cloud computing (CC), artificial intelligence (AI) and machine learning (ML), which collectively enable the fourth industrial revolution[1] (Lasi et al., 2014; Lu, 2017). These technologies are often deployed in cyber–physical systems (CPS) which are tightly integrated, digitized, connected and automated processes for creating value for end users (Lasi et al., 2014; Rossow, 2018). As a result, Industry 4.0 has become a central theme in the literature on GnSBMs (García-Muiña et al., 2020; Nica et al., 2019; Prause, 2015; Tirabeni et al., 2019; Zamani & Giaglis, 2018).

Some of the applications of Industry 4.0 in GnSBMs include cloud-based BMs for sustainable energy distribution networks (Rossignoli & Lionzo, 2018; Tao et al., 2015); smart manufacturing BMs (García-Muiña et al., 2020; Rauch et al., 2016); BMs for 3D visualization, 3D prototyping and 3D printing in the fashion industry (Papahristou & Bilalis, 2017); BMs based on IoT to improve safety and efficiency of air navigation service providers (Fiorentino et al., 2020); BMs that manage smart contracts between stakeholders by using blockchain technology (Dal Mas et al., 2020); and BMs that use blockchain technology for improving traceability of items in supply chains (Tiscini et al., 2020).

Product-service systems

A product service system (PSS) is a 'marketable set of products and services capable of jointly fulfilling a user's need' (Mont, 2002, p. 238). PSSs are distinct in that they are predominantly service-based BMs in which an integration of products and services is offered to customers rather than the products alone (Yang et al., 2017). PSSs are often designed

[1] According to Lu (2017), the first industrial revolution began at the end of the eighteenth century and was represented by mechanical production plants based on water and steam power; the second industrial revolution started at the beginning of the twentieth century with the symbol of mass labour production based on electrical energy; the third industrial revolution began in the 1970s with the characteristic of automatic production based on electronics and internet technology; and right now, the fourth industrial revolution, namely Industry 4.0, is ongoing.

to satisfy consumers' societal needs in an economically and environmentally sustainable manner (Hannon et al., 2015).

A PSS reduces waste and improves resource efficiency through dematerialization (Barquet et al., 2016a, 2016b) and collaborative consumptions of products and services (Laura Piscicelli et al., 2015). The transition from selling products to services or to a combination of products and services through PSSs is, therefore, more sustainable for all stakeholders (Scheepens et al., 2016; Zhang et al., 2018). Additionally, upgradable products with longer life cycles disseminate better in PSSs by appealing to a wider range of stakeholders (Khan et al., 2018). However, adoption of PSSs in BMs is hindered by the degree of uncertainty in the quality, reliability and added value of service components (Catulli, 2012).

Two distinct types of GnSBMs have been discussed in the literature on PSSs: servitization and servicization.[2] The former refers to BMs which create value by adding service components to product offerings (Kowalkowski et al., 2017; Perona et al., 2017), whereas the latter refers to BMs which commercialize functions or features of products instead of selling physical products (Agrawal & Bellos, 2017; Hokyoung Ryu et al., 2018).

A servicizing BM is based on the premise that a function, not form, is the source of added value delivered to the customer (Reiskin et al., 2000). It redefines a business as a service provider instead of a product manufacturer and changes how it manages material input, throughput and output. Agrawal and Bellos (2017) enumerate three advantages of servicizing BMs: (1) the firm charges customers on the basis of the product usage, (2) the quantity of products required to meet customer needs may be smaller because the firm may be able to pool customer needs and (3) the firm may have an incentive to offer products with higher efficiency" (p.1454). Ryu et al. (2018) identify four forms of servicization: (1) adding a function with servicizing solutions, (2) offsetting a product's weakness using servicizing solutions, (3) proposing new user experience (UX) solutions and (4) mixing products and services on the other firm's strengths (i.e. inter-firms' cooperation).

Servicizing BMs require partnerships wherein the financial rewards of reduced material consumption are shared between suppliers and customers (Reiskin et al., 2000). For instance, in pay-per-use BMs (Chun, 2020), on-demand printing and car sharing services, consumers only pay for the unit of service they need to use without gaining product ownership (Bocken et al., 2018). Furthermore, consumers become more conscious about pricing (Chun, 2020; Dowling et al., 2020) and consumption patterns and companies take more responsibility for inefficiencies in their products' life cycles (Bocken et al., 2018; Gebauer et al., 2017; Sato & Nakashima, 2020). Similarly, manufacturers can make their operations more sustainable and more profitable by focussing on services that extend the efficiency and value of their products (Rothenberg, 2007). Overall, servicization can simultaneously increase a firm's profits and significantly decrease its environmental impact (Örsdemir et al., 2018).

Servitization, also known as serficification (Thangavelu et al., 2018), has a longer history than servicization (Vandermerwe & Rada, 1988). Servitization does not replace products with services; rather, it adds services to products to complement their value and increase their competitiveness (Hakanen et al., 2017; Kamp & Parry, 2017; Vandermerwe & Rada, 1988). Servitization contributes to the sustainability in multiple ways: (1) it extends products' life cycle, reduces life cycle costs and lowers use of consumables (Tukker, 2004); (2) it reduces negative social impacts by offering more complete solutions to

[2] Servicification is another closely related concept which refers to the added value of service to the manufacturing productivity in an economy (Thangavelu et al., 2018).

customers (Yang & Evans, 2019); and (3) it fosters interactive service relationships which often lead to less capital-intensive and more sustainable recurrent revenue streams (Kamp & Parry, 2017).

Despite their benefits, companies do not adopt servitization or servicization BMs owing to the transactional costs and organizational complexities (Perona et al., 2017). Some companies may also de-servitize by reducing or discontinuing their service offerings when they become uncommercial (Kowalkowski et al., 2017).

Circular BMs

Closely related to the concept of PSS is the notion of circular economy. As noted by Murray et al. (2017), failure of traditional BMs to address concerns related to sustainable development created a global urgency to look for alternative BMs. The 'circular economy' emerged as a possible strategy that companies of all sizes might adopt to contribute to sustainable development (Lewandowski, 2016; Murray et al., 2017). A circular economy is an antonym of a linear economy in which natural resources are directly converted into waste and pollution via production (Murray et al., 2017). By being the opposite of linear, a circular economy minimizes its net effect on the environment. It restores any damage done in resource acquisition while ensuring little waste is generated throughout the production process and in the life history of the product (Murray et al., 2017).

Any BM can have a degree of circularity ranging from non-circular or linear to circular, which includes upstream circular, downstream circular and full circular (Urbinati et al., 2017). A BM can increase its degree of circularity by incorporating recycling, reusing, remanufacturing and refurbishing procedures into its design (Geissdoerfer et al., 2017; Lewandowski, 2016). Ranta et al. (2018) found that recycling is often easier to implement in circular BMs than reducing or reusing.

Circular BMs reduce externalities and resource depletion by focussing on two interrelated concepts: 'closed loop economy' and 'design to redesign' (Geissdoerfer et al., 2017; Murray et al., 2017). The former refers to restorative value creation methods by using two types of materials: 'biological nutrients, designed to re-enter the biosphere safely, and technical nutrients, which are designed to circulate at high quality without entering the biosphere' (Murray et al., 2017). The latter refers to processes which redesign traditional operations to circular ones. Geissdoerfer et al. (2018a, 2018b) argue that these two concepts allow circular BMs to drive sustainability in five ways: closing loops, slowing loops, intensifying loops, narrowing loops and dematerializing loops.

Circular BMs are designed in different ways. Some of the main techniques include organizational decoupling (Also, Stål & Corvellec, 2018), circulating materials and components into a new product life cycle at the end of their use (Cong et al., 2019), utilizing PSSs (Kjaer et al., 2018) and using technologies such as IoT (Heyes et al., 2018). Svensson and Funck (2019) add cultural control, long-range communication plans, cost accounting and investment appraisal as key control mechanisms required for designing circular BMs. Additionally, ISO 14001 and ISO 9001 affect how benefits of circular BMs are perceived by organizations (Chiappetta Jabbour et al. 2020).

A network of circular BMs creates an industrial symbiosis (Baldassarre et al., 2019; Cervo et al., 2019; Fraccascia et al., 2019) where different BMs exchange materials, energy, water and/or products (Baldassarre et al., 2019). This cooperative network creates additional values by reducing material use, minimizing waste, reusing resources, reducing pollution and generating more eco-friendly business processes (Baldassarre et al., 2019;

Cantele et al., 2020). Some examples of such symbioses are in the textile industry (Dissanayake & Sinha, 2013; Savageau, 2011), smart cities (Ladhe et al., 2014), wastewater management facilities (Gebrezgabher et al., 2015), industrial waste (Lahti et al., 2018) and food waste recycling facilities (Ribeiro et al., 2018).

Success of an industrial symbiosis is a function of the coordination and decentralization of control among all constituent circular BMs (Fraccascia et al., 2019). Such a coordinated effort demands joint institutional alignments which balance the adaptive tensions between social mission, environmental stewardship and economic growth across sectors (Fehrer & Wieland, 2020). Relatedly, Leipold and Petit-Boix (2018) argue that strengthening the link between circular economy and established linear economic activities via public debates is crucial for the success of an industrial symbiosis.

Lastly, measuring the effectiveness of circular BMs is challenging (Geissdoerfer et al., 2017; Korhonen et al., 2018). Rizos et al. (2016) identify inadequate policies for greening consumer preferences, weak market value chains and recognition of nuances in organizational cultures as key barriers in measuring effectiveness of circular BMs. Scheepens et al. (2016) proposed eco-efficient value creation (EVC) and the circular transition framework (CTF) as two metrics to evaluate circular BMs. Life cycle assessment (LCA) is another tool to assess effectiveness of circular BMs (Finnveden et al., 2009; Hoffmann et al., 2020; Scheepens et al., 2016).

Sharing BMs

Sharing economy refers to an economic system in which consumers 'grant each other temporary access to under-utilized physical assets ("idle capacity"), possibly for money' (Frenken & Schor, 2017, p. 5). A sharing economy has three actors: the resource user, the resource owner and the sharing platform (Curtis & Mont, 2020). Goods such as cars, rooms, homes, parking spots and tools which are shared on a sharing platform are called shareable goods (Frenken & Schor, 2017). Recent advances in ICT have digitized sharing economies by creating platforms that allow actors to share goods, resources, experiences and knowledge (Ryu et al., 2019).

Sharing economies are governed by sharing economy BMs (SEBMs), also known as platform BMs (PBMs), community-based and peer-to-peer BMs (Acquier et al., 2017; Ranjbari et al., 2018). BMs of Uber, Airtasker and Airbnb are examples of SEBMs. According to Acquier et al. (2017), there are seven types of SEBMs: (1) access economy BMs, (2) community-based BMs, (3) platform BMs, (4) community-based access BMs, (5) community-based platform, (6) access platform and (7) sharing economy ideal. Ritter and Schanz (2019) identified four market segments for these SEBMs: (1) singular transaction models, (2) subscription-based models, (3) commission-based platforms and (4) unlimited platforms. Additionally, Netter et al. (2019) distinguished between user-driven, communal and platform-driven/commercial SEBMs.

SEBMs contribute to sustainability by enabling collaborative consumption and creating value by merging the value potential of second-hand economy, on-demand economy and a service-oriented logic (Botsman & Rogers, 2010; Frenken & Schor, 2017; Mont et al., 2020). These features allow SEBMs to mitigate overproduction, reduce net consumption, optimize allocation of emergent and temporary demands, and alleviate global warming, poverty, inequality and conflict (Botsman & Rogers, 2010; Heylighen, 2017; Joyner Armstrong & Park, 2017). Additionally, SEBMs have redefined the concepts of ownership and employment and changed the way people generate income.[3] (Acquier et al., 2017; Frenken & Schor, 2017; Leung et al., 2019).

Empirical research on SEBMs follows three streams. The first stream relates to when SEBMs succeed. Piscicelli et al. (2018) found that the success or failure of a SEBM is a function of its design rather than type of its users. Vaskelainen and Piscicelli (2018) observed that geographic communities (e.g. neighbourhood) are more important than relational communities (e.g. friends and families) in the success of SEBMs. Comparably, Cocquyt et al. (2020) observed that users of a SEBM in the fashion industry prefer a small sharing platform to not partner with large clothing retailers and to have the possibility to participate in decision-making but not require shareholding.

The second stream pertains to the adoption of SEBMs by large firms. Ciulli and Kolk (2019) explored how incumbent firms adopt SEBMs through internal investment, partnership or acquisition. Fan et al. (2019) found that social embeddedness (cognitive, cultural, historical and structural) plays a central role in organizational legitimacy of SEBMs. Similarly, Ma et al. (2019) showed that value co-creation in SEBMs depends on how well relationships between governments, sharing business firms and consumers are aligned.

The last stream concerns situations where SEBMs fail to fulfil their promise. Bocken et al. (2020) found car sharing BMs might not be as sustainable as expected because they are complementary to existing private car usage in cities, rather than a replacement. Similarly, Amatuni et al. (2020) observed that car sharing reduces greenhouse gas emissions but to a level much less than previously assumed. Finally, Gao and Li (2020) illustrated how an incorrect understanding of business environment (market, political and legal, economic, social and technological factors) can cause a bike sharing BM to collapse.

Social BMs

A social BM has two principles. First, it replaces traditional shareholders with stakeholders (Hysa et al., 2018). Second, although it sells goods and/or services to create economic value, its value creation is primarily driven by a mission which addresses a societal or an environmental problem, such as hunger, poverty, homelessness, pollution, illiteracy or poor healthcare (Dobson et al., 2018).

Social BMs are developed by social entrepreneurs who see societal problems as opportunities to exploit (Bohnet-Joschko et al., 2019; Spiess-Knafl et al., 2015). Literature offers several ways to develop a social BM. Porter and Kramer (2006, 2011) proposed preconception of product/service designs, reconfiguration of value-chains and creation of local clusters as three models for designing social BMs. Dembek et al. (2018) discussed delivering products and services to impoverished communities, sourcing products and services from impoverished communities and reorganizing how impoverished communities and systems around them operate jointly to benefit each other as three methods to develop social BMs. Spiess-Knafl et al. (2015), identified opportunity creation, smart distribution, ecosystem engineering, cheap sourcing, smart pricing and inclusive production as six ways to develop social BMs.

All social BMs synthesize competing paradigms (economic and social purpose) within one venture (Wilson & Post, 2013). Therefore, they are subject to hybridity-related tensions

[3] In sharing economy, people can move from one project to another, rather than seeking permanent employment. As a result, sharing economy is associated with the term gig economy (Sundararajan, 2015).

between socio-environmental and economic forces. These tensions cause mission drifts which undermine success of social BMs and eventually lead to their failure (Matzembacher et al., 2020). To alleviate hybridity-related tensions, social BMs need to align and balance forces between socio-environmental and economic goals (Davies & Chambers, 2018).

Countries at the bottom of the wealth pyramid (BOP) offer numerous opportunities for launching social BMs (Prahalad & Hammond, 2002; Prahalad & Hart, 2002). For instance, Kuriyan et al. (2008) studied a social BM that offers computer literacy and financial viability to rural communities in India. Yunus et al. (2010a, 2010b) discussed the social BM of Grameen bank in Bangladesh. Esposito et al. (2012) explored social BMs that provide basic healthcare service in rural India. Angeli and Jaiswal (2015) identified strategies to develop social BMs for inclusive health care delivery at BOP. Goyal et al. (2017) and Scott (2017) described social BMs that offer clean energy solutions to communities in rural India.

Although BOP is a fertile ground for social BMs, it is replete with imperfections, such as information asymmetries, market fragmentation, weak legal institutions, weak infrastructures, resource scarcity and poverty penalty (Goyal et al., 2016; Prahalad, 2005). These imperfections have detrimental effects on social BMs. For instance, Matos and Silvestre (2013) studied conflicting interests that hinder development of social BMs in the energy sector in Brazil. Goyal et al. (2016) identified the challenges caused by an absence of a social impact assessment framework for social BMs in BOP. Bittencourt Marconatto et al. (2016) studied ways to counteract coercive pressures when developing social BMs in Brazil. Finally, Palomares-Aguirre et al. (2018) identified community engagement and government collaboration as two requirements for the scaling of the affordable housing BMs in Mexico.

Having reviewed key themes in the past research on GnSBMs, we next elaborate our methodology to study the historical roots, lifecycle and conceptual evolution of the extant body of knowledge on GnSBMs.

Methodology and results

We adopted the methodological workflow of Zupic and Cater (2015) to address our research questions. Table 1 illustrates this workflow.

Research design and selection of techniques to address RQs

To address the first RQ, we used reference publication year spectroscopy (RPYS) introduced by Marx et al. (2014). RPYS is a bibliometric technique widely used to 'determine the historical roots of research fields and quantify their impact on current research'. (Marx et al., 2014, p. 751).

To address the second RQ, we used life cycle analysis (LCA) (Meyer et al., 1999). Ernst (1997) and Rezaeian et al. (2017) argue that scientific evolution over time represents an S-shaped curve similar to an industry life cycle where, if the current stage of a scientific field or technology is already known, it would be possible to forecast its future trends and growth trajectory.

To address the third RQ, we employed co-word analysis (CWA) (Callon et al., 1983), CWA assumes that 'when words frequently co-occur in documents, it means that the concepts behind those words are closely related' (Zupic & Cater, 2015). CWA maps the

Table 1 Methodology workflow

Stages of bibliometric analysis	Description
Stage one: research design	Formulation of research questions
	Selection of techniques to address research questions
Stage two: compilation of bibliometric data	Selection of database
	Filtering and exporting data
Stage three: analysis	Data cleaning and pre-processing of data
	Choice of appropriate software
	Analysis of data and formation of subgroups, clusters
Stage four: visualization of results	Choice of visualization method
	Choice of visualizing software
Stage five: interpretation	Describing & interpreting findings

pertinent literature directly from the interactions of key terms instead of the interactions of citations (Coulter et al., 1998). CWA is the primary technique to explore and build the underlying conceptual structure of a scientific field (Zupic & Cater, 2015).

Compilation of bibliometric data

Bibliometric data are available at multiple debases such as Scopus, Clarivate Analytics' Web of Sconce,[4] Google Scholar, and Microsoft Academics (see Harzing & Alakangas, 2017 for a comparison). For the purpose of this study, we used Scopus for three reasons. First, Scopus is the largest scientific database and has a better coverage of journals than other databases (Martín-Martín et al., 2018; Zupic & Cater, 2015). Second, Scopus is more accurate than other databases (Franceschini et al., 2016). Finally, unlike other databases, Scopus contains data for all authors in cited references, making interpretation and discussion of findings easier and more accurate (Zupic & Cater, 2015).

After selecting the database, we followed the method used by Chabowski et al. (2013) to identify the relevant terms for retrieving publications from the database. Accordingly, we reviewed literature on GnSBMs and developed an initial list of terms. Then, we asked three experts to review and finalize the list. Next, we used the list in Scopus to retrieve all relevant publications. The initial search resulted in 1297 records. We scanned the records' abstracts, titles and keywords and identified and removed 188 irrelevant records. We also removed 28 notes, erratum and editorials. Next, we filtered by subject area to business, management, accounting, economics and social sciences ($N=938$). Finally, we excluded all non-English records ($N=67$) and removed duplicates ($N=18$). The final dataset included 851 unique (deduplicated) records.[5]

[4] We are grateful to an anonymous reviewer for pointing us to the correct naming of Clarivate Analytics' Web of Sconce.

[5] Since different software tools require different formats, we downloaded data in three formats (CSV, BIB &, RIS). Since converting from one format to another is not always easy, this result in the loss of records or erroneous transformations many times.

Analysis and visualization of results

Data cleaning and pre-processing

Data cleaning, disambiguation and preparation constitute a key prerequisite for accurate bibliometric data analysis (Zupic & Cater, 2015). Consistent with Castriotta et al. (2018), we carefully checked the data for duplicate records ($N=18$), incomplete and erroneous authors' names ($N=56$ records were identified and corrected), synonymous, plurals and misspelled keywords ($N=145$ keywords were corrected), incorrect cited references (338 cited referenced were identified and 330 were corrected and 8 removed) and incomplete journal names ($N=25$ incorrect journal names were corrected). This process took 3 weeks and was carried out in three steps.[6] First, we used normalizing functions of BibExcel to normalize names of authors and journals (Persson et al., 2009). Then, we created a thesaurus to consolidate plural words, words appearing in different forms and same words with different spellings (e.g. model with models, organization and organisation, Business Modelling with Business Modelling) (Eck & Waltman, 2020). Next, we disambiguated the dataset for incorrect journal names and cited references (CR), using the disambiguation function of CRExplorer which detects variants of the same CR, clusters them and merges their occurrences (number of CRs) (Thor et al., 2018). The final output file was then saved for processing.

Exploring the historical roots of research on GnSBMs using RPYS

We employed Cited References Explorer (CRExplorer) package developed by Thor et al. (2018) to perform RPYS analysis. CRExplorer creates a graph based on the frequency of citations of the cited references (CRs) over time[7] with the year of publication of a cited reference on the *x*-axis and the total number of citations to the cited reference on the *y*-axis (Fig. 1). The spectrogram visualizes peaks which can be interpreted as important dates for the publication of possible influential historical contributions[8] (Bornmann et al., 2018).

Influential historical contributions which were illustrated in Fig. 1 have been listed in Table 2. We did not impose any citation threshold to select peaks. Our intention was to offer a complete picture of all significant contributions in the history of research on GnSBMs. Therefore, we illustrated all peaks in the history. CRExplorer identified ten peaks.[9] We reviewed these peaks and grouped them into five types in terms of their primary contribution: (1) sustainability contributions which offered conceptual breakthroughs for sustainable and green business models, (2) methodological contributions which offered methodological breakthroughs for researchers, (3) theoretical contributions which offered formal

[6] We are grateful to an anonymous reviewer for requesting to clarify and expand this section. It resulted in an improved degree of replicability and validity of our manuscript.

[7] An absolute deviation from the 5-year median (Y−2, Y−1, Y 0, Y+1, Y+2) was used, because according to Marx et al. (2014), it is particularly easy to see the peaks created by the frequently cited historical publications in the deviations normalized as a percentage of the cited references in the corresponding 5 years.

[8] We appreciate an anonymous reviewer for the suggested wording of this statement on the main use of the spectrogram in the RPYS analysis.

[9] When historical peaks are not clearly distinguishable, researchers can use a code for STATA, called PLOTRPYS, developed by Bornmann in 2017 available at http://fmwww.bc.edu/repec/bocode/p/plotrpys.ado) to extract peaks in the RPYS graph. We are grateful to an anonymous reviewer for adding this point.

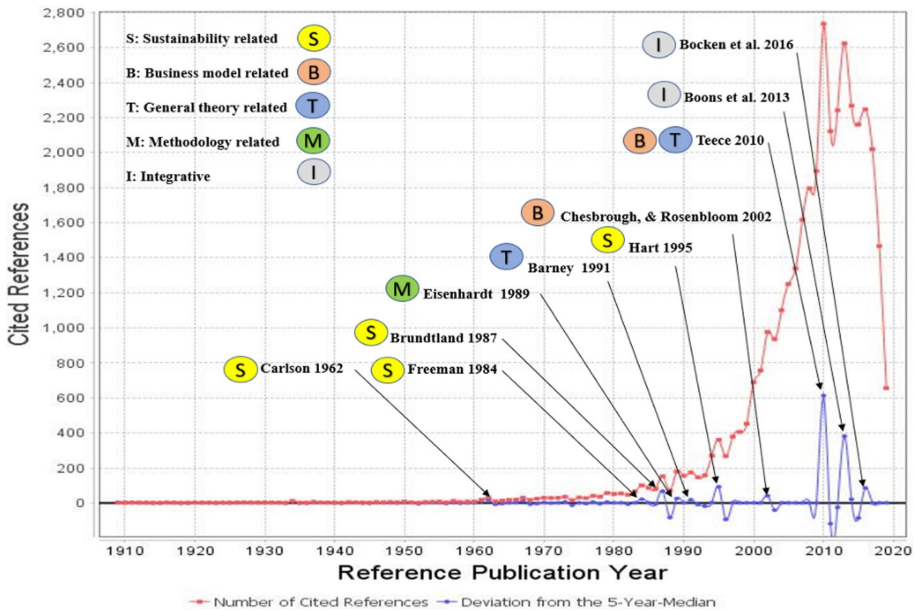

Fig. 1 Reference publication year spectroscopy of research on GnSBM

theories to help researchers structure their research, (4) BM contributions which illustrated the application of the BM concept in the context of sustainability and (5) integrative contributions which paved the way for future research by integrating different aspects of research on GnSBMs.

In addition, we used the export function of the CRExplorer to extract 'sleeping beauties' in the field of GnSBMs. A sleeping beauty is a publication 'that goes unnoticed ("sleeps") for a long time and then, almost suddenly, attracts a lot of attention ("is awakened by a prince")' (Van Raan, 2004, p. 461).[10] Sleeping beauties represent important contributions and often paradigmatic innovations in the history of a scientific field owing to being ahead of their times (Fang, 2018; Li & Ye, 2016). The search for sleeping beauties is not just an exotic whim, but a necessity to answer key questions about the historical evolution of a field (van Rann, 2004). CRExplorer unearthed 13 sleeping beauties in the history of research on GnSBMs (Table 2). These 13 publications represent historical milestones with delayed recognitions. Not only do these publications mesh with the same typology of historical peaks as discussed before, but they also provide complementary rather than supplementary insights into the historical evolution of research on GnSBMs. As such, these publications, when taken together, paint an interesting portrait of the key historical contributions to the growth of research on GnSBMs. In what follows, we review these publications.

[10] We are grateful to an anonymous reviewer for the inclusion of sleeping beauties into the historical assessment of research on GnSBMs and suggesting the use of the seminal definition from Van Raan (2004) to avoid confusion surrounding the definition of sleeping beauties.

Table 2 Historical roots of research on GnSBM

No	Publication	Type of contribution	Type of reference
1	Carson (1962)	Sustainability	Peak in RPYS
2	Freeman (1984)	General business theory	Peak in RPYS
3	Brundtland (1987)	Sustainability	Peak in RPYS
4	Eisenhardt (1989)	Methodology	Peak in RPYS
5	Barney (1991)	General business theory	Peak in RPYS
6	Hart (1995)	General business theory	Peak in RPYS
7	Chesbrough and Rosenbloom (2002)	Business model	Peak in RPYS
8	Boons and Lüdeke-Freund (2013)	Integrative	Peak in RPYS
9	Bocken et al. (2016)	Integrative	Peak in RPYS
10	Teece (2010)	Business model	Peak in RPYS and sleeping beauty
11	Eisenhardt and Graebner (2007)	Methodology	Sleeping beauty
12	Stubbs and Cocklin (2008)	Integrative	Sleeping beauty
13	Richardson (2008)	Business model	Sleeping beauty
14	Osterwalder and Pigneur (2010)	Business model	Sleeping beauty
15	Lüdeke-Freund (2010)	Integrative	Sleeping beauty
16	Zott and Amit (2010)	Business model	Sleeping beauty
17	Schaltegger et al. (2012)	Integrative	Sleeping beauty
18	Rashid et al. (2013)	Integrative	Sleeping beauty
19	Su et al. (2013)	Sustainability	Sleeping beauty
20	Yin (2014)	Methodology	Sleeping beauty
21	Belk (2014)	Sustainability	Sleeping beauty
22	Tukker (2015)	Sustainability	Sleeping beauty

Historical peaks in the evolution of research on GnSBMs

Silent Spring by Carson (1962) represents the first peak. Carlson eloquently reported the harmful side effects of pesticides on the environment. Her work has been repeatedly cited in research on GnSBMs as a seminal work that stresses the need for greening BMs. Freeman's (1984) book on stakeholder management shapes the second peak in the history of research on GnSBMs. The stakeholder theory raised awareness about the significance of including all stakeholders in business decision-making, and contended that BMs must include interests of different stakeholders. Similarly, the 'common future' by the World Commission on Environment and Development urged nations to arrive at a universal agenda for business sustainability. The first three peaks marked by these contributions, each one in its own way, revolutionized rules, regulations and mentalities that define how BMs ought to be designed and implemented in a green and sustainable manner.

Prevalence of exploratory research methods aimed at developing new theories from case studies is a key characteristic of a young research field (Edmondson & McManus, 2007). It is not surprising to find that Eisenhardt's (1989) work on developing theories from case studies is the only methodological peak in the history of research on GnSBMs.

As noted, a BM defines how a business uses its resources and capabilities to create, deliver and capture value (Teece, 2010). Therefore, a theory for organizational resources is needed to understand how GnSBMs actually work. Barney's (1991) work on the resource-based theory of the firm offered such an understanding and expectedly represents the fifth peak in the history of research on GnSBMs. The sixth peak belongs to Hart's (1995) work on a natural resource-based view of the firm. Building on Barney's (1991) seminal work, Hart argued that if resources were used in pollution prevention, product stewardship and sustainable development, they would create sustainable competitive advantage.

The next two peaks are specifically about the BM concept. Chesbrough and Rosenbloom (2002) argued that every new technology and venture needs a BM to succeed. New green and sustainable technologies need specific BMs to succeed, and this is a principle in the genesis of GnSBMs. Relatedly, Teece (2010) argued that every business venture has a BM. This BM forms the micro-donation of how it operates and evolves over time. Arguably, every green and sustainable idea must be incorporated into a BM before it enters the market.

The last two peaks are integrative contributions. Boons and Lüdeke-Freund (2013) offered a normative view of research on GnSBMs by arguing that research on sustainable innovations must incorporate BM concept into its agenda. Bocken et al. (2016) synthesized research on product design for circular BMs.

Exploring the historical roots of research on GnSBMs implies that it is a multidisciplinary field that is evolving towards an interdisciplinary one. This movement can be explained from two different but closely related perspectives: epistemological and bibliometrical.[11] From an epistemological view, Jovanovic and Schinckus (2013) argue that in a multidisciplinary field 'several disciplines are in association for the purpose of analysing a common object with their own theories, models and concepts' (p. 167). The bibliometircal view focuses on the voice of authors and a holistic view of the field. For instance, Wagner et al. (2011) describe a multidisciplinary field as a field in which authors 'speak as separate voices, in encyclopedic alignment, an ad hoc mix, or a mélange' (p. 16). A unifying angle between two perspectives is their focus on the absence of a disciplinary synergy. In both perspectives, multidisciplinary research is just sum of the disciplinary contributions without a clear integration. As shown, ecological roots (e.g. Brundtland, 1987; Carson, 1962) and organizational roots (e.g. Barney, 1991; Freeman, 1984; Hart, 1995) have advanced separately in their own disciplines to shape the early foundation of knowledge on GnSBMs.

In an interdisciplinary field, researchers from different disciplines 'have common roles and they try to arrive at integration and synthesis of the disciplines involved by developing a common methodology, models and theories' (Jovanovic & Schinckus, 2013, p. 167). The bibliometrical view of an interdisciplinary domain offers a similar portrait. 'It integrates separate disciplinary data, methods, tools, concepts and theories in order to create a holistic view or common understanding of a complex issue, question, or problem' (Wagner et al., 2011, p. 16). The last two peaks in the historical foundation of GnSBMs research denote the formation of an interdisciplinary domain where 'disciplinary knowledge, concepts and tools of investigation are considered and combined in such way that the resulting understanding is greater than the sum of its disciplinary parts' (Jovanovic & Schinckus, 2013, p. 167), and offers a larger, more holistic understanding of the core problem or question (Wagner et al., 2011).

[11] We are grateful to an anonymous reviewer for the suggestion to include a unifying lens to this argument where epistemological and bibliometrical views can be combined to substantiate our argument about the disciplinary dynamics of research on GnSBMs.

Further, existence of only nine peaks and recency of integrative contributions indicate that research on GnSBMs is in its formative stage and has not reached its full potential yet. The life cycle analysis substantiates this observation.

Sleeping beauties in the history of research on GnSBMs

As noted, sleeping beauties are a specific type of historical publication which go through an initial period of little or no recognition and then receive remarkable recognitions. As such, sleeping beauties often contain unpresented significance which takes time to attract scholarly attention (van Rann, 2004).

The first sleeping beauty in the field of research on GnSBMs is the methodological study of Eisenhardt and Graebner (2007) which builds on an earlier study of Eisenhardt (1989) on developing theories from case studies. Eisenhardt and Graebner (2007) enumerate challenges in using case studies and offer several practical solutions to translate challenges into opportunities. This publication is a sleeping beauty because earlier work on GnSBMs often used single case studies as descriptive and illustrative tools rather than theory-building ones. As research on GnSBMs grow in relevance and popularity, the need to develop theories based on multiple case studies strengthened, resulting in a sudden appreciation of the recommendations outlined by Eisenhardt and Graebner (2007). This reasoning can also explain the sudden awakening of another sleeping beauty: Yin (2014) on case research. Yin (2014) provides a comprehensive explanation for case study as a scientific research methodology in this seminal work.

The next sleeping beauty is the study of Richardson (2008), who portrays business model as a framework for strategy execution. Richardson (2008) argues that a business model can help to think strategically about the details of the way a firm does business. Thus, it can be used to execute strategies. This view of business model as a strategic rather than commercial or operational tool was novel and unprecedented at the time, and was later substantiated and expanded in the works of Teece (2010), Zott and Amit (2010) and Osterwalder and Pigneur (2010), all of which are among the sleeping beauties we identified. Teece (2010), as described earlier, offered novel insights into the connection between BM and strategy from a capability view, whereas Zott and Amit (2010) conceptualized business models as activity systems. Osterwalder and Pigneur (2010) proposed business model canvas as a conceptual took to describe, visualise, assess and change business models. The contribution of these studies was to the general domain of business model because they paved the way for future work on GnSBMs by helping researchers look at sustainable practices through a wider business model lens.

The study of Stubbs and Cocklin (2008) represents another sleeping beauty. It uses two descriptive case studies to demonstrate that a sustainable business model requires a mix of both structural and cultural capabilities to enable organizational wide collaboration with all stakeholders in an organization's ecosystem. This contribution is an integrative one because it brings sustainability into the domain of business model design. There are at least two reasons why this study is a sleeping beauty. First, Stubbs and Cocklin's (2008) account of organizational sustainability in the intersection of structural and cultural capabilities was unprecedented in the field. Second, it conceptualizes an organization's business model as a managerial paradigm that challenges the neoclassical economic view of the firm as a productive entity. Although this view served the purpose of the research, it was different from the dominant view of BM as the time which was primarily about the logic of value creation in an organization (Chesbrough & Rosenbloom, 2002).

Similarly, Lüdeke-Freund (2010) used the concept of business model as a coherent set of meta factors that defines how individual value, value equity (i.e. appropriated value) and public value (i.e. externalities) can be integrated to support sustainable production and consumption. The work of Lüdeke-Freund (2010) was integrative because it conceptually synthesized business model and sustainable production and consumption. However, it received delayed recognition for doing so because its conceptualization of business model as the logic of value creation and its classification of value into individual value, value equity and public value were unorthodox at the time and took a while to enter the mainstream value-based research on GnSBMs.

Rashid et al. (2013) presented the concept of Resource Conservative Manufacturing (ResCoM) as a paradigmatic shift on how the prevailing open-loop manufacturing system can be transformed into a closed-loop one. Although these authors did not specifically discuss business model concept, their study proposes a novel way to create sustainable value. Consequently, we classified it as an integrative sleeping beauty. Being a conceptual study aimed at proposing a new sophisticated manufacturing system based on conservation of energy, material and value added with waste prevention and environment protection could explain why this study didn't receive instant recognition.

The last three sleeping beauties addressed key issues about circular and shared economy by offering novel views which were ahead of their time. As such, we classified their contribution as generic to the domain of sustainability. Su et al. (2013), reviewed national policies on the implementation of circular economy in China and offered an overview of underlying problems and challenges as well as practical recommendations. The initial economic growth of China by relying on fossil fuels and adopting traditional unsustainable manufacturing systems before its modernization in recent years could explain why this article did not attract early attention. Analogously, Belk (2014) reviewed the tenets of sharing economy and argue that a post-ownership economy driven by sharing and collaborative consumptions will overtake the existing ownership-based economy.

Lastly, Tukker (2015) addressed a vexing issue at the time; the slow adoption of product service systems (PSS) in the context of circular economies. Tukker's review of research suggested that for consumers, having control over things, artefacts and behavioural freedom are very important. However, PSSs are often less accessible or have less tangible value than the competing products. Tukker's study did not receive early recognition because of the nascency of research on both PSSs and circular economy BMs. As research on GnSBMs expanded, the importance of methods to increase popularity and adoption of PSSs rose, resulting in a refreshed interest in studies such as Tukker's.

As noted, peaks in RPYS and sleeping beauties highlighted a number of key historical themes, such as generic theories of sustainability and early conceptualizations of business models, as well as more specific research on the architecture of sustainable business models and challenges of shared and circular economies. These developments on their own, albeit informative, do not show the growth trajectory of research on GnSBMs over its life cycle. We address this issue in the next section.

Drawing the growth trajectory and life cycle of research on GnSBMs

The life cycle of a scientific field is characterized by four distinctive phases: introduction, growth, maturity and saturation (Ernst, 1997; Rezaeian et al., 2017). In the introduction phase we witness a little growth in the number of publications, while in the growth phase, the number of publications increases exponentially. The maturity phase shows signs of

Table 3 Results growth curve on GnSBM

Parameters	Values	95% CI, low	95% CI, high	95% CI, median
d	0	0	0	0
K	2542	1374	2618	1786
a	16.72	14.17	16.38	15.36
t_m	2022	2019	2022	2020
10%	2014	2011	2013	2014
90%	2031	2025	2031	2028
99%	2040	2032	2036	2040

decline in the number of publications until the saturation stage is reached, in which only a limited growth with few new publications can be expected. However, 'saturation level does not mark an end but rather advancements into a new level; that is to say, the growth period can still be extended, if there are new breakthrough innovations in this area' (Zanjirchi et al., 2019, p. 1299). This curve can be modelled via Eq. 1 (Meyer et al., 1999).

$$N(t) = \frac{K}{1 + \exp[-\frac{\ln(81)}{\Delta t}(t - tm)]}, \quad (1)$$

where K is the asymptotic limit that the growth curve approaches and shows the saturation level of growth, Δt is the characteristic duration that specifies the time required for a trajectory to grow from 10 to 90% of the limit K, and t_m is the midpoint of the growth trajectory (Meyer et al., 1999). To estimate these parameters, it is customary to transform the logistic curve into a straight line using the Fisher-Pry Transform (Meyer et al., 1999) as shown in Eq. 2:

$$FP(t) = \left(\frac{F(t)}{1 - F(t)}\right), \quad (2)$$

$$\text{where } F(t) = \frac{N(t)}{k}.$$

We used LogletLab 4.0 (Yung et al., 1999) to perform LCA. Consistent with Postnikov (2020), we used a Monte Carlo simulation with 10,000 iterations and confidence interval of 95%. Estimated parameters are presented in Table 3.

Figure 2 illustrates the life cycle of research on GnSBMs. It suggests that research on GnSBMs went through an introductory period from 2002 to 2013 and reached its 10% point in 2014, when it commenced a period of scientific growth which is expected to continue until 2040 with over 2542 publications (Fig. 2A). The growth period can still be extended if there are new breakthrough innovations in this area. Thus, this extrapolation indicates a clear potential for further developments in this field.

Publications of influential integrative works such as Boons and Lüdeke-Freund (2013) explain why the year 2014 marks the start of a new period characterized with an accelerated growth in research on GnSBMs. This acceleration is expected to increase until 2022 when the field enters its maturity phase (Fig. 2C), when growth will slow down. The Fisher-Pry transformation in Fig. 2B supports this growth curve and suggests that the field is expected to grow from 10 to 90% in 17 years (2014–2031).

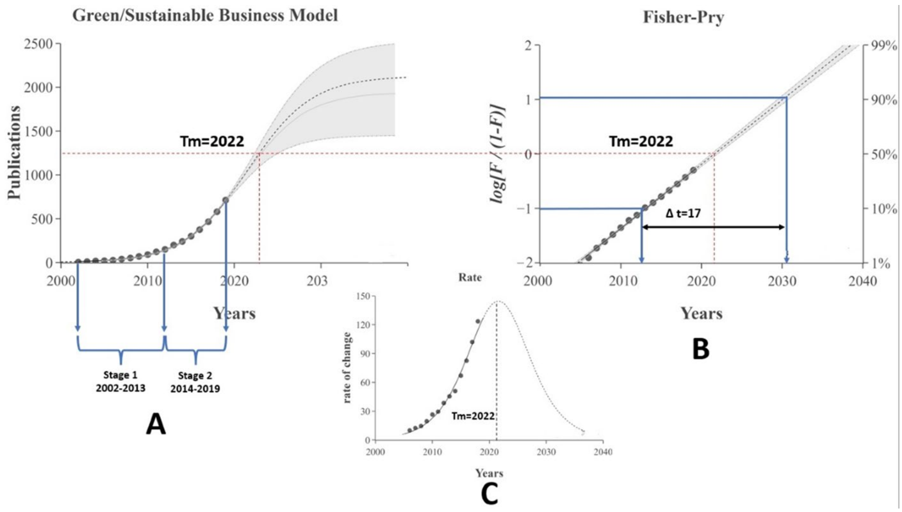

Fig. 2 Growth curves of research on GnSBM

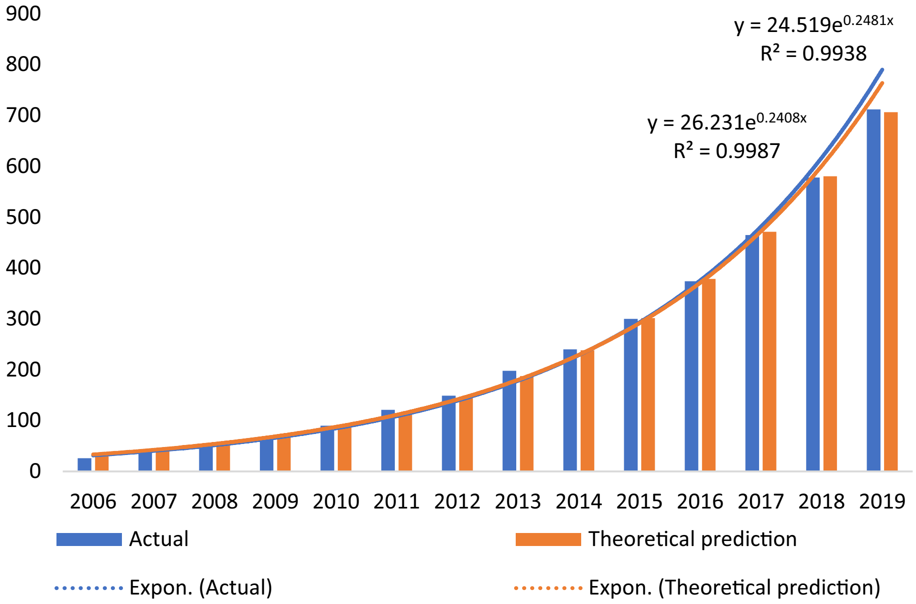

Fig. 3 Sensitivity analysis of predicted growth of research on GnSBM

We carried out a sensitivity analysis by comparing the actual numbers of publications with the predicted numbers to assess the accuracy of the predictions in the growth curve. The results as shown in Fig. 3 indicate a considerably high level of accuracy of the predictions in the results of growth curve analysis.

We conclude that research on GnSBMs has, so far, gone through two phases of its life cycle. We consider the year 2014 as a point when the field moved from an introductory

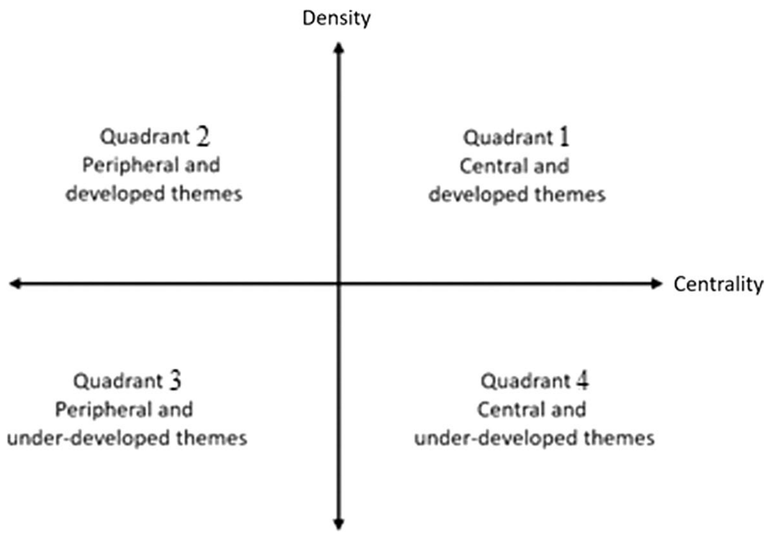

Fig. 4 Quadrants in a strategic diagram

stage into a growth stage (Fig. 2A). Informed by this observation, we performed two rounds of CWA to assess the conceptual structure of research in each stage (2002–2013 & 2014–2020).

Mapping the conceptual structure of research on GnSBMs

CWA extracts 'the themes of science and detect the linkages among these themes directly from the subject content of texts. It does not rely on any a priori definition of research themes in science' (He, 1999, p. 138); therefore, it allows an objective and unbiased assessment of publications in a field and dynamics of relationships between its keywords (Callon et al., 1983, 1991).

To perform CWA, researchers can use either title words or author keywords. We used author keywords because it creates results which are 'substantially more detailed than that created by title word analysis' (He, 1999, p. 154). Title words are also less representative of an article's content (Zhang et al., 2016). The Bibliometrix package in R (available at http://www.bibliometrix.org) via its Biblioshiny GUI (Aria & Cuccurullo, 2017) was used to perform this analysis. We followed the method outlined by Callon et al. (1991) and He (1999) to draw strategic diagrams for clusters of themes emerged from CWA. Appendix explains this procedure.

Fig. 5 Strategic diagram (2002–2013)

A strategic diagram as demonstrated in Fig. 4 presents a conceptual structure based on a classification of themes in relation to their centrality and density scores.[12] This classification allows us to detect established and emerging themes in a research field for a specific period of time (Callon et al., 1991). We accordingly created two strategic diagrams, one for 2002–2013 and one for 2014–2020, and reviewed relevant literature in each phase.

[12] According to Callon et al. (1991, p. 164), a cluster can be defined in two different ways. Firstly, it can be seen as a point in a general network, one which is characterized by its position; that is to say, by the bundle of links uniting it to other clusters/points in the general network. Secondly, it can be seen as a cluster, made up of words linked with each other; it itself defines a more or less dense network, one which is more or less coherent and robust. Centrality measures the intensity of a given cluster's links with other clusters. The more numerous and stronger these links are, the more this cluster designates a set of research problems considered crucial by the scientific or technological community. Density characterizes the strength of the links that tie the words making up the cluster together. The stronger these links are, the more the research problems corresponding to the cluster constitute a coherent and integrated whole.

A strategic diagram for research from 2002 to 2013

Figure 5 exhibits the strategic diagram for the period between 2002 and 2013. In quadrant one we have three themes: (1) corporate social responsibility (CSR), (2) BM concept and (3) telemedicine. CSR represents the biggest theme in this quadrant. It is a central concept in the literature on business sustainability (Barry, 2003; Kleine & von Hauff, 2009), and has been associated with other concepts such as triple bottom line (Birkin et al., 2009) and corporate environmental reporting (Carvalho, 2010; Duran-Encalada & Paucar-Caceres, 2012). CSR is embedded in every GnSBM because, according to the Commission of the European Communities (CEC), 'CSR is a fundamental concept whereby companies integrate social and environmental concerns into their business operations and in their interactions with their stakeholders on a voluntary basis' (CEC, 2001, p. 5). Research in this phase demonstrates how organizations such as Petrobras (Carvalho, 2010), Marks & Spencer (Barry, 2003), Lee Zen (Chang et al., 2011), Pemex (Duran-Encalada & Paucar-Caceres, 2012) and Unilever (Polman, 2013) have adjusted their BMs to embrace CSR.

The BM concept was a central and developed theme in this phase because it offered researchers an umbrella concept to explain various sustainable business activities such as sustainable furniture manufacturing (Høgevold, 2003), eco-friendly fashion design and production (Štrukelj, 2010), design of better product recovery and recycling systems (Rahimifard et al., 2009), adoption of e-governance in rural areas (Naik, 2011), management of textile waste (Savageau, 2011), manufacturing and distributing of improved biomass stoves to underprivileged families (Shrimali et al., 2011), design of better e-health systems (Mettler & Eurich, 2012) and development of sustainable product-service ecosystems (Resta, 2010) through the lens of BM.

Compared with CSR and BM concept, telemedicine is a smaller theme with less centrality and a lower degree of density. Telemedicine refers to the application of ICT in BMs which offers healthcare and medical services remotely through a phone line (Barry, 2003; Bell, 2013; Chang et al., 2011; Duran-Encalada & Paucar-Caceres, 2012; Kleine & von Hauff, 2009; Ramesh, 2010). The centrality of this theme can be attributed to its focus on novel BMs that leverage ICT to expand healthcare services internationally (Pak et al., 2008). Telemedicine is also central to e-health ecosystems which use different BMs to promote an active and healthy ageing around the world (Dimitrova, 2013). Additionally, transforming medical and health records into an electronic format lies at the heart of healthcare reforms which are often embodied in GnSBMs (Abraham et al., 2011; Adler-Milstein et al., 2013).

Moving on to the second quadrant, service quality and information processing and security were two themes in this phase. Service quality is a quintessential factor in the success of GnSBMs which use PSSs. Consumers prefer flexible, reliable and personalized services when assessing advantages of PSSs over traditional BMs (Beuren et al., 2013). Uncertainty about service quality explains why consumers might be distrustful of PSSs (Catulli, 2012). Continuous improvement of service quality is, thus, germane to the competitiveness of such GnSBMs (Schweitzer et al., 2010).

Information security and processing are essential factors in the success of every GnSBM which works with users' personal information. For instance, Gomes et al., (2010) identified information security as a key barrier in the implementation of BMs that generate universal broadband access in developing regions. Similarly, lack of infrastructure to ensure trust, information security and information accuracy has been a concern for the success of GnSBMs in the public health sector (Anthony et al., 2013; Dowling et al., 2010).

The third quadrant contains 'energy poverty' and 'education'. Energy poverty concerns BMs such as solar panel initiatives that enable access to the electricity grid for more than 1.5 billion people (Myers, 2013b). Associated terms with this theme include 'rural electrification', 'economics of power networks' and 'cheap energy', predominantly in the developing world (Myers, 2013a, 2013b).

The presence of 'education' in this quadrant can be explained from two perspectives. First, several studies have argued that educating students about GnSBMs in fields such as engineers (Shartrand et al., 2010) and nursing (Capezuti et al., 2013) facilitates global sustainable development. Second, BMs such as open educational resources (de Langen, 2013), mobile learning services (Maske et al., 2011) and affordable higher education loans (Ramachandran & Lavanya, 2012) bring higher education to the forefront of sustainable development.

Two themes, namely 'sustainable BM' and 'bottom of the pyramid' (BOP), appeared in the fourth quadrant. The former includes research on the conceptualizations of GnSBMs (e.g. Stubbs et al., 2008; Wilson & Post, 2013), social BMs which create shared value (Porter & Kramer, 2011) and rhetoric of 'BM sustainability' (Jenkins, 2006; Schaltegger et al., 2012). The latter encapsulates research on the design of GnSBMs for BOP (Prahalad & Hart, 2002; Myers, 2013a). Innovative BMs such as rural solar panels (Myers, 2013a), rural healthcare (Alur & Schoormans, 2011; Esposito et al., 2012), affordable education and sanitation (Prahalad, 2005) and rural banking (Mohan & Potnis, 2010) are among GnSBMs which have been successfully launched at BOP.

A strategic diagram for research from 2014 to 2020

The strategic diagram for research on GnSBM published between 2014 and 2020 is illustrated in Fig. 6.

The thematic structure of the second stage is consistent with the findings of the life cycle and the RPYS analyses. As a young field in its formative phase, we did not observe any central and developed theme in the first quadrant. In contrast, there are two peripheral and developed themes in the second quadrant. The first is the 'supply chain', which captures two streams: (1) the role of GnSBMs in sustainable supply chains (Dubey et al., 2015; Geissdoerfer et al., 2018a, 2018b) or socially responsible supply chains (Eriksson & Svensson, 2015; Wit & Pylak, 2020) and (2) the role played by GnSBMs in disrupting traditional supply chains (Chun, 2020; García-Muiña et al., 2020; Massaro et al., 2020; Melkonyan & Krumme, 2019; Nosratabadi et al., 2019a, 2019b; Pal & Gander, 2018; Papahristou & Bilalis, 2017; Rajesh Karthik & Millath, 2019; Tiscini et al., 2020; Zufall et al., 2020).

The second theme is the 'sustainable innovation' which is an umbrella theme related to how innovative BMs drive economic transition towards sustainability (Geissdoerfer et al., 2018a, 2018b). It encompasses topics such as collaboration mechanisms between different GnSBMs (Reficco et al., 2018), eco-innovations (Al-Saleh & Mahroum, 2015; Barbieri & Santos, 2020; Bocken et al., 2014; Li & Evans, 2019) and social entrepreneurship (Dentchev et al., 2018; Mongelli et al., 2017). Additionally, this theme included research on BMs for greener infrastructural projects (Haavaldsen et al., 2014), sustainable sources of energy (Nair & Paulose, 2014), BMs for eco-tourism (Naramski & Herman, 2020), BMs which reuse and recycle products in innovative ways (Reinhardt et al., 2020; Xue et al., 2019) and new BMs to manage plastic waste (Dijkstra et al., 2020).

Fig. 6 Strategic diagram (2014–2020)

Two themes populated the third quadrant: 'Internet of Things' (IoT) and 'cloud computing' (CC). These two are complementary technologies in Industry 4.0 and numerous opportunities for developing GnSBMs arise when these two are integrated in a 'cloud of things' model (Aazam et al., 2016; Lardo et al., 2020; Stergiou et al., 2018).

IoT enables everyday objects to communicate with one another over the internet to achieve some useful objectives (Whitmore et al., 2015). In the context of GnSBMs, IoT can convert linear BMs into circular ones (Ingemarsdotter et al., 2019), improve urban resource recycling (Xue et al., 2019), facilitate redistributed manufacturing systems (Turner, et al., 2019) and enable sharing economy BMs (Gao & Li, 2020).

Cloud computing (CC) refers to an 'ubiquitous, convenient, on-demand network access to a shared pool of computing resources that can be rapidly provisioned and released with minimal management effort or service provider interaction' (Chun, 2020, p. 50). Applications of CC in GnSBMs are vast. For instance, CC improves cost and energy efficiency in big data environments (Rehman et al., 2016), enables better management of resources in high traffic networks (Kunsemoller et al., 2017), reduces cost and energy consumption of manufacturing systems (Fisher et al., 2018) and facilitates ICT provision in different sectors such as higher education (Tao et al., 2015).

Quadrant four is represented by three themes: 'circular economy', 'sharing economy' and 'blockchain'. Circular economy is the most prominent theme for two reasons. First, transition to circularity is a key area of research in GnSBMs (Hofmann, 2019; Leipold & Petit-Boix, 2018; Meissner et al., 2020; Mishra et al., 2020; Scheepens et al., 2016). Second, circular BMs are versatile (Baldassarre et al., 2019; Cong et al., 2019) and can be linked to sharing economy (Bocken et al., 2020; Ciulli & Kolk, 2019; Curtis & Mont, 2020), PSS (Barquet et al., 2016a, 2016b; Ingemarsdotter et al., 2019), resource efficiency (Hofmann, 2019; Martens, 2007; Rizos et al., 2016; Yang & Evans, 2019) and Industry 4.0 (Bodkhe et al., 2020; García-Muiña et al., 2020; Rajesh Karthik & Millath, 2019; Strandhagen et al., 2017).

Moving on to the sharing economy, sharing BMs are used to rent, share, lend, sell or exchange shareable goods on the basis of the premise of liberty, democracy, social justice and environmental justice (Martin, 2016). Although sharing BMs promote a more sustainable consumption regime (Geissinger et al., 2019), they also bring about paradoxical challenges such as creating unregulated marketplace, decreasing consumer trust, disturbing labour market, increasing reliance on technology and advocating social exclusivity (only those who own a shareable asset can join the network) (Frenken et al., 2017; Laurell et al., 2019; Martin, 2016; Plewnia & Guenther, 2018). Such paradoxes and ambiguities surrounding sharing BMs and their actual costs and benefits could explain why this is a central yet underdeveloped theme in the research on GnSBMs.

Lastly, blockchain (BC) is a decentralized ledger system which records all forms of transactions while guaranteeing security, anonymity and data integrity without any external actor in charge of controlling transactions (Tiscini et al., 2020; Yli-Huumo et al., 2016). According to Tiscini et al. (2020), the main feature in BC technology is that 'no record or data can be overwritten, and every transaction is certified in time through a timestamp' (p. 1624). As such, BC technology improves trust and fosters inclusivity by allowing widespread distribution of the benefits of a BM to the community involved (Massaro et al., 2020). Owing to these benefits, BC has become a central theme in the research on various GnSBMs agri-food (Tiscini et al., 2020), finance (Zamani & Giaglis, 2018), higher education (Turkanovic et al., 2018) and public health (Roehrs et al., 2017).

Towards an agenda for future research

Our multi-methodical bibliometric approach reveals numerous avenues for future research. In this section we discuss 14 of them with a hope to simulate continued interests in conducting more focussed research on GnSBMs.

First, research on GnSBMs is an incipient and multi-disciplinary field characterized by an absence of a universal paradigm and prevalence of ad hoc case studies. With a focus on specific case studies, researchers miss causal mechanisms and interactions between both the internal elements of GnSBMs and the broader ecosystem in which they operate. As a result, a fruitful research direction is to examine causal mechanisms between value creating, delivery systems and value capture elements of GnSBMs and how they interact with environmental forces. This would initially lead to addressing questions such as 'how', 'when' and 'under what conditions' GnSBMs succeed or fail and what institutional factors facilitate or hinder adoption of GnSBMs in different contexts. Addressing such questions through normative causal research approaches would broaden our perspective on the underlying processes and mechanisms involved in the success and failure of GnSBMs.

Second, rather than simply using case studies to explain different designs of GnSBMs, researchers might consider other exploratory techniques such as fuzzy-set qualitative comparative analysis (FsQCA) (Ragin, 2009), and association rule mining (Aguinis et al., 2013) to unearth configurations and hidden associations in the design and implementation of GnSBMs. Such investigations help us gain a deeper and more nuanced understanding of how GnSBMs operate.

Third, most of the existing research on circular BMs focuses on either a descriptive or a prescriptive view of circular BMs. The former concerns the design of circular BMs for specific concerns, whereas the latter attempts to distinguish between circular and linear BMs. We believe that it could be insightful to take a more holistic approach to study circular BMs. For instance, issues such as transformation of linear BMs to circular ones, measuring the efficiency of circular BMs, or how different technologies can be combined to design more circular BMs are fruitful directions for future research.

Fourth, notwithstanding past research on sharing BMs, this stream of research still remains underdeveloped for two reasons. First, there is a lack of consensus on how environmental benefits of sharing economy can be objectively measured (Comin et al., 2019; Piscicelli et al., 2018). Second, little research has been done on how sharing economy BMs can be absorbed by and utilized in traditional business ecosystems (see Cocquyt et al., 2020 for a recent case study). For future research, we argue it is important to continue exploring the design themes, measurement approaches and adoption of BMs in sharing economy. Assessing the impact of adopting BMs based on sharing platforms and the extent of collaborative consumption in these BMs require new ways of thinking beyond a priori and binary distinction of sharing versus non-sharing platforms. It necessitates new methods, new theoretical views and new research designs. This aligns with a growing interest in further theory development in the broader domain of GnSBMs.

Fifth, blockchain (BC) has an immense potential to advance the design and functionality of GnSBMs (Tiscini et al., 2020). Very few studies have explicitly discussed the use of BC in GnSBMs. A promising line of research pertains to the existing embryonic body of knowledge on the application of BC technology in types of GnSBMs such as social businesses (Mukkamala et al., 2018), PSSs (Li et al., 2021), provision of clean energy and circular BMs.

Sixth, a business can operate multiple BMs concurrently (Snihur & Tarzijan, 2018). Embracing the variety of GnSBMs as discussed in this paper and elsewhere (Dentchev et al., 2018), we call for more research on the design, operational procedures, challenges and applications of GnSBMs which combine features of circularity, collaborative consumption and social business agendas to achieve sustainability goals. Studying such complex GnSBMs both conceptually and empirically will push knowledge frontiers in sustainable development forward and open new scientific horizons in the design of innovative GnSBMs which address multiple sustainability goals.

Seventh, in 2015 the United Nations developed a set of 17 goals as part of the 2030 agenda for sustainable development (Envision 2030).[13] As we illustrated in this paper, GnSBMs play crucial roles in achieving these goals. Although progress has been made in

[13] According to the Envision 2030 program available at: https://www.un.org/development/desa/disabilities/envision2030.html these 17 Sustainable Development Goals (SDGs) include: (1) no poverty, (2) zero hunger, (3) good health and wellbeing, (4) quality education, (5) gender equality, (6) clean water and sanitation, (7) affordable and clean energy, (8) decent work and economic growth, (9) industry, innovation and infrastructure, (10) reduced inequality, (11) sustainable cities and communities, (12) responsible consumption and production, (13) climate action, (14) life below water, (15) life on land, (16) peace and justice strong institutions and (17) partnerships to achieve the goal.

many areas, such as energy efficiency (e.g. Wagner et al., 2020; Zhang et al., 2018), poverty reduction (e.g. Dembek et al., 2018; Grimm & Gilbert, 2019) and responsible consumption via sharing and circular systems (e.g. Hofmann, 2019; Mont et al., 2020), actions have not been at the space and scale to achieve these goals by 2030 (United Nations, 2021). Therefore, more research is needed to explore and explain the design of GnSBMs which are focussed on specific sustainable development goals. For instance, more research is needed to understand BMs which address sustainable life under water, eradicating hunger, developing more sustainable cities and communities and providing clean water and sanitation.

Eighth, although IoT & cloud computing were peripheral themes, they represent two fertile grounds for research on GnSBMs. First, more research is needed to better understand how the power of IoT and CC can be harnessed separately in developing BMs which explicitly address a wider range of the UN's sustainable goals such as reducing hunger, eradicating poverty, providing sanitation, improving energy efficiency, reducing waste, etc. Second, our review did not reveal any research on the joint application of IoT and CC in GnSBMs. Studying the possibilities emanating from combining IoT and CC in developing new GnSBMs is a promising direction for future research.

Ninth, themes in the presented strategic diagrams such as CSR, blockchain, circular BM and sharing BM were created by the co-word analysis from a holistic perspective. Although these themes represent broad clusters of research, one could argue that they are somewhat vague and need to be more fine-grained. Future research can add value to this stream by narrowing the analytical lens and focussing only on specific domains such as circular BM or sharing BM to generate more fine-grained and domain-specific strategic diagrams. Nesting these new paradigms into our broad diagrams would create a more detailed picture of the core and peripheral areas of research on GnSBMs.

Tenth, we used co-word analysis as a bibliometric technique to develop strategic diagrams. Although these diagrams offer fertile grounds for theory development, they are by no means definitive. Such diagrams must be validated and extended from different angles. We encourage researchers to apply text mining techniques such as topic modelling using latent Dirichlet allocation (LDA) (Chauhan & Shah, 2021; Moro et al., 2015), and machine-learning-based thematic modelling of the literature using Leximancer (Angus et al., 2013; Aryal et al., 2020) to validate and extend the strategic diagrams we proposed here. Such attempts open new avenues to advance theory development and refinement in the growing field of GnSBMs.[14]

Eleventh, we did not explicitly explore the forces that caused changes in the architecture of themes from the first phase (2002–2013) to the second (2014–2020). One of the key forces, as revealed by the identification of sleeping beauties, is the awakening of research on the circular economies' paradigm (Bocken et al., 2016; Geissdoerfer et al., 2018a, 2018b), and specifically its impact on the conceptual boundaries of CSR (Murray et al., 2017). Another force which could account for the rise of blockchain, sharing BMs, telemedicine and information security in the second phase is the technological acceleration of industry 4.0 and the rapid digitization of various services (Furstenau et al., 2020; Raut et al., 2019). Future research is required to investigate other potential forces behind the current thematic structure of research on GnSBMs.[15]

[14] We are thankful to an anonymous reviewer for suggesting that we discuss the opportunities in testing and expanding the co-word strategic diagrams using text mining techniques.

[15] We acknowledge the importance of this assessment and are grateful to an anonymous reviewer for raising this point. It was not within the scope of the study but certainly opens fruitful avenues for future research.

Twelfth, we argued that research on GnSBMs is moving from a multidisciplinary status to an interdisciplinary one where synergistic collaboration between authors across disciplines increases. Future studies need to investigate cross-disciplinary collaborations more explicitly by studying dynamics of co-authorship and structures of communities of practice in the body of research on GnSBMs to assess the pace and extent of this trend.

Thirteenth, review of sleeping beauties unearthed the pivotal contributions of research on the challenges in the adoption of both circular and shared economies to the extant body of knowledge on GnSBMs. Despite these works, there is still a lack of theoretical and empirical research in this domain. We encourage researchers to consider this deficiency as a fruitful direction for further research. Addressing questions such as when, why, and under what conditions parties involved in a business model show resistance to sharing or circular economy systems can advance this growing field significantly.

Lastly, we adopted van Rann (2004)'s recommended 5-year threshold to identify sleeping beauties. There are three variables: (1) depth of sleep (i.e. average citations per year); (2) length of the sleep (i.e. duration of the above period); and (3) awake intensity (i.e. number of citations per year, for 4 years following the sleeping period) (van Raan, 2004, p. 462)[16] which not only affect the number but also change the identification of sleeping beauties. We encourage researchers interested in this field to adjust these variables and explore the existence and contributions of other sleeping beauties in the field of research on GnSBMs as it goes through other stages of its life cycle portrayed in this manuscript. Such explorations will provide numerous opportunities for theory development and refinement.

Discussion and conclusions

Implications for theory development

Our findings have three implications for theory development on GnSBMs. First, in terms of the disciplinary autonomy, we showed that theory development on GnSBMs has moved from a multidisciplinary architecture to an interdisciplinary one. Interdisciplinary fields tend to move towards a transdisciplinary mode where 'researchers from different fields not only work closely together on a common problem over an extended period but also create a shared conceptual model of the problem that integrates and transcends each of their separate disciplinary perspectives' (Rosenfield, 1992). According to Jovanovic and Schinckus (2013), in a transdisciplinary field 'disciplines must be looked on as necessarily complementary in order to better understand the complexity of realities'. Similarly, Wagner et al. (2011) argue that a transdisciplinary field has 'transcendent interdisciplinary research' and fosters systematic theoretical frameworks that refine existing models and define new ones. Given the nascency of research on GnSBMs, we expect to see transdisciplinary research in this field in which new theoretical models using a greater degree of synergy between disciplines emerge. This, of course, requires a higher level of collaboration between disciplines such as engineering, ecology and business than the interdisciplinary status. Theory development in a transdisciplinary field commences when different disciplines bring complementary insights into the design and execution of new theories, frameworks and practical

[16] We are thankful to an anonymous reviewer for suggesting discussing thresholds and variables in the process of identifying sleeping beauties and the importance of adjusting them to identify more and different publications with historical significance.

applications. Given the multifaceted posture of research on GnSBMs, theory development in this field benefits significantly from and is likely to rapidly move towards a transdisciplinary posture.[17]

Second, we provided nuanced insights into the growth trajectory of research on GnSBMs. We are perhaps the first study to methodically show that research on GnSBMs is in its infancy phase. Absence of fully evaluated and universally accepted models place this field at the bottom of the science hierarchy (Cole, 1983). Our directions for future research enhance theoretical progress which can ultimately lead to the development of more rigorous research to support scholars and practitioners with decision-making regarding sustainable development.

Finally, our review and synthesis of research reduced conceptual ambiguity surrounding GnSBMs and offered a simpler and clearer scientific language to communicate about GnSBMs. This increased clarity and improved simplicity allow the concept of GnSBM to be used more sturdily in a universal journey towards a more sustainable future.

A note on post-pandemic recovery

When we started this research project, the world had been hit hard by an unprecedented crisis. The COVID-19 pandemic had spread to over 220 countries, affecting over 150 million people and causing over 3 million deaths (Worldometers, 2021). Millions of people had lost their jobs, were forced to work part time or work from home, and a countless number of businesses were shut down or had to go through extraordinary transformations to survive. The road to post-pandemic recovery will be a long and challenging one fraught with risk and uncertainty.

Recent research suggests that GnSBMs will play an integral part in the journey to recovery. Research by McKinsey (Pinner, 2020) shows that sustainability must be core to the recovery because a low-carbon recovery could not only significantly reduce emissions, but also create more jobs and economic growth. Barbier (2020) argues that rebuilding economies after the pandemic requires rethinking what type of economy we need and want in the future. Simply reviving the existing 'brown' economy will exacerbate irreversible climate change and other environmental risks (Barbier, 2020). Considering these findings, we believe our analysis of research on GnSBMs will pave the way towards a sustainable post-pandemic recovery by providing a deeper and a broader understanding of GnSBMs for policymakers, practitioners and researchers.

Limitations and conclusions

In this study we offered a comprehensive assessment of the life cycle, growth trajectory, historical roots and conceptual structures of research on GnSBMs. Despite its contributions, this study has some limitations which should be considered when interpreting its results. First, we only included publications indexed in the Scopus database. For future research, comparison of these results is recommended with those obtained from other databases such as Web of Science, Google Scholar or Microsoft Academic (Harzing & Alakangas, 2017).

[17] Other fields which have moved from a multidisciplinary to an interdisciplinary status are cultural evolution (Youngblood & Lahti, 2018) and data mining algorithms for smart cities (Kousis & Tjortjis, 2021)

Secondly, the temporal range of our data was limited to 2020. Future research can reassess the growth trajectory and conceptual structures of GnSBMs against our predictions using a longer time span, especially at points closer to the year 2022 where we predicted growth of research on GnSBM will start to slow down.

Thirdly, we built our co-word metrics on author keywords. To assess the validity of our findings we recommend that researchers recreate our strategic diagrams using other indexing methods such as keyword plus (Zhang et al., 2016). Such assessments are worthwhile because they will either result in new findings about the scientific architecture of research on GnSBMs or cement the validity of our findings.

Finally, bibliometric software packages and algorithms constantly evolve and continue to advance. Researchers interested in this field can use other techniques such as bibliometric coupling (Boyack & Klavans, 2010) to assess the forefront of research on GnSBMs from other perspectives, or use other software packages such as SciMAT (Cobo et al., 2012) to test the replicability of strategic diagrams presented in this paper.

Taken together, through this research we have purposefully sought to inspire scholars to gain a broader and deeper understanding of what GnSBMs are and how research in this field can advance. We demonstrated the application of several bibliometrical techniques in assessing the past, present and potential future posture of research in this field and illustrated how a predictive approach can project potential evolutionary paths for theory development in such a broad domain. We hope our research boosts cumulative scientific productivity on GnSBMs by helping researchers across disciplines collaborate more closely to leverage their broad knowledge base and address intriguing questions related to the design and implementation of various GnSBMs.

Appendix

First, we calculated the equivalence index for every pair of co-occurred keywords using Eq. 3.

$$Eij = \frac{Cij^2}{Ci.Cj}, \tag{3}$$

where Cij in the frequency of co-occurrence of keywords i and j, Ci is the frequency of occurrence of keyword i and Cj is the frequency of occurrence of keyword j. Next, we calculated density and centrality of each cluster of keywords using formulas given in Eqs. 4 and 5, respectively.

$$\text{Density} = \frac{\sum Eij}{n-1} \text{ for } i \neq j, \tag{4}$$

$$\text{Centrality} = \frac{\sum Eij}{N-n}, \tag{5}$$

where n is the number of keywords in the cluster and N is the number of all keywords in the network. Then, we plotted themes using their centrality and density values in a strategic diagram (Callon et al., 1991; He, 1999).

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