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Innovation in the bioeconomy: Perspectives of entrepreneurs on relevant framework conditions

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Innovation in the bioeconomy: Perspectives of entrepreneurs on relevant framework conditions

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ABSTRACT

Although entrepreneurial activities are of key importance in a properly functioning innovation system, the micro level of actors is often neglected in the innovation systems' literature. The goal of this paper is to show how the configuration of innovation systems shapes entrepreneurs' perceptions and behaviors. The originality of the present article rests upon a novel framework that distinguishes between the willingness, capability, and perceived opportunities of entrepreneurs embedded in specific innovation systems. We explore the perceptions of 30 entrepreneurs from two European bioeconomy cluster regions who are engaged in R&D and collaborative experimentation in the chemical, plastics, and construction materials industries. Our findings show that with documented innovation willingness, entrepreneurs' innovation capacity is not the decisive bottleneck. Rather, bioeconomy actors perceive that innovation opportunities are blocked by institutions at the national and international levels. The configuration of relevant sectoral innovation systems and value-chains is crucial. We conclude that bioeconomy promotion should emphasis the demand side and systemic multi-level policies that address innovation barriers with due consideration for industry-specific innovation systems and value-chain configurations.

1. Introduction

Major environmental, social, and economic challenges have led to the claim that Europe must radically change its approach to production, consumption, processing, storage, recycling and disposal of biological resources (EC, 2012). The bioeconomy has emerged as a novel economic paradigm in science, technology, and innovation (STI) policy with a mission to minimize adverse environmental impacts of economic activities, thereby aiming to achieve important sustainable development goals (SDGs) (Robert et al., 2020; Fritsche et al., 2020). The transition to a bioeconomy involves the replacement of fossil inputs in a broad range of industries by renewable carbon sources, as well as increased resource efficiency and the preservation of the resource values in material circles (Giampietro, 2019). Alongside the environmental benefits associated with such innovation, the bioeconomy also holds promises regarding the creation of new economic opportunities. New business formation in rural areas, reduced import dependence, and strengthened knowledge-based sectors are widely expected by promoters (Aguilar et al., 2018; Befort, 2020; Brunori, 2013).

Examples of bioeconomy related innovations comprise not only a range of new products such as biopolymers, fuels, and novel food additives (Frisvold et al., 2021; Wydra et al., 2021), but also new processes associated with biorefining (Dahiya et al., 2018; Hellsmark et al., 2016) and industrial biotechnology (Wohlgemuth et al., 2021; Wydra, 2019). In 2015, non-traditional bioeconomy activities only accounted for 4.7% of the European GDP (Kuosmanen et al., 2020). This implies that the bioeconomy still has a long way to go to deliver on its promises. Therefore, it is of interest to investigate the drivers and barriers that might spur or hinder dynamic bioeconomy development.

A wide range of recent research has addressed innovation barriers for segments of the bioeconomy, mostly using an innovation systems (IS) perspective at the national level (e.g., Bosman and Rotmans, 2016; Chung, 2018; Giurca and Späth, 2017; Hellsmark et al., 2016; Nevzorova and Karakaya, 2020; Purkus et al., 2018). However, related assessments lack the perspective of the actors who actually effect these innovations: the entrepreneurs. For this article, we investigated the barriers and drivers that entrepreneurs identified concerning opportunities in the bioeconomy field. By addressing this research gap, we aim to make a theoretical, empirical and practical contribution to the literature. Our theoretical contribution derives from the introduction of a novel framework that links the characteristics of the innovation system

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List of abbreviations

BBD	Biobased Delta in the Netherlands
GAP	European General Agricultural Policy
IS	Innovation System
LMC	Large and Multinational Company
MNTQ	Metrology, Norming, Testing, and Quality Management
NIS	National Innovation System
OEM	Original Equipment Manufacturer
R&D	Research and Development
RG	Respondent from Germany
RIS	Regional Innovation System
RN	Respondent from the Netherlands
SCM	Spitzencluster Mitteldeutschland in Germany
SDG	Sustainable Development Goal
SIS	Sectoral Innovation System
STI	Science, Technology and Innovation

to entrepreneurial innovation behavior at the micro-level. As such, our paper combines two research fields that, so far, have not been combined: entrepreneurial behavior and IS. Combining these two knowledge streams addresses the frequently raised criticism of the IS approach that it ignores the agency of micro-level actors (Kern, 2015; Markard and Truffer, 2008). The empirical contribution comes from a comparative analysis of two regional case studies in the Netherlands and Germany. We highlight the differences of entrepreneurs' perceptions in distinct segments of an evolving bioeconomy (i.e. the chemical, polymer processing, and construction materials industries). Based on these data, we identify differences in regional and sectoral ISs. Our results allow for a number of STI policy recommendations that serve to improve the effectiveness of regional bioeconomy promotion. Thus, we strive to inform the operationalization of STI policies with sustainability missions, thereby potentially contributing to the associated SDGs.

This paper starts with an elaboration our theoretical framework in Section 2. Here we discuss the different actor-internal elements that co-determine entrepreneurial behavior and link these to the relevant context conditions at various levels. In Section 3, we elucidate our methodological approach to answer the research question as also visualized by a flow chart. The subsections describe the study regions, industry and respondent selection, data collection, and analysis. In Section 4, we report our results in view of decisive components of geographic and sectoral IS. Implications for theory and policy follow in Section 5, which ends with some conclusions.

2. Theoretical framing

From the STI policy perspective, the required changes in lifestyle, production processes, and resource use associated with bioeconomy concepts call for system innovations or transitions, including changes in the architecture, components, and interfaces of entire sociotechnical or socioeconomic systems (Geels, 2005). Although entrepreneurs are often seen as key drivers of sustainability transitions, the field lacks a systematic investigation of innovation decisions, specific innovation hurdles, and drivers from their perspective (Devaney and Henchion, 2018). So far, firm behavior is hardly covered by research on national ISs (NISs) and regional ISs (RISs). Conceptualized as one of the seven main functions of ISs (Hekkert et al., 2007), the dynamics of entrepreneurial activities and their embeddedness in ISs still lack a theoretical foundation (Coenen and Díaz López, 2010). Tracing ongoing transitions requires attention to the dynamic interaction of actors and other system components (Ács et al., 2014; Farla et al., 2012; Hermans, 2018). To enable policy makers to assess the impact of promotional approaches, a systematic assessment of barriers and drivers of bioeconomy innovation is needed (Wydra, 2020). So far, little is known about companies' attention to risks, synergies, rebound effects, and trade-offs. Comprehensive assessment tools are still in development (Zeug et al., 2020). Certainly research needs to incorporate how entrepreneurs experience and contribute to the enactment of complex processes such as innovation and system transformation (Upham et al., 2018).

Against this background, we build our framework using studies on innovation at the firm level. Obviously, innovation requires entrepreneurs – specifically, their "perception of opportunities to productively change existing routines or resource configurations, their willingness to undertake such change, and their ability to implement these changes" (Zahra et al., 2006: p. 918). We assume that actors are aware of their capabilities, interests, and values and continuously scan their environment for risks, opportunities, and change with uncertain outcomes (Wilden and Gudergan, 2015). In our framework, *innovation behavior* therefore depends on an entrepreneurial actors' evaluation of their perceived innovation opportunities in view of their innovation capabilities and willingness (see Fig. 1). In other words, a positive evaluation of the desirability and feasibility of addressing an opportunity successfully is the crucial prerequisite for relevant activities. We describe these different elements in more detail below.

Innovation willingness alludes to human attitudes as well as organizations' learning and performance orientation. Researchers have studied innovation willingness using psychological, organizational, institutional, and economic lenses (e.g., Crossan and Apaydin, 2010). The phenomenon may boil down to the "willingness to learn, willingness to work hard and persistently, willingness to exercise self-discipline, willingness to adapt and to apply the right policies and practices" (Drucker, 2014, p. 173). An organizations' innovation willingness is shaped by the culturally and socially embedded values, experiences, and preferences of its entrepreneurs and managers. Earlier research has revealed that, in particular, environmental innovations can be driven by values and deep environmental concerns (Hojnik and Ruzzier, 2016; Ploum et al., 2018). The structural properties of relevant ISs and STI policy can influence the prevalence of innovation willingness among firms (e.g., Díaz-García et al., 2015; Mueller et al., 2013; Yitshaki and Kropp, 2016).

In this article, innovation *capabilities* refer to companies' characteristics. They indicate the ability to leverage, combine, and recombine knowledge and resources so that new products, technologies, and markets result (Iddris, 2016; Lawson and Samson, 2001). A specific actor's set of capabilities results from a multitude of resources and competencies, which are often acquired through learning by repeated trials (Crossan and Apaydin, 2010). Public resources in the vicinity, the capabilities of close allies (within the supply chain or separate, see, e.g., Chowdhury and Quaddus, 2021; Duygan et al., 2021; Lau and Lo, 2015), and the company's externally attributed legitimacy and status might expand or restrict its maneuvering room (Balland et al., 2016; Bitektine and Haack, 2015). Moreover, companies in different industries can be characterized by typical sets of different innovation capabilities (Giuliani and Bell, 2005; Malerba, 2005; Nooteboom et al., 2007). Thus, entrepreneurs' embeddedness leads them to account for proprietary capabilities as well as those of other actors and the own social position during assessments. What constitutes the relevant set of capabilities, however, not only differs across industries, but also depends on the type of innovation favored (Kabongo and Boiral, 2017; Mahmud et al., 2020). Different types of sustainability strategies require different capabilities to create value in different ways (Bocken and Geradts, 2020; Khan et al., 2020; Salim et al., 2019).

Actors evaluate their innovation willingness, as well as proprietary and accessible capabilities, against the incidence and shape of perceived *innovation opportunities*. From the ontological position of social constructivism, opportunities are discovered, created, or co-created by individuals who perceive, imagine, and interpret their external environments, which are uncertain and subject to change (Sarasvathy et al., 2010). The perception and evaluation of uncertainties, risks, and benefits differs among individuals and with external conditions (Alvarez

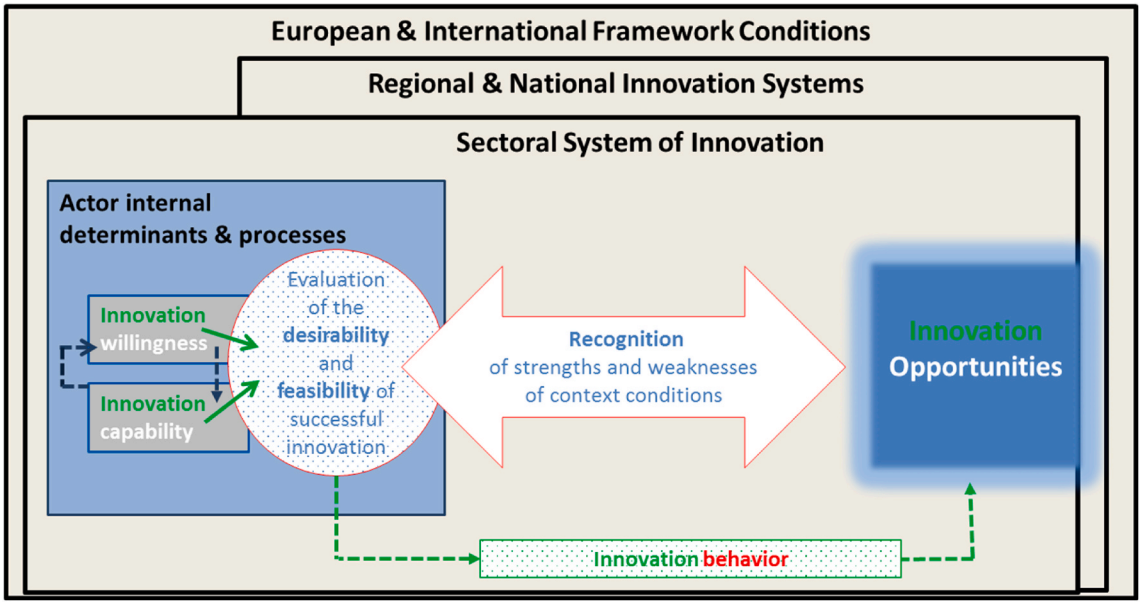


Fig. 1. Assessment of the desirability and feasibility of successful innovation at the company level.

and Barney, 2013; Martin and Wilson, 2016). Thus, our conceptualization goes beyond the construct of "opportunity confidence" as defined by Davidsson (2015). It accounts not only for a subjective evaluation of the opportunities' attractiveness—or lack thereof—but also for the concomitant evaluation of the likelihood of innovation success in view of available capabilities. By success, we mean the establishment of a viable economic activity with significantly novel input composition, value proposition, or value architecture.

Opportunity desirability and opportunity feasibility are distinct but related constructs that refer to the *why* and *how* aspects of entrepreneurial action (Ivanova et al., 2018). While "desirability" refers to an actor's goals, beliefs and values, "feasibility" has been characterized as a function of perceived knowledge, skills, abilities, and resources controlled by an entrepreneur relative to the knowledge, skills, abilities, and resources required by the opportunity. According to Haynie et al. (2009), established entrepreneurs assess opportunities as more attractive when those opportunities relate to their existing capabilities. For new ventures, this evaluation of endogenously and exogenously shaped circumstances has been characterized as an essential part of the incubation cycle (Vogel, 2017).

New opportunity spaces may evolve based on new knowledge, infrastructures, materials, equipment, relations, trends, regulations, or crises. With respect to the bioeconomy and related sustainability goals, the evaluation is complex (e.g., Leipold and Petit-Boix, 2018). The different time horizons and life cycle stages of relevant industries and technologies might influence opportunity evaluation. In addition, the inherently collective nature of innovation requires a certain degree of shared imagination (Pham et al., 2019) and collective responsibility for opportunity development (Stilgoe et al., 2013). If perceived opportunities are unappealing or successful innovation is deemed unfeasible under the current conditions, related activities might be confined to further observation.

This highlights the core of the conceptual model: The company-specific nature of context and opportunity perceptions lead to subjective evaluations and decision-making regarding innovation behavior. The same resources, actor networks, institutions, or incidents might be interpreted differently by different actors. This also applies to uncertainties related to raw material and access to other resources, the competitive environment, consumers' acceptance, and regulatory or political conditions (Shepherd et al., 2015).

To better structure these disparate elements, we propose applying an IS perspective. Central to the IS concept is the idea that some system configurations are much more effective than others in terms of inducing and facilitating learning and innovation success (Lundvall, 2007). The insufficiency or rigidity of critical IS components might block or slow the performance of an entire dynamic system (Boekholt, 2010; Grillitsch and Trippl, 2016; Wieczorek and Hekkert, 2012). Depending on the aims of an analysis and the consequential drawing of system boundaries, different IS types have been distinguished in the literature. NISs and RISs are conceptualized on a spatial basis, whereas sectoral ISs (SISs) are determined by the economic sector, knowledge base, technologies, and product groups that unify actors (Coenen and Díaz López, 2010). With respect to the impact of bioeconomy promotion, changing components such as institutions or actor constellations might affect one or several RISs and NISs, whereas new technologies might take effect across several sectors (Hermans, 2018).

In summary, our conceptual model posits that the structural components (i.e. actor populations, networks, institutions, and infrastructures) of relevant innovation systems are in continuous interaction with the firm-level determinants of innovative behavior: innovation willingness and capability evaluated with respect to perceived opportunities. On the one hand, the resources, competencies, and relational ties, as well as the opportunity spaces themselves, are shaped in specific ways by different international, national, regional, and sectoral determinants (see, e.g., Kiefer et al., 2019; Pieroni et al., 2020). On the other hand, by acting on the perceived opportunities, entrepreneurs actively shape relevant components of interrelated ISs. As recently underlined anew by Sotarauta, "institutions not only confine and mould aspirations of actors but also are dependent on them" (2016, p.14). The conceptual framework highlights the embeddedness of actors' innovation behaviors and the related outcomes.

The aim of this paper is to acquire a better understanding of the national, regional, and sectoral determinants of observable innovation behavior in specific segments of the evolving bioeconomy. By referring to both analytic IS conceptualizations (i.e. the geographic and the sectoral), we also explore whether progress is easier in specific industries or regions than in others. We address the following research question:

Which IS components do entrepreneurs from different industries regard as prominent barriers to or potential drivers of their innovation capability and opportunities?

3. Methodological approach

The following subsections describe the methodological approach. An overview is provided in Fig. 2.

3.1. Purposive sampling: introduction to the study areas

We focused our investigations on Germany and the Netherlands. These two countries belong to the group of European countries with early and comprehensive national STI programs that promote the bioeconomy (Langeveld, 2015). Both national bioeconomy conceptualizations are aligned with the EU strategy (EC, 2012). They emphasize commitments to the Paris agreement, the relevance of the efficient use of natural resources, and the need to reach higher levels of environmental sustainability in economic undertakings (BMEL, 2014; MEZ, 2013). Economic competitiveness and attention to entrepreneurship also play an important role in both countries. Neither strategy includes broad-based awareness-raising or dedicated educational interventions. In essence, the Dutch bioeconomy promotion policy targets mainly company-driven innovations for near-term growth, whereas the German policy has a stronger focus on science-driven opportunity exploration in a medium-to long-term perspective.

When looking for agglomerations of bioeconomy actors, it was a logical step to turn to clusters that emerged with dedicated bioeconomy promotion. Actors' involvement in clusters provides evidence of collaborative R&D and learning efforts and confirms their innovation willingness. It guarantees entrepreneurs' experience with a specific regional context and facilitates the establishment of trusted contacts via backing of the study by cluster management units.

We focused our investigations on the Spitzencluster Mitteldeutschland (SCM) in Germany and Biobased Delta (BBD) in the Netherlands. The SCM is centered near Halle/Leipzig, and a large majority of its members reside in the federal states of Saxony-Anhalt, Saxony, and Thuringia. The BBD cluster covers the provinces of North Brabant, Zeeland, and South Holland, with a focal point at Bergen op Zoom. The regional context of the two clusters differs in some important aspects, as evidenced by indicators of the European Regional Innovation Scoreboard (EC, 2019, see Fig. 3).

First, the framework conditions are more favorable in terms of the populations' educational levels and the general attractiveness of the research systems in the BBD context. Second, innovation investments rather originate in the public sector in the SCM regions, with SMEs more involved in non-R&D investments such as equipment purchases or the acquisition of patents compared to their BBD counterparts. Third, innovation activities result in considerably higher levels of public-private co-publications and patent, trademark, and design applications in the BBD context, whereas there is more SME collaboration and in-house, marketing, and process innovation in the SCM context. Nevertheless, the two impact indicators reported for the regions show high homogeneity with very similar employment levels in knowledge-intensive activities and SME achievements measured in terms of sales of new-to-market/firm innovations.

3.2. Purposive sampling: selection of industries and companies

Ehrenfeld and Kropfhäuser (2017) identified 0.2% of all companies in the SCM cluster region as belonging to the plant-based bioeconomy. Out of these researchers' total sub-sample of 139 actors with workforce data, 83% were micro and small enterprises and only 4% had more than 250 employees (Ehrenfeld and Kropfhäuser, 2017, p. 9). The researchers found that about half of the companies were less than 10 years old, and 53 companies were active in manufacturing. Analysis of the project and membership lists made available by the SCM management unit revealed that innovations in chemical products, polymer processing, and construction materials production were at the core of activities. Joint efforts were aimed at substitutions for fossil inputs or the development of new bio-based products.

Purposive sample construction (heterogeneous sampling) was performed in line with the specifications of Etikan et al. (2016). We preferred companies involved in ongoing or recently completed R&D projects. The projects' lead partners were addressed unless attention to the coverage of all company sizes and of all three German regions suggested doing otherwise. In this way, ten companies located in Saxony-Anhalt, two in Thuringia, and three in Saxony, were approached. For an outsider's perspective on conditions in the SCM region, we also included four enterprises from two other regions.

The BBD cluster has no official membership administration. During several in-person and phone discussions, the cluster leadership assisted with identifying suitable interview partners based on their engagement in cluster activities. A matching sample was constructed in the selected

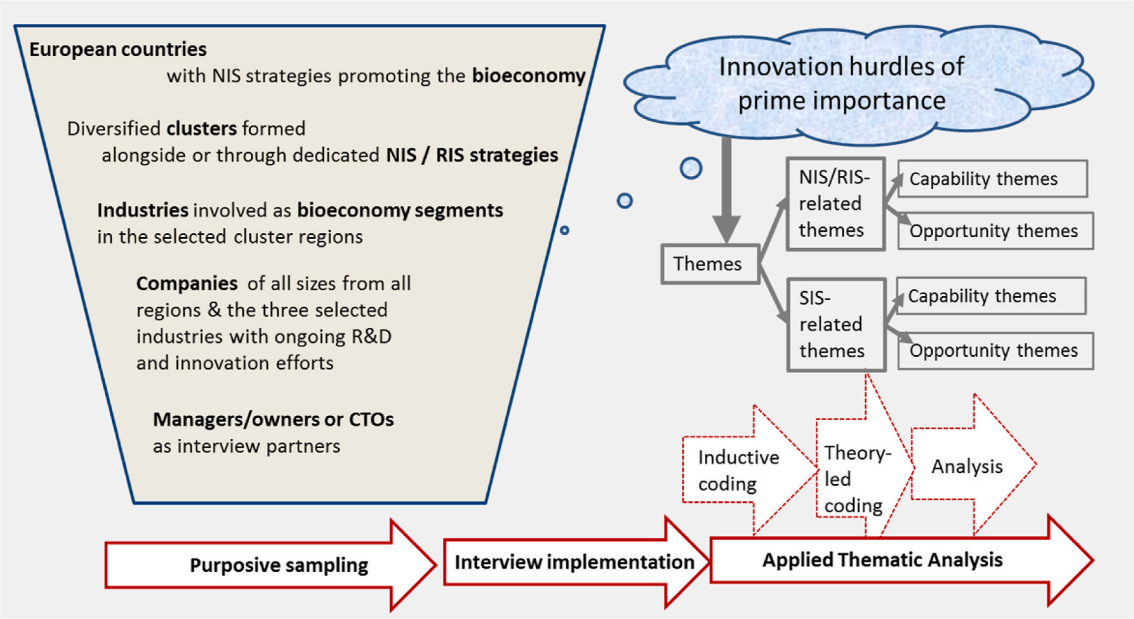
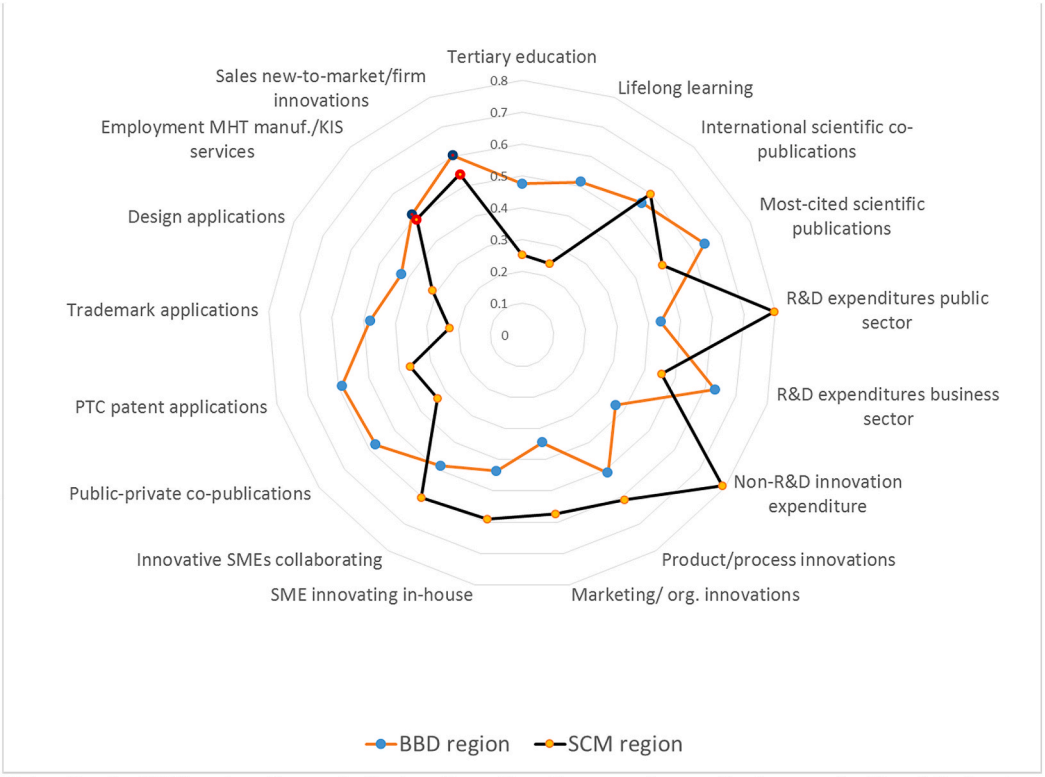


Fig. 2. Research process and methodology.



Notes: For the BBD region, the graph displays the arithmetic mean of normalized scores for Noord-Brabant, Zeeland, and Zuid-Holland Provinces. For the MSC region, the mean of normalized scores for Saxony-Anhalt, Thuringia, and the Saxonian sub-regions of Leipzig, Chemnitz and Dresden is indicated.
Source: Based on data from EC, 2019

Fig. 3. Average normalized scores of the European Regional Innovation Scoreboard, 2019.
Notes: For the BBD region, the graph displays the arithmetic mean of normalized scores for Noord-Brabant, Zeeland, and Zuid-Holland Provinces. For the MSC region, the mean of normalized scores for Saxony-Anhalt, Thuringia, and the Saxonian sub-regions of Leipzig, Chemnitz and Dresden is indicated.
Source: Based on data from EC, 2019.

industries and with companies engaged in ongoing R&D and innovation efforts. Here, six representatives of companies located in North-Brabant were selected alongside two in Zeeland and three in Zuid-Holland. Overall, 30 companies were covered, including 19 in Germany and 11 in the Netherlands. See Fig. 4 for their size and industry distribution.

The industry sample from fine chemicals in both cluster regions includes companies established based on fossil feedstocks, as well as actors using only renewable inputs. All respondents grouped under the "plastic

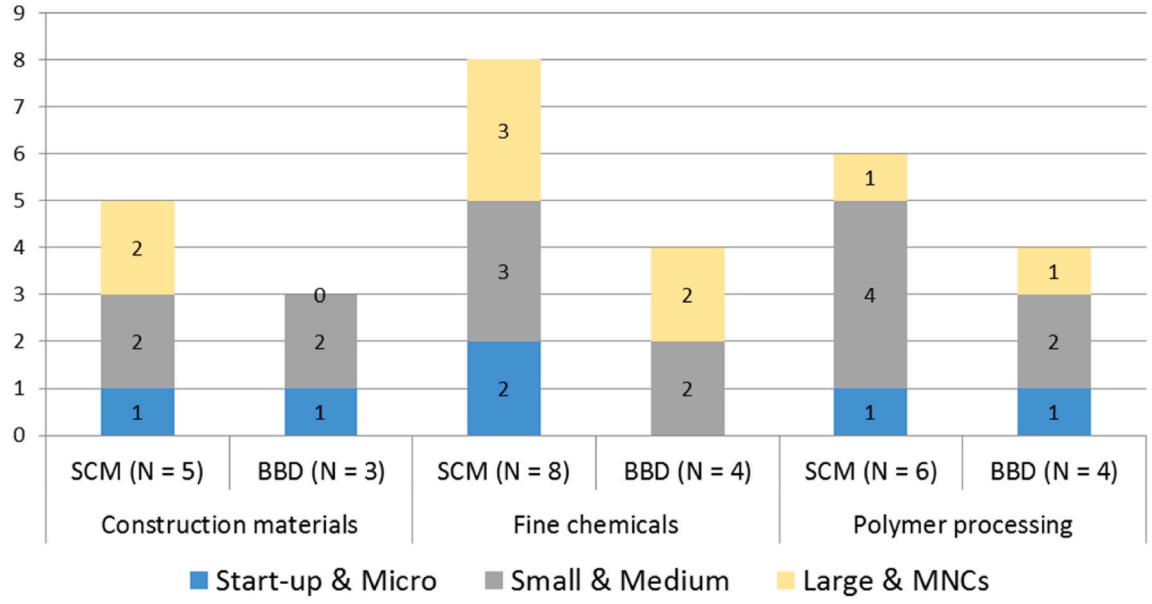


Fig. 4. Respondents from business by industry, cluster affiliation, and size (N = 30).
Note: Company size categories correspond to the EU standards in terms of employees: <10 micro enterprises, 11 to 249 SMEs, >250 large enterprises. To better specify companies' characteristics, their age (<10 years) was also considered: all start-ups had <10 employees. Subsidiaries of multinational companies were grouped with large enterprises even in cases where units had fewer than 250 employees.

industry" category belonged to plastic converters, with some covering compounding activities as well. In the construction materials industry, wood was the basis of operations for three respondents. Others dealt with fossil and renewable resources or the manufacturing of joining elements.

3.3. Interview implementation

Semi-structured in-depth interviews combine features from formal and informal interviews. They allow for more "natural" cognitions, emotions, and behaviors while focusing on personal experiences that can lead to unexpected results (Hair et al., 2019; Lee et al., 1999). A typical interview took about an hour and was conducted with owners or managers and chief technical officers at the respondent's place of work. In a few cases, they asked additional members of the company management team to join. After the clarification of issues related to anonymity, confidentiality, and the purpose of the study, as well as the core activities and innovation endeavors of the company, the key questions were addressed based on a pre-tested interview guide elaborated in line with Helfferich (2011) and Glaser and Laudel (2010). This approach safeguards coverage of all themes identified from a theoretical point of view, as well as flexibility in a variety of contexts. The formulation and sequencing of key questions was performed as follows: Questioning began with the company context at the local level: "In view of a dynamic, innovation-driven bioeconomy development: what are the most important strengths and weaknesses in your local context from your perspective?" This question allowed respondents to reflect on, for example, their company history, infrastructure endowment, or supplier relations - issues that had mostly positive associations and minimal political implications. It also provided us with insight into the respondent's conceptualization of a bioeconomy while gently directing their attention to IS components and the respondent's innovation activities. Rephrasing the same question for the regional and national levels facilitated the exploration the respondent's perceptions of RIS and NIS components, as well as STI policies. Finally, the same question was reformulated for the European/international level to capture the relevance and evaluation of institutions and network relations beyond national authority. Inductive probing questions were used throughout the interview to clarify meanings and the attribution of relevance to specific themes.

Throughout this process, keywords from respondents' statements were written on Post-it notes and stuck to the table so that the interview partners had a visual overview of the factors mentioned. This visualization effort was meant to minimize "priming", the mechanism by which a response is influenced by a preceding question (Moss and Lawrence, 1997). This was important in view of the crucial point where the central constructs of "capability" and "opportunity" were addressed. Following the rationale of Vitale et al. (2008), we thereby sought to avoid a bias in the results toward internationally co-determined factors of influence when asking respondents the following: "Considering all of the factors you highlighted at the different levels, which factors have the strongest impact on your innovation capabilities?" A simple explanation (i.e. "resources and competencies") was given in each interview, thereby preventing completely divergent interpretations. The final question, "Which factors have the strongest relevance for bioeconomy innovation opportunities from your perspective?", was raised to explore the relevance of different IS characteristics to opportunity spaces perceived by the respondents.

The interviewees were allowed to pursue an idea or response in more detail, thereby diverging from the preconceived sequence of addressing the different governance levels. As emphasized by Gill et al. (2008), the flexibility of this approach, especially compared to that of structured interviews, supports the discovery of aspects the researchers had not previously considered pertinent.

3.4. Data analysis and coding

Field note recording utilized the Post-its notes and included themes raised before or after the actual interview. The voice-recorded interviews were transcribed verbatim. Applied thematic analysis was used for further data analysis. Thematic analysis entails a search for themes that emerge as important to the description of a phenomenon (Daly et al., 1997). This approach is a "rigorous, yet inductive, set of procedures designed to identify and examine themes from textual data in a way that is transparent and credible" (Guest et al., 2011, p. 14). As a first step, the researcher who conducted all the interviews used inductive coding to identify relevant themes using MAXQDA software (Standard version, Release 18.2.5). Accordingly, relevant parts of the transcripts were assigned labels that best represented the text. In line with a descriptive and exploratory orientation, the code book was allowed to develop iteratively with coding. A second round of reviewing all interviews' coding led to adjustments and a congruent application of codes across the whole sample, as also recommended by Saldaña (2015). Field notes were used to check for consistency and missing items. The themes found inductively are listed in Tables A1 and A2 in the appendix.

Using theory-led coding, themes were then sorted by their reference to RIS/NIS or SIS characteristics. Further analysis led to the differentiation of themes with relevance for the respondents' own innovation capability or perceived opportunities. Several parts of the transcripts were revisited to clarify the respondents' causal reasoning. Positive and negative connotations and neutral and mixed evaluations of specific factors were differentiated. Code categories and related quotes were then transferred to Excel. The table of summarized results was evaluated by searching for divergent statements across the Dutch and German samples, as well as by industry. Finally, the quantitative mentioning records were visualized.

4. Results

The exploration of two European cluster regions, where substantial public and private resources were invested during several years of R&D and innovation efforts geared towards advancing a bioeconomy, revealed *no* case of a company actually replacing fossil with bio-based feedstocks: the companies that used fossil inputs since their establishment continued to do so routinely. Knowledge-intensive start-ups were found among the group of companies that were "born green", meaning they never had a fossil raw material base (Demirel et al., 2019). However, these had evolved five to ten years earlier, *unrelated* to the clusters and dedicated bioeconomy promotion at the national and regional levels. Likewise, *no* spin-off from a university or research institute was found in the context of bioeconomy cluster activities. Consequently, the following results are exclusively focused on innovation barriers—that is, hurdles perceived by entrepreneurs as preventing them from building upon new knowledge, technologies, or partners and effect the use, application, and market-based exploitation of their learning.

4.1. Perceived hurdles to innovation originating from properties of NISs/RISs

When participants were asked about the most important factors affecting their *innovation capacity*, some form of finances emerged as a prioritized theme in most of the interviews. Access to risk and growth capital was reported most often as prime hurdle in the German context, where many public R&D grants are available and appreciated as helpful. When Dutch actors referred to public R&D grants and subsidies for experimentation, they repeatedly talked about a "jungle" where consultancy services were needed. By contrast, problems in mobilizing risk or growth capital did not lead to strong emotional arousal.

In both study regions, some entrepreneurs complained about the "non-neutrality" of public co-investment or funding decisions (RG15, RN5): "big companies, big names" get it and "networks" from which

proposal evaluators are drawn into public administration decision-making lead to situations where "own partners are supported and others are consciously not supported".

Access to knowledge received slightly less attention. Respondents specified knowledge in terms of scientific knowledge and qualified R&D partners, business partners with complementary knowledge, strategic business consultancy, market intelligence for bio-based materials, or strengthened efforts in knowledge consolidation. Two Dutch respondents outlined how the government's funding of university research on bioeconomy topics generally was insufficient and specified that institutes also do not have the equipment to contribute meaningfully to R&D. The theme led to mixed and often ambivalent reactions in the context of German regions. Some entrepreneurs perceived the universities' or research institutes' expertise as an asset, while others evaluated their mode of operation as a threat or of limited use. The following statements exemplify aspects of reported dissatisfaction from both sub-samples:

> RG29: "An economic evaluation of the research results … is not at all wanted in the institutes … They go for technical questions, do a few years of research … and when it is over, they move to the next project."

> RN4: "[P]rofessors, they want to have a perfect product and they want to sit … in their chamber … two years – I mean: I have clients [waiting]."

In both study regions, entrepreneurs nevertheless invested time into contributing to higher education, not only with an objective to motivate students but primarily to raise researchers' awareness on relevant topics.

Access to a skilled workforce was a relevant theme in sparely populated and structurally weak German regions. The respondents called for dedicated study programs and generally strengthened efforts in education. Here, also business partners with complementary knowledge were mentioned as a bottleneck. Smaller units requested consolidated technical or market knowledge and consultancy, predominantly in the German context. Although rarely prioritized by Dutch respondents, access to R&D and testing infrastructures also received some attention.

There were 11 interviews with explicit statements about innovation capacity not being a bottleneck holding back bioeconomy innovation (see Fig. 5). In these cases, opportunities for launching innovation projects successfully were not evaluated as convincing enough to use or upgrade capabilities. This was because the potential economic and ecological benefits of exploiting perceived opportunities were questioned, the respondent's business was not under major competitive threat, or resistance along the downstream value-chain was rather high.

> RG12: "[I]nnovation willingness is comparatively high and the innovation capacities will be established – if that is a good idea."

> RG6: "Or, there's not enough distress to develop that [innovation capacity] now."

> RG22: "[T]he innovation willingness for transition, I think, is not really given with many … When we approach a company … they say: 'Bioeconomy – what a crock', 'Doesn't work!', 'Never change a running system' or similar."

Respondents perceived a large variety of conditions, mostly at the national or international level, as affecting market conditions and blocking *innovation opportunities*. All of the Dutch and a majority of the German entrepreneurs raised the theme of unfavorable factor price relations (see Fig. 6). Due to the low prices of fossil fuels as well as the absence of effective CO_2 emissions pricing, products based on renewable resources could not flourish in the market. A CO_2 tax was relatively more often requested in the Dutch as compared to the German context. Actors from both sub-samples believed that environmental footprints should be considered in international trade regulation. In addition, German entrepreneurs repeatedly mentioned the European General Agricultural Policy (GAP) as a problem and its reform as a priority. Increased biomass production as well as farmers who are more responsive and entrepreneurial would be needed. The government was called upon to draft a resource strategy and acknowledge true scarcities.

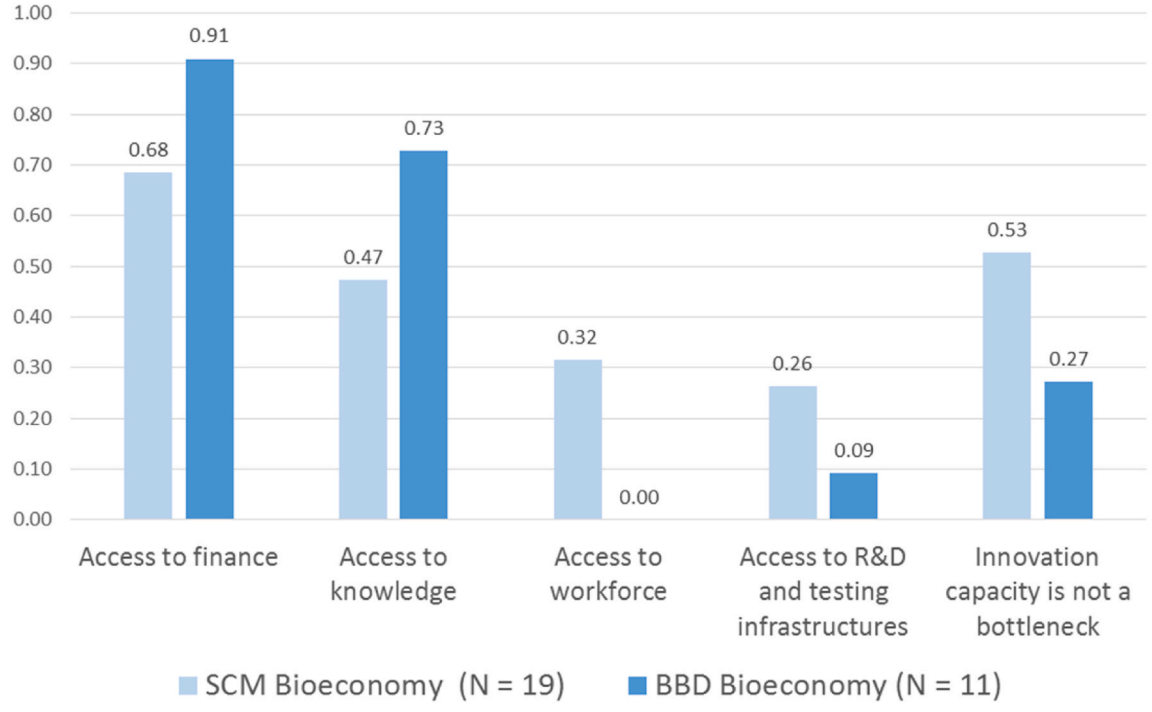


Fig. 5. Perceived hurdles to strengthened innovation capacities by cluster area (N = 30, number of mentions relative to the number of actors in each group). Note: Some actors mentioned two topics that were clustered in one category. Thus, 100% does not necessarily mean that all of the group members mentioned the topic.

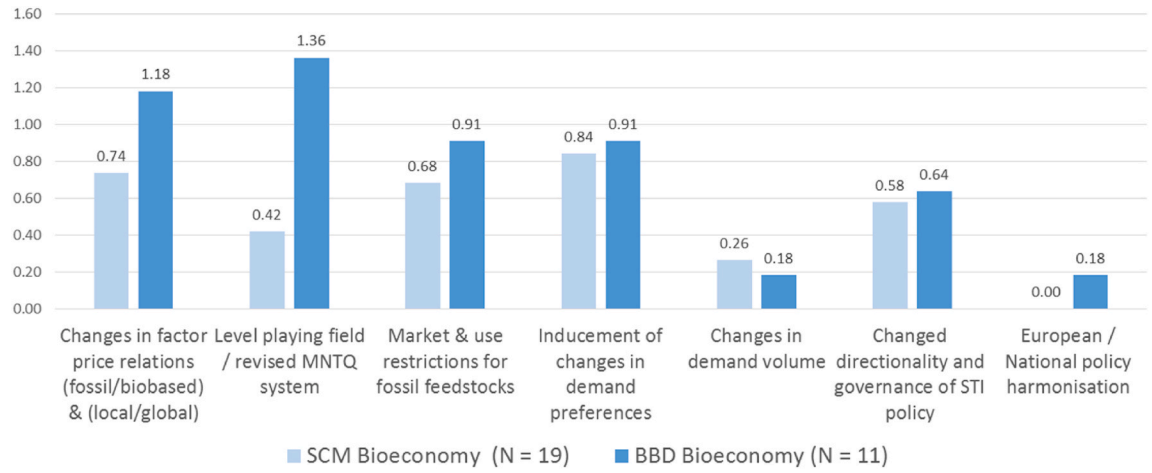


Fig. 6. Drivers of innovation opportunities, by NIS (N = 30, number of mentions relative to the number of actors in each group).
Note: Some actors mentioned two topics that were clustered in one category. Thus, 100% does not necessarily mean that all group members mentioned the topic.

RG9: "High plants with a lot of biomass as a side stream should be the breeding priority."

Dutch actors highlighted "fair play" as the most important potential driver of new opportunities. Both countries' energy regulations provide subsidies for the use of biomass for energy but not for its material uses. In addition, predominantly Dutch respondents requested adjustment of norms, standards, testing procedures, and certification. Furthermore, market and use restrictions for fossil feedstocks were envisioned as potentially boosting opportunities for bio-based products. These could take the form of stricter environmental or health regulations, up to outright bans of certain materials. However, against the background of Dutch pension provisions which are invested widely in the country's oil and gas industry, two respondents also warned against fast policy changes.

Respondents in both countries advocated for government interventions to foster awareness and change in values: from the education sector up to "normal" consumers. These interventions concern overall resource use and pollution (as exemplified by statement RN12) as well as biotechnology applications that face acceptance problems among consumers (statement RN11).

RN12: "I would really like more people to understand what we are doing to our planet today."

RN11: "What we have not done properly is … educate people."

Cross-country agreement was also evident, with respondents underlining that changes in the waste system could have positive effects on consumer preferences. Limiting possibilities to just dump or burn waste and increasing recycling obligations could open up new bioeconomy opportunity spaces ("Inducement of changes in demand preferences" in Fig. 6).

The German respondents placed the highest emphasis on government intervention to change demand preferences. Cultural change was perceived as requiring stimuli.

RG12: "The German market is stone on stone … and perceives wood construction as inferior …"

4.2. Innovation hurdles perceived as originating from SISs properties

The characteristics of the national and regional ISs apply to all of the firms located in the same geographical area. We found that the industry characteristics relevant for a specific firm — and therefore the aligned SIS configurations — additionally played a crucial role in entrepreneurs' perceptions of their opportunities and capabilities. For instance, predominantly actors from the chemical industry believed that more risk or venture capital was needed to strengthen *innovation capabilities*. Interviewees explained that new bio-based processes currently cannot meet "normal" profitability expectations because continuous experimentation over an extended time period would be needed to reach acceptable efficiency levels.

RN11: "I think we could already build new factories today: first of their kind, new bio-based factories. Will they be very efficient? Probably not. If you look at the oil industry … it took also more than 50 years to become really efficient and use everything that is in oil … up to asphalt."

Respondents in this industry also raised problems like the substantial STI policy budget cuts in the recent past (Netherlands) and high hurdles to sizeable R&D funding or public co-investments (Germany). German respondents in the fine chemicals industry more often reported difficulties with attracting the right workforce and (partners') expertise.

The prime concern of the respondents in the polymer-processing group was access to knowledge: neither university curricula nor professional education include topics related to bio-based polymers well enough, and public R&D investment is insufficient. Change would enable these (predominantly small) actors operating with tight profit margins to make room for more in-house efforts. Access to R&D and testing infrastructures is a related concern: in-house facilities normally are blocked by ongoing production and in-house quality-assurance processes.

The construction materials industry rated capital and the overall national university capacities as crucial bottlenecks. In the German context, the public image of the construction and construction materials industry was not sufficiently "knowledge-driven" to qualify for STI policy attention. Dutch respondents pointed to the huge investments necessary to adjust to the end of cheap national gas for residential heating – a debate that hardly leaves space for augmented funding of other innovations. Expertise appears to be dying out gradually, with renowned professors reaching the retirement age in Germany. The quantity of basic research currently implemented on bio-based construction was deemed inadequate in both countries (see also Fig. 7).

Regarding expanded *innovation opportunities*, the chemical industry actors were not fond of market or use restrictions for fossil feedstocks as well as efforts to create a level playing field. Instead, they emphasized inducing change to demand preferences alongside (step-wise) adjustments of the factor price relations. STI policy reform ranked high on their agendas, beyond the view of co-investment or risk minimization for biorefineries. Respondents complained about national and/or regional

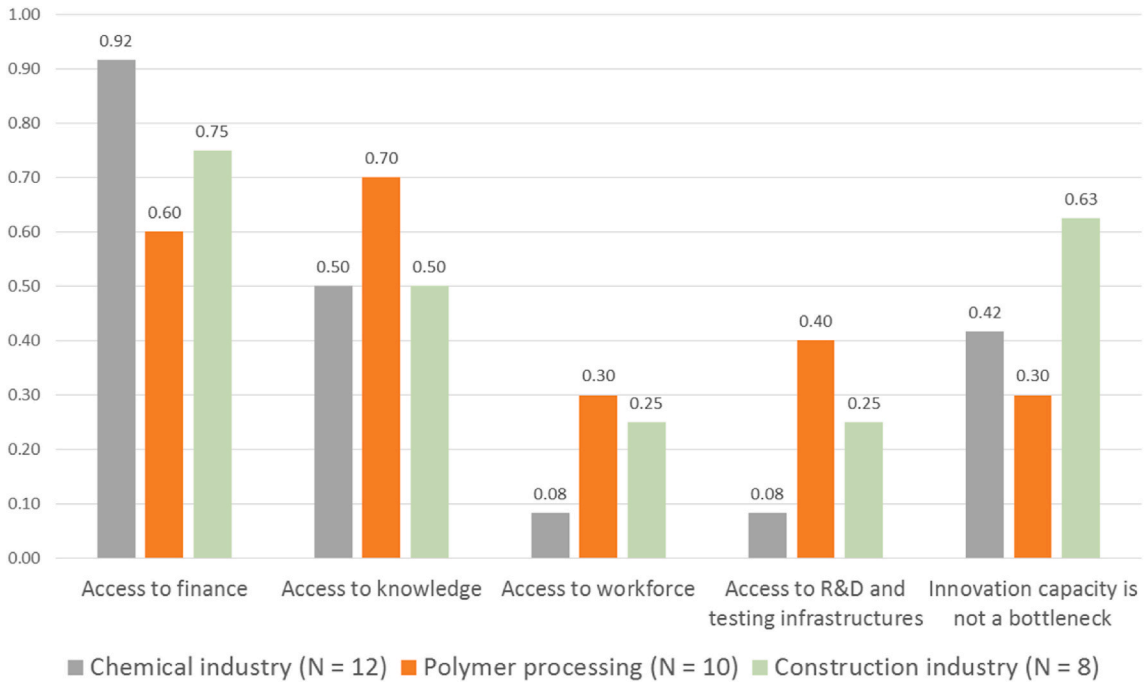


Fig. 7. Perceived hurdles to strengthened innovation capacities by industry (N = 30, number of mentions relative to the number of actors in each group).
Note: Some actors mentioned two topics that were clustered in one category. Thus, 100% does not necessarily mean that all group members mentioned the topic.

policy-makers being insufficiently dedicated to the bioeconomy vision and transition to sustainability. Bottlenecks in sectoral and international policy harmonization were diagnosed as causing policy inconsistencies, which hampered many actors. Policy decisiveness and consistency with a long-term perspective were rated as being insufficient.

> RG29: "I can understand that promotional projects do not run for 10–20 years. I can see that our democratic system does not allow for that. Nevertheless, that's annoying."

Two respondents recommended a radical mind shift and consequential revision of bioeconomy-promoting policies.

> RN11: "That is a choice: do we stick to our original thinking that scale factors really are dominant … ? If you are bio-based, then you could also go for smaller plants - localized - close to the feedstock."
> RN16: "There is no vision for 20 - 40 years. But you need big decisions. …When governments … are making these big decisions and visions, then it's easier to get the business cases right".

For both, the chemical and plastic industries, profit-driven waste-incineration plants and landfills were perceived as a problem. Residue and waste streams could represent alternative resources from entrepreneurial perspectives. Polymer compounders and processors were convinced that (forced) recycling cost inclusion would open up new bioeconomy markets. However, the advantages of bio-based (and eventually compostable) bioplastics can only take effect with a separate collection system or if these materials are accepted in waste containers for compost. Accordingly, the government and the EU were called upon to reform the entire waste sector.

Themes related to a level playing field received the highest attention within the plastic industry. Respondents often perceived normal consumers as being overcharged with multiple non-transparent labels and disposal instructions. In addition, the high costs and efforts required to prove the origins or characteristics of and certify bio-based products were regarded as unfair burdens, as compared to the situation for traditional suppliers.

> RN10: "The … overall migration tests: they have been laid out for the traditional plastics … so they are not very suitable to test bio-based plastics. The … testing [is] about the inertness of the material. So it doesn't say anything about the toxicity …"

> RN15: "[We need] one extra clause that raises the possibility of bioplastic [companies] to demonstrate that a product is safe by self-assessment."

Alongside their strong agreement with chemical industry respondents on raising customer awareness, polymer processors would also welcome some demand stimulation. Regarding STI policy implementation, a German respondent criticized how having no government sanctions follows the research institutes' pattern of overambitious goal setting in funding proposals and subsequent failures to deliver promised results. Some respondents from the industry could not find sufficient STI policy support for improved (hybrid) solutions, as exemplified by the following statement:

> RN19: "[W]e want to move from the current situation to the ideal situation … which is unfeasible. You need to move … in different phases and stages … and this is not seen as a transition yet …"

From the points of view of the construction materials industry, the low fossil fuels, emissions, and transportation prices constrict opportunities based on renewable (local) feedstocks:

> RN5: "If … you really sanction the conventional building industry, the problem [of an unfavorable competitive situation of bio-based materials] is solved. So, get the fees, the penalties, where they belong … the one who is polluting ought to pay."

> RG32: "[Y]ou have to regulate it again. You cannot globalize on the one hand, and then, on the other hand, just let slide all the negative effects that arise."

Respondents underlined problems in the realm of metrology, norming, testing, and quality management (MNTQ), similarly to their peers in the plastic industry (see Fig. 8). The actors explained how measurement standards and norms were outdated, biased toward fossil fuel based

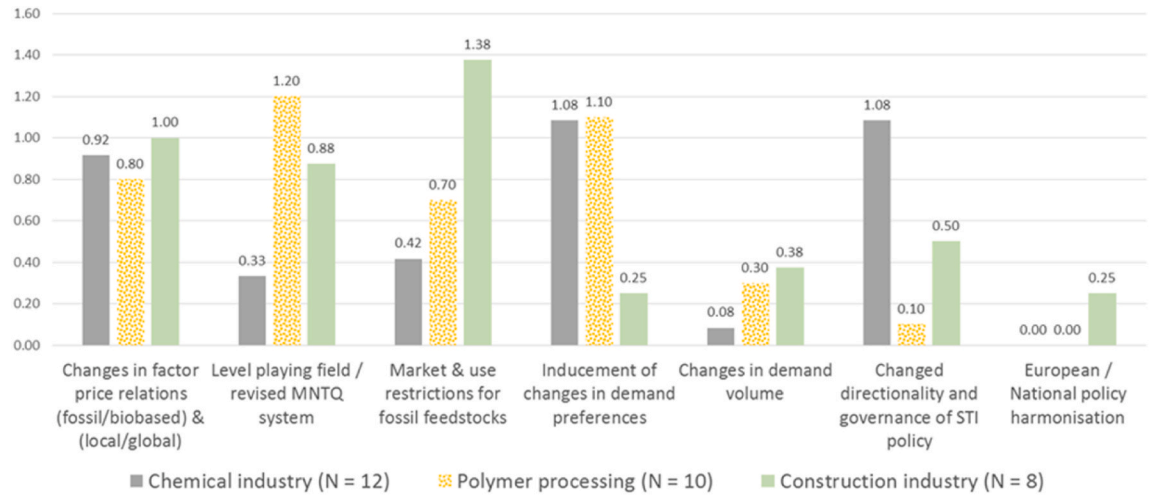


Fig. 8. Drivers of innovation opportunities, by industry (N = 30, number of mentions relative to the number of actors in each group).
Note: Some actors mentioned two topics that were clustered in one category. Thus, 100% does not necessarily mean that all group members mentioned the topic.

products, or inappropriately translated from other industries. A reform would remove or lower innovation hurdles and shorten time to market. They also provided specific ideas concerning building standards (including for fire safety) and regulations as well as a call to abolish non-bio-based insulation materials. Stricter regulation was understood as a short-term remedy in view of the current (unsustainable) consumption patterns and demand preferences blocking bioeconomy innovation spaces. The immediate evolution of bioeconomy-innovation opportunities is expected from effective demand on markets, such as government-ordered kindergartens, schools, and low cost housing.

Policy harmonization across German federal states or Dutch provinces as well as concerted efforts were deemed indispensable in the construction industry, in which fragmented structures and regulatory barriers prevail. A value-chain approach should involve planning offices, construction firms, traders, producers of materials, and companies with the required craftsmanship.

5. Discussion

We proposed a theoretical framework that combines firm-level determinants of innovation behavior and characteristics of the ISs in which entrepreneurs are embedded. In this way, we analyzed the effects of interrelated ISs on entrepreneurs' evaluation of the desirability and feasibility of successful innovation within an emerging bioeconomy. The application of our framework in two cluster regions offers new theoretic and empirical insights. We will first discuss this study's theoretical and empirical contributions. We will end this section with some policy recommendations.

5.1. Integration of entrepreneurial perspectives and innovation systems

At the theoretical level, our framework addresses the existing criticism that the IS literature ignores the micro-level. By integrating the micro-level determinants of entrepreneurial behavior, we offer a new bottom-up perspective on innovation systems. Most of the IS research is directed to system "failures" (Grillitsch and Trippl, 2016; Klein Woolthuis et al., 2005; Metcalfe, 2005). Especially with regard to the bioeconomy, a strong policy discourse exists at the European level that emphasizes the hurdles (e.g., Purkus et al., 2018) and threats in view of other countries' competitive strength (e.g., Birch et al., 2014). Although our results also highlight substantial barriers to innovation, the entrepreneurial perspective explicitly takes into account various pathways toward expanded innovation opportunities. In that sense, our framework not only covers the negative aspects, but also allows for the positive perspective of opportunity creation within the dynamics of interrelated ISs. This approach offers a promising starting point for connecting innovation research on the bioeconomy with a "smart specialization" strategy of regional development that takes a differentiated view on a region's existing industrial base (Hassink and Gong, 2019).

The second theoretical implication of results derived on the basis of our conceptual framework is attention for the necessity of performing an integrated IS analysis that covers the barriers and opportunities at multiple geographic levels and that accounts for embeddedness in a specific industry/SIS, as relevant from an entrepreneur's perspective. Most of the academic studies on ISs limit themselves to analyzing either a geographically bounded IS (at a regional or national level, e.g., Bosman and Rotmans, 2016; Grundel and Dahlström, 2016), focus on a specific natural resource (e.g., Mertens et al., 2019; Purkus et al., 2018), or analyzing the IS in view of a specific technology (Dahiya et al., 2018; Nevzorova and Karakaya, 2020; Wohlgemuth et al., 2021). However, as our results show, these academic distinctions mean little to entrepreneurs, who experience hurdles to innovation and perceive opportunities in specific industries and places with effects that unfold across geographies and bioeconomy segments.

Empirical results demonstrate the importance of including both the sectoral and the geographical IS conceptualizations in respective analyses. Currently, standard RIS and NIS indicators are unspecific and blind to SIS components. European RIS indicators (see Fig. 3) hid the paucity of relevant and dedicated research facilities for all industrial segments of the bioeconomy in two Dutch provinces as well as the fact that the construction industry representatives in the German study regions were actually in relatively sparse RIS. In addition, the relevance of regulation — and respective hurdles or opportunities for innovation — on interrelated governance levels differs by industry/SIS. So far, these particularities are not considered in recommendations for 'smart specialization' (e.g., Asheim et al., 2020; Haarich et al., 2017). Not only are the interests, opportunities, and power relations at other geographic levels generally relevant as underlined by Zukauskaite et al. (2017). In fact, innovation opportunities that require a modernization of material or product testing processes, standards and certification in Europe cannot be unblocked by conducive STI policy at the regional level.

Furthermore, our results emphasize the importance of the characteristics of the value-chain within the SIS for actors' innovation capabilities. The significance of positions in value networks can be illustrated by the example of polymer processors. Most companies in this industry build their competitive strength on specific recipes or cost-saving process innovations, in close cooperation with polymer producers,

customers, and OEMs. The integrated nature of relevant value networks makes it very difficult for a single firm to innovate on its own. This result is line with other research on this industry (de Vargas Mores et al., 2018; Paletta et al., 2019; Van den Oever et al., 2017), and other bioeconomy segments (e.g., Carraresi et al., 2018; Gregg et al., 2020; Wohlfahrt et al., 2019).

Value-chain positions also come with differing distances to end consumers. Most products of the construction materials and chemical industries are invisible to customers when built into, or used in a final product. Based on ten country case studies, the OECD concluded that only a small proportion of all bioeconomy products concern the business-to-consumer market (Philp and Winickoff, 2019). However, earlier research proposed in particular that radical innovation is more likely to appear in consumer goods industries that operate (with visible products) in close contact with consumers (Galliano and Nadel, 2015). It follows that radical changes in rather "invisible" industries rather requires triggers by, e.g., performance-based regulation, international establishment or harmonization of production standards (Berg et al., 2018; Iles and Martin, 2013; Kedir and Hall, 2020).

5.2. Implications for STI policy promoting the bioeconomy

A somewhat surprising result of our study is that the entrepreneurs found the lack of innovation opportunities as a far more limiting factor for innovation than they did lacking innovation capabilities. Supply-side promotion in the framework of STI policy (science push measures) is meant to strengthen the innovation capabilities of bioeconomy actors and was mostly welcomed in both study regions. Likewise, demand-side projects, stimulating the use of new materials or products in the Netherlands, were overwhelmingly evaluated as somewhat helpful, but insufficient. None of the interviewed firms in this study had phased out the use of fossil feedstocks on a significant scale. Those firms that did favor renewable resources anyway (the "born green" firms) mostly were established before the bioeconomy concept became popular. As demand-side measures are meant to widen or deepen innovation opportunities (e.g., Edler and Georghiou, 2007; Fevolden et al., 2017), we have to conclude that STI policy should design more effective instruments for market-making in view of clean products and services. Evidence from this study, thus, supports the diagnosis that bioeconomy market-making by government procurement is difficult (Philp and Winickoff, 2019) and sustainability transitions require changes in fields beyond STI policy (e.g., Schot and Steinmueller, 2018).

Lastly, our interviewees' statements regarding missing opportunities can be attributed to a missing societal consensus on the significance and shape of relevant problems or attainable objectives of bioeconomy promotion. It might be true that RIS policy can become better with improved understanding of the sector-specific needs of knowledge-intensive entrepreneurship as proposed by Gifford and McKelvey (2019). The Grand Challenges, however, call for 'concerted action' according to Kuhlmann and Rip (2018). The different bioeconomy actors still had vastly different expectations and visions (see also Wilde and Hermans, 2021). Our findings show that "systemic policies" (e.g., cluster- or value-chain-based interventions) must link entrepreneurs to policy-makers with influence on regulatory hurdles and other bottlenecks perceived to originate from the national and international levels. In this regard, our study further strengthens calls for more coordination in view of a "transformative shift toward sustainability" through increased competence and effort in policy design (e.g., Mazzucato, 2018; Diercks et al., 2019) and more attention for policy orchestration across scales and governance levels of ISs in the bioeconomy (Ayrapetyan and Hermans, 2020; Chaminade, 2020; Nong et al., 2020).

5.3. Limitations and further research

This study is confined to only three segments of the emerging bioeconomy. Only a small fraction of the technologies and activities in the selected industries has been covered. However, based on earlier evidence and rationales provided through and for SIS analysis, we would assume that the main findings are generalizable for companies within these industries located elsewhere in Europe. While we covered entrepreneurs' perceptions in rather similar and comparatively strong RIS/NIS contexts. The findings in other parts of Europe may differ.

The study did not reveal how more start-ups could be supported to evolve. Yet, this is a crucial aspect for accelerating sustainability transitions, regional development, and SDG attainment. Additional comparative case studies might be helpful in this regard. Finally, our framework did neither explore entrepreneurial motives nor differentiate among degrees of innovation willingness. A more nuanced analysis could allow for further insights on the differences in innovation behavior between incumbents and "born green" bioeconomy entrepreneurs.

5.4. Conclusion

Our study explored the context conditions perceived as relevant for entrepreneurs' innovation capabilities and opportunities in an emerging bioeconomy. We have introduced a conceptual framework that links companies' innovation behavior to structural properties of interrelated innovation systems in which they are embedded. The connection of the micro level of actors to the system level is a new conceptualization for IS analysis. In addition, this study lifts IS analysis beyond its focus on failures by explicitly taking into account the opportunity spaces. Furthermore, our results show the importance of integrating RISs, SISs and TISs. Finally, our empirical results show that bioeconomy entrepreneurs rather negated the lack of innovation capabilities as decisive limiting factor for innovation, accelerated sustainability transition and SDG attainment. Respondents in the two study regions pointed out how innovation opportunities are blocked by unsuitable institutions mostly at the national, European, and international levels. We therefore concluded that effective bioeconomy promotion requires greater emphasis on the demand side and on systemic multi-level policies addressing innovation barriers, along with due consideration of industry-specific IS and value-chain configurations.

CRediT authorship contribution statement

Kerstin Wilde: Conceptualization, Methodology, Investigation, Visualization, Writing – original draft. **Frans Hermans:** Supervision, Writing – review & editing, Project administration, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclepro.2021.127979.

Appendix

Table A.1
Inductive coding themes and categorisation for strengthened innovation capacity

Access to finance	(Public/private) start-up or growth capital
	Public R&D grants & subsidies
	Neutrality in R&D funding/public investment decisions
Access to knowledge	Qualified R&D partners
	Scientific knowledge
	Business partners with complementary knowledge
	Strategic business consultancy
	Knowledge consolidation and effort coordination
	Market intelligence for bio-based materials
Access to workforce	Skilled workers and competent employees
	(Good and more) Education, education facilities
	Students with awareness, competence and motivation
	Attractive living conditions for highly skilled experts
Access to R& D and testing infrastructures	Accessible R&D facilities
	Testing facilities

Table A.2
Inductive coding themes and categorisation for strengthened innovation opportunities

Changes in factor price relations (fossil/bio-based) & (local/global)	Increase in the price of fossil feedstocks (oil price and price of CO2 emissions)
	Governmental resource strategy
	GAP reform & increased biomass production
	Trade regime reform
Level playing field/revised MNTQ system	Adjustment of norms, standards and testing
	Transparent & reliable certification
	Energy sector reform
Market & use restrictions for fossil feedstocks	Stricter environmental regulation
	More health & consumer protection
	Updated thermal insulation regulation
	Reform of building standards & regulation
Inducement of changes in demand preferences	Development of customer, consumer awareness and value change
	Strengthened efforts in education
	Reform of the waste system
	Use of recyclats, circular economy promotion
Changes in demand volume	Public demand stimulation and innovative procurement
	Private demand stimulation
Changed directionality and governance of STI policy	Political support for the bioeconomy/transition
	Consistent policy formulation and implementation
	Reform research funding system
	Coordination of efforts & knowledge
	Biotechnology promotion
	Start-up promotion
	Tax reform
	Attraction of large and MNCs
	Fostering a “felt urgency” (in policy & industry)
European/National policy harmonization	National policy harmonization of research, economic promotion, agriculture and natural resources
	European policy harmonization

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