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Review

Sustainability Benefits and Challenges of Inter-Organizational Collaboration in Bio-Based Business: A Systematic Literature Review

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Abstract: Bio-based businesses are often considered to be sustainable. However, they are also linked to sustainability challenges such as deforestation and soil erosion. Encouraged to exploit innovative solutions and enhance sustainability, organizations engaged in bio-based activities extensively explore collaboration possibilities with external partners. The objective of this paper is to integrate the available knowledge on sustainability of inter-organisational collaborations in bio-based businesses, while considering the three aspects of sustainability: environmental, economic, and social. We collected data from three academic sources—Web of Science, Scopus, and EconLit—and conducted a systematic literature review. The results show the importance of geographical proximity and complementarity in creating sustainability benefits such as reduced emissions, reduced waste, economic synergies, and socio-economic activities. Based on the findings, we have developed a framework that illustrates sustainability benefits and challenges. Interestingly, the studies emphasize sustainability benefits more in emerging than in industrialised economies, especially relating to the social aspects of sustainability. In conclusion, although the scholars have not discussed mitigation of several sustainability challenges in bio-based businesses, such as land use conflicts, they have found evidence of vital sustainability benefits, such as energy availability, lower emissions, improved socio-economic life, and poverty reduction, which are essential in emerging economies.

Keywords: inter-organisational collaborations; bio-based business; sustainability

1. Introduction

The societal demand to address increasing scarcity of natural resources and climate change has resulted in the expansion of renewable activities such as bio-based business (BioB). In this study, we refer to BioB as commercial activities that use renewable biological resources and related technologies to produce food, feed, energy, chemicals, pharmaceuticals and other products and materials [1–3]. BioB is often considered to be sustainable because the renewable products of bio-based bring environmental benefits such as less carbon and greenhouse gas (GHG) emissions by substituting fossil-fuel-based products [3]. Additionally, BioB creates economic and social activities [4]. However, BioB is also associated with sustainability challenges, such as conflicts in land use [4], deforestation, decrease in biodiversity, and soil erosion due to long-term mono-crop production [5–9]. Encouraged to exploit innovative solutions and enhance sustainability, organization engaged in bio-based activities extensively explore collaboration possibilities with external partners [10,11]. Many organizations have already established inter-organisational collaborations (IOCs) with external partners through joint ventures, strategic alliances, and public-private partnerships [10]. These IOCs are often claimed to increase the sustainability of BioB through providing technological solutions for cleaner production, such as reuse of waste streams, reduction of solid wastes, and optimisation of energy use [1,6,12]. The aim of the present study is to show the added value (if any) of such IOCs in terms of sustainability.

A wide variety of knowledge is available on BioB in general, as well as on IOCs in BioB specifically. This knowledge has a multidisciplinary background in, among other things, biochemistry, agricultural engineering, environmental management, and industrial ecology [3,13]. However, the available knowledge is scattered and not systematically integrated, which hampers the formulation of a clear statement about whether IOCs in BioB can indeed improve the sustainability of BioB. The objective of this paper is therefore to find and integrate the available knowledge on sustainability of IOCs in BioB while considering the three aspects of sustainability: environmental, economic, and social. We conducted a systematic literature review which allowed us to find, gather, and integrate the existing knowledge on IOCs in BioB in a systematic, explicit, transparent, and accountable manner. We developed a framework showing sustainability benefits and challenges as investigated by scholars [14,15].

In the following section we outline the methodology used to conduct the systematic review. In the third section we present the main results and develop the framework, and in the final section we discuss the results and draw conclusions.

2. Methodology

To conduct the systematic literature review, a group of academics with a multidisciplinary background developed a review protocol as the main guideline [14,15]. According to this review protocol, the following steps were followed: operationalisation of the main concepts; identification of keywords and search strings; identification of inclusion criteria; identification of exclusion criteria; operation of the final search; screening the references based on titles and abstracts; and running the synthesis. Afterwards, we focused on the most relevant articles and conducted a context analysis. Below, we detail the steps from the protocol and provide the methodological considerations.

Main concepts. The two concepts "bio-based" and "sustainability" [3] are studied by various sciences such as chemistry, biochemistry, agricultural engineering, environmental management, and environmental ecology [3,16,17]. For the sake of clarity and precision, we define "bio-based business" (BioB) as commercial activities that use renewable biological resources and technologies to replace fossil fuels [1–3]. "Sustainability outcome" is defined as any benefit or challenge in any of the three aspects of sustainability: environmental, economic, and social [16–18]. Thus, sustainability benefits refer to environmentally friendly, economically beneficial, and socially supportive production [17]. Finally, "inter-organisational collaborations" are defined as collaborations between two or more companies [11], in contrast to collaborations among entities within one organisation.

Keywords and search strings. We performed a preliminary literature study to refine the keywords and construct search strings. In total, we identified three keywords and, due to similarity between terms in use, about 90 search strings (Appendix A). We conducted the prime search operation using the databases ISI Web of Science (WoS), Scopus, and EconLit. This resulted in a few hundred thousand citations (n = 364, 387).

Inclusion criteria. The study team identified six inclusion criteria referring to the science discipline, language, year, and type of articles (Appendix B).

Exclusion criteria. The study team identified three exclusion criteria to reduce the data in such a way that only relevant articles remained in the final set. Due to a lack of precision in use, we operationalized the exclusion criteria by 47 terms, 16 categories, and 7 themes (see Appendix C).

Final search. To get rid of irrelevant articles (e.g., due to key terms pointing at alternative meanings, such as the term "network" referring to computer networks instead of inter-organizational networks) we applied the inclusion and exclusion criteria to filter the titles and abstracts (Appendix C). The results of these advanced search operations have been exported to EndNote: 148 articles from WoS, 1560 from Scopus, and 272 from EconLit, which add up to 1980 articles. The removal of duplicates resulted in a total set of 1867 articles. We observed that sometimes different search engines recorded the same reference differently, causing malfunctioning of the Endnote "remove duplicates" command. Therefore we manually re-examined the set and removed another 40 duplicates, resulting in a set of 1827 non-identical articles (Table 1).

Table 1. Data reduction process of final set selection.

Processes	In	Out	Reason
Merging, among which	1980	362,451	Irrelevant
WoS	148	34,163	
Scopus	1560	68,390	
EconLit	272	259,898	
Cleaning for duplicates—automatic function	1867	113	Duplicates
Cleaning for duplicates—manually	1827	40	Duplicates
Screening titles and abstracts	99	1728	Irrelevant + 1 duplicate *
Synthesis	24	75	Quality

* Note: while reading articles in detail, we found that one article was still present twice in the set because the same article was registered under different names in different search engines.

Screening the titles and the abstracts. Two academics from the study team separately evaluated the relevancy of the articles by judging the titles and abstracts. In this evaluation, they excluded the articles that (1) referred to intra-organizational collaborations instead of inter-organizational collaborations; (2) focused on developing models; and/or (3) discussed IOC normatively without providing empirical evidence. Afterwards, they discussed the disagreements and achieved essential agreement on including 99 articles in the set for content analysis (Cohen's kappa = 0.65). These 99 articles were published primarily in dedicated journals, such as Energy Policy, International Journal of Biotechnology, Organization Science, Journal of Industrial Ecology, Biomass & Bioenergy, Business Strategy and the Environment, Journal of Cleaner Production, and Waste and Biomass Valorization. About 81% of these articles were found in WoS, 95% in Scopus, and only 31% in EconLit. WoS provided two unique articles, Scopus seventeen, and EconLit two, which indicates a substantial overlap among the databases.

Interestingly, we found that the number of articles per year (1993–2013), has increased notably (Figure 1), with more than 80 % of the articles published after 2007.

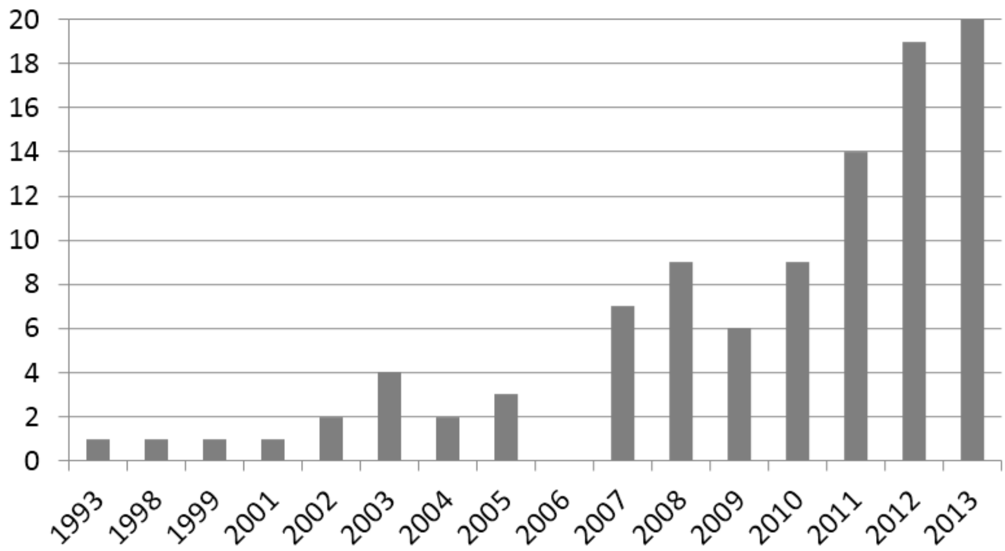

Figure 1. Number of articles on IOCs in BioB by year of publication.

Running synthesis. The selected 99 articles were judged based on the combination of the following three selection criteria: inter-organizational collaborations; bio-based business; and benefits or challenges to any of the three aspects of sustainability. Articles were considered relevant if they satisfied all three criteria. Two academics from the study team independently synthesised the data by reading the articles in more detail, and systematically discussed the articles that one of them thought deficient of the criteria. They achieved a substantial inter-rater agreement of Kappa 0.63 (Table 2).

Table 2. Inter-rater agreement on data synthesis.

		Rater 2		
		Include	Exclude	Total
Rater 1	Include	24	12	36
	Exclude	3	60	63
	Total	27	72	99
			Kappa	0.63

In total, the entire data-reduction process ran from a few hundred thousand citations (n = 364, 387) via 1827 and 99, towards the 24 most relevant ones (Table 1). The final core set of 24 articles was examined for content analysis.

Finally, we conducted content analysis using Atlas.ti software [19], thereby systematically categorising, coding and examining the 24 core articles. We integrated the results from the individual studies that addressed similar topics [20]. Out of the 24 articles in the dataset sixteen used case studies, six used surveys, and two used literature reviews as the main method of studying IOCs in BioB. Although all articles were designed as a cross-sectional study, the methodological variety of datasets helped us to capture the different dimensions of IOCs in BioB.

Finding a focus regarding the three main concepts (IOC, sustainability outcomes, and BioB) was a major challenge for this literature study because each of these three domains was ambiguous, complex, and multidimensional. Therefore, studying interrelations between these concepts required extra efforts to find a balance between precision and comprehensiveness. We discussed the issue within the study team and, as a result of several brainstorming sessions, jointly arrived at more specific key words and search string (Appendix A). Additionally, we strengthened the inclusion-exclusion criteria (Appendix B and Appendix C), and followed an iterative process by executing the search function several times.

3. Results

The results of this paper are presented in three subsections. First an overview of IOCs in BioB is given, such as their types, means, and characteristics. Second, the sustainability benefits are presented, followed by the third subsection where the sustainability challenges are shown.

3.1. Overview of Inter-Organisational Collaborations

Table 3 presents an overview of the 24 articles with discussed type and means of collaboration.

Types of IOCs. As Table 3 shows, various types of IOCs in BioB have been studied, the most popular type of which are (eco-)industrial parks. More than 60% of the papers refer to and analyse (eco-)industrial parks. "(Eco-)industrial park" refers to industrial ecology and constitutes industrial clusters, energy clusters, eco-industrial clusters, and biotechnological clusters. The next popular type of collaboration is the strategic alliance, which encompasses innovation alliances and public-private partnerships.

The results show that organisations aim to eliminate the negative effects of BioB to the environment and create sustainability benefits through collaboration. Moreover, it is believed that BioB can only be sustainable through collaboration, which attracts organisations from various industries such as agriculture, horticulture, aquaculture, fisheries, pharmaceuticals, chemicals, and energy. It is claimed that IOCs among these heterogeneous organisations can bring competitive advantages and synergetic opportunities along the chains of rest-stream processing and resource sharing [21]. IOCs are not only promising for increasing the environmental performance and ensuring sustainability of BioB, but also for ensuring the intensive innovations [22,23].

Table 3. Overview of the final set of articles.

Reference	Type of Collaboration	Means of Collaboration
Industrialized		
[6]*	Bioenergy clusters in Australia, Sweden, Austria, Finland and Denmark	Exchange material and energy, (bio-)waste, waste heat. Integration of production systems, of bio-based with other industries.
[7]*	Bio-fuel alliances in the USA and Europe	Exchange (bio-)waste. Share property rights. Integration of production system.
[10]	Wood biomass industrial cluster in Japan	Exchange material and energy, waste heat, knowledge. Sharing resources, personnel, facilities and infrastructure. Integration of production system, integration of bio-based with other industries.
[21]	Industrial symbiosis in Sweden	Exchange material and energy, waste heat, industrial waste. Share utilities. Integration of bio-based with other industries, of CHP with bio-gas/bio-fuel plant, of CHP with district heating system.
[22]	Biotechnology alliances in the USA	Exchange knowledge and R&D. Share personnel.
[23]	Biotechnology cluster in Canada	Exchange knowledge and R&D. Share resources, personnel.
[24]	Industrial symbioses in the Netherlands and in Sweden	Exchange material and energy, waste heat, CO_2, knowledge, bio-waste, waste water. Sharing buildings, facilities, resources, personnel, social network, and other utilities. Integration of CHP with bio-gas/bio-fuel plant, of CHP with district heating system.
[25]	Industrial symbiosis in Sweden	Exchange waste heat, steam. Integration of processes, of CHP with district heating system.
[26]	Bio-fuel clusters in Sweden	Exchange material and energy, by-product. Share utilities.
[27]	Biotechnology partnerships in Germany, Canada and France	Exchange knowledge and R&D. Share resources, physical goods and services, and social network.
[28]	Wood biomass cluster in Norway	Exchange material and energy, wood waste, waste heat, knowledge, and other resources. Share social network.
[29]	Biotechnology clusters in the USA	Exchange knowledge. Share innovation and social network.
[30]	Biotechnology alliances in the USA	Exchange knowledge and innovation. Share partner-specific experience.
[31]	Integrated supply chain bio-gas plants in Germany	Exchange (bio-)waste, energy, waste heat. Integration of supply chain.
[32]	Closed-loop supply chain in Denmark	Exchange material and energy, (bio-)waste, energy. Integration of processes, of CHP with district heating system, of supply chain.
[33]	Biomass collaboration in the Netherlands	Exchange (bio-)waste, knowledge. Share resources.
[34]	Wood biomass industrial symbiosis in Sweden	Exchange material and energy, waste heat, (bio-)waste. Integration of processes, of bio-fuel and sawdust plant productions, of CHP with district heating system.
[35]	Agricultural knowledge and innovation system in Belgium	Exchange knowledge and R&D. Share personnel.

Table 3. *Cont.*

Reference	Type of Collaboration	Means of Collaboration
Emerging		
[7]*	Bio-fuel alliances in Asian, South American and African countries	Exchange (bio-)waste. Share property rights. Integration of production system.
[6]*	Bioenergy clusters in India and Uganda	Exchange material and energy, (bio-)waste, waste heat. Integration of production systems, of bio-based with other industries.
[5]	Integrated biodiesel supply chain in Brazil	Exchange (bio-)waste, knowledge.
[36]	Industrial symbiosis in Chile	Exchange material and energy, waste heat, (bio-)waste. Integration of water system, of processes.
[37]	Integrated production system in Slovenia	Exchange material and energy, waste heat, (bio-)waste. Integration of processes, of CHP with bio-gas/bio-fuel plant, of CHP with district heating system.
[38]	Biotechnology cluster in South Korea	Exchange knowledge and learning. Share social network.
[39]	Eco-industrial park in China	Exchange material and energy, waste heat, (bio-) waste. Share utilities. Integration of water system.
[40]	Industrial park in China	Share facilities and infrastructure. Integration of waste water system.

* Articles [6] and [7] study cases from both industrialised and emerging economies.

Means of IOCs. Table 3 presents the three means of IOCs in BioB that exchange waste streams, share utilities, and integrate systems.

First, exchanging waste streams refer to the flow of material and energy (for instance heat), steam, bio- and industrial waste, by-products, and information and knowledge, among collaborating organisations. For example, exchanges are conducted through delivery of electricity from a pulp mill to a sawmill and dispatch of sawdust and wood chips from the sawmill to the pulp mill [10,24]. When it comes to heat exchanges, many authors refer to collaborations between industries and district heating companies as economically and environmentally beneficial. Authors also refer to the steam exchanges between, for example, a combined heat and power plant (CHP) and an ethanol plant, between a paper mill and pulp mill [21,24,25]. Additionally, authors refer to carbon emission as industrial waste and emphasise the importance of CO_2 use in greenhouses [21,24,26]. Another exchange is the flow of information, knowledge, and experience among local organisations and local research institutes and universities. The exchange of relevant information and knowledge brings a competitive advantage to collaborating organisations [27,41].

Second, sharing utilities refers to joint use of resources such as raw material, buildings, personnel, infrastructure, and information. Sharing resources decreases information asymmetry and breeds trust and commitments in collaborations [27,28]. In particular, sharing personal contacts in the form of social relations plays an essential role in IOCs being an important channel to transfer tacit knowledge, skills, and experiences necessary for innovation [22,29,30].

Third, integrating systems refer to the integration of processes, production systems, water, and heat systems. For instance, integration of processes refer to joint bio-fuel combustion and bio-gas production [25], and integration of production systems refers to the closed-loop material flows where the waste and by-product from one production are used by another [6,21].

Characteristics of IOCs in BioB. The key characteristics of IOCs in BioB are heterogeneity, geographical proximity, technological proximity, cultural proximity, and complementarity.

Heterogeneity refers mainly to the differences in the industry in which the organisations operate. Many organisations attach a high importance to collaborations with organisations from other industries (such as agricultural centres), universities, and local scientists. Additionally, industries such as biotechnology, bio-fuel, forestry, agricultural biotechnology, agri-food, the chemical sector, and cosmetics provide potential partners for IOCs in BioB. Heterogeneity not only allows for exchange of waste streams among different organisations, but also enables a wider access to local resources such as information, knowledge, skilled labour, and finance [42,43], eventually increasing innovation [29].

Geographical proximity refers to the co-location of heterogeneous organisations, and offers opportunities for synergy for successful formation of IOCs in BioB [26,36,44]. Synergy is created among co-located companies via exchange channels, shared services and logistics, and integration systems such as water flow and heat integration systems [26]. Geographical proximity is especially important for heat integration systems, because its storage and/or transportation can be technically and economically impossible [36,37]. Regarding geographical proximity, a radius of 20 km or less is recommended [6,31]. Co-located companies usually develop social networks through which innovation, information, and knowledge are exchanged [29]. Additionally, geographical proximity reduces transportation costs and fuel use within collaborating organisations [6]. Available local resources and local markets provide an opportunity to close the supply chain with no or low transportation costs [6].

Technological proximity refers to the ability of an organisation to collaborate with other co-located organizations without needing to implement any radical changes [10]. Technological proximity exists if none of collaborating organisations have to shift their business. Organisations that are geographically co-located but are technologically incompatible need to implement radical changes because their absorptive capacities may lie beyond the capabilities of collaborations [10].

Cultural proximity refers to the non-tangible issues such as norms, values, trust, and understanding. Cultural experience is usually built in time while building common experiences [30]. Organisations that are culturally far apart will prefer formal governance despite high transaction costs [30].

Complementarity refers to the equilibrium of supply and demand [22,32,33,41]. The complementarity of supply and demand shows that the availability of required biological resources and the demand for bio-based products in local markets are essential. For example, a bio-gas plant needs a certain quantity of biomass (e.g., manure) to operate and meet the local demand for bio-gas [32]. Supply and demand complementarity is difficult to fulfil because of uncertainties in biomass supply such as unpredictable yields and fluctuating prices of biomass [31,32].

In summary, the predominant type of IOCs in BioB is an (eco-)industrial park where organisations collaborate by exchanging waste streams, sharing utilities, and integrating systems. IOCs in BioB are characterised by the involvement of heterogeneous organisations that have a certain degree of geographical, technological, and cultural proximity and complementarity.

3.2. Sustainability Benefits

In this subsection, the environmental, economic, and social benefits of IOCs in BioB are presented.

Environmental benefits. The most important environmental benefit is the substantial reduction of carbon emission. The distribution and use of CO_2 emission of bio-based and industrial production in agricultural production, such as in greenhouses, may result in the reduction of substantial amounts of CO_2. The CO_2 savings here are twofold: (1) CO_2 emission from bio-based and industrial companies is used rather than expelled into the atmosphere, and (2) avoiding costs of burning natural gas in greenhouses [21,24].

> *"A new private company ... captures CO_2 emissions from the Shell plant, and distributes the waste emissions to 500 greenhouse companies to the North of Rotterdam. ... In 2007, the greenhouse companies achieved a reduction of 170,000 tonnes CO_2 emissions by avoiding the burning of 95 million m^3 natural gas."* ([24], pp. 432–433)

Besides greenhouses, other local companies can also capture CO_2 for carbon use in for example soft drinks, cooling applications, and algae production [21]. Studies show an extensive potential to reduce CO_2 emission (more than 500,000 tones CO_2 per year) through energy cooperation among local integrated paper and pulp mills, district heating systems, and bio-fuel production [25]. Additionally, it has been found that the collaborations among local companies in Maniwa, Japan, can turn the cluster into a zero-emission zone [10]:

> *"The energy generated from the system not only meets the company's own demand but is also sold to other companies. This green energy is estimated to be an equivalent of 58,000 tonne of CO_2, an environmental benefit."* ([10], p. 368)

Additionally, CO_2 reduction can also be achieved through the reduced transportation offered by geographical proximity. Use of local raw materials, as well as local production and supply to local markets reduce the need for transportation within the entire supply chain, and through this reduce use of fossil fuels [6,39]. In addition, the reuse of waste heat of local companies as substitutes for fossil fuel for heating [6,25], eventually reduces carbon emission even further. For example, in Sweden, the combustion of biomass and the production of ethanol in combination with CHP plants reduced GHG emissions by about 80% as compared to plants that were based on fossil fuel [21].

Another environmental benefit is waste reduction. The valorisation of (bio-)waste from agro-food, forestry, and other industries in closed-loop models, minimises solid waste and reduces environmental pollution [6]. For instance, manure from livestock production is degassed in bio-gas installations, which produce bio-gas and replace the mineral fertilisers with organic compost. Degassing of manure reduces methane and nitrous oxide emissions and provides green energy for local industries or local residences [6,32]. It is apparent that the whole process of using agricultural waste for bio-based purposes provides value to the waste and produces organic fertilisers [32]:

> *"... the biogas technology facilitates ... an improvement of the residual product's fertilizer value, which leads to an increased uptake by plants, reduced runoff of nutrients to surface water, and reduced leaching to groundwater as well as reduced costs for purchase of mineral fertilizers."* ([32]; p. 139)

Waste reduction is also achieved by the use of oil and fat waste, organic household waste, and organic waste from food industries such as vegetable oil waste from fast-food industries, all in biodiesel, bio-gas, bio-fuel, biodegradables, and other bio-based productions [21,26]. Other environmental benefits of IOCs are evident in the use, reuse, and recycling of waste water and waste heat [21,34]:

> *"Greenhouses in particular can also use waste heat from the ethanol and biogas industry."* ([21]; p. 1751)

> *"Waste heat from the pulp mill, the sawmill and the biofuel upgrading plant is used as a resource base to cover the base load of the heat demand in the district heating system."* ([34]; p. 1541)

In general, the integration of renewables to a company system (such as bio-energy production and use, and the integration of CHPs with district heating systems) is an alternative solution to improve companies' environmental performance [37]. IOCs in BioB bring substantial environmental benefits and tackle the more alarming sustainability issues such as increasing carbon and GHG emissions, and increasing waste.

Economic benefits. First, IOCs in BioB creates various economic synergies [10,25,36]. Synergy in the implementation of new technologies, improvement of material use and energy handling such as water, utility, services, logistics, and renewable solutions [21,26,31,36], create economies of scope that can be decisive for sustainability performance [22,28,39]. Another important synergy is the joint discovery of new knowledge, knowledge generation and transfer, and uncovering tacit knowledge, ultimately leading to improved trust and supportive relationships [22,35].

> *"Synergies between the biofuel industry and food industry are primarily of two different types: using biofuel by-products for human and animal food and feed; and using food industry by-products for biofuel production."* ([26]; p. 54)

Second, IOCs in BioB can result in cost reduction in for instance waste disposal, waste incineration, and waste taxation [32]. Referring to cost reduction, [40] shows that the shared systems (e.g., of waste water treatment) are more than 150 times more cost-efficient than single uses. Integration of chemical pulp mills, sawmills, bio-fuel plants, and district heating systems, can bring about 18% cost efficiency for the companies involved in the system [34]. IOC effects on cost can also be visible in the reduction of transportation and fuel costs [6], and overhead costs related to R&D, production, and distribution [22].

> *"Slaughterhouse wastes in the city of Linköping are sent to the local biogas facilities as a method for disposal. This greatly benefits the meat processing industry, with reduced waste handling costs and produces biogas used for vehicle fuel in the community."* ([21]; p. 1753)

Additionally, collaborations enable the shared use of techniques and technologies. This reduces start-up costs and enables investments that are often not affordable by stand-alone companies [28]. IOCs open new opportunities, especially for small and medium-sized enterprises (SMEs) [33,36]. SMEs can benefit from using the resources and technologies of large companies that they would not be able to afford on their own [29]. IOCs can provide new business-development and business-expansion opportunities [10]. Especially in emerging economies, new business developments and economic opportunities are of high importance [7,28,45].

Third, IOCs can result in enhanced innovation performance and competitive advantages through the exchange of resources, materials, energy, water, by-products, and so forth [26,39], and through the exchange of relevant knowledge, technical knowhow, and innovative ideas (Dyer and Singh 1998). Companies that collaborate intensively are stronger competitors regarding biomass utilisation [10].

> *"Given the growing interest in the valorisation of bio-waste it is posited that entrepreneurial firms develop interorganisational relationships to generate competitive advantages."* ([33]; p. 261)

Geographical proximity of collaborating organisations (e.g., firms, research organisations, industry organisations, venture capitalists and universities) effectively allows access to knowledge and skilled labour, and promotes knowledge-sharing essential for innovation [29,46]. Collaborating organisations are on average more innovative than stand-alone ones [29]. The diversity of information and capabilities has a positive influence on a company's innovation performance [22,23,38]. Collaborations enable not only exchange of knowledge that enhances innovation, but also exchange of existing techniques and shared use of technologies [28], and through that provides benefits of innovation availability [22] and supports SMEs to sustain innovations in bio-based production.

Fourth, IOCs in BioB can result in improved reputation of the involved actors. The involvement in green supply chains, the use of renewable technologies, and the implementation of sustainable innovations are branding opportunities for collaborating companies [32]. On top of improving their reputation, IOCs enable companies to actually invest in reducing their carbon footprint [5]. Through this, companies capture not only financial benefits but also goodwill that enhances the investment climate and gives a green image regarding cleaner production [32,39].

Finally, IOCs in BioB brings not only economic benefits for the engaged companies but also benefits for local, regional, and national economies, which is especially important in emerging economies [10]:

> *"Many of the new alliances reveal the growing economic and political strength of some developing countries, such as Brazil and Indonesia."* ([7]; p. 639)

In general, IOCs in BioB are discussed to bring substantial economic benefits. This is demonstrable especially in cases from emerging economies, where BioB is of essential importance to national economic growth and poverty reduction [6,7].

Social benefits. IOCs in BioB have potential ability to support socio-economic activities and create employment [6,10], improve living conditions [10], and provide higher-paid jobs [5]. Collaborations attract competent human capital, such as multidisciplinary researchers [22,46]:

> *"Bio-energy production company in Maniwa cluster has created employment opportunities of 110 man/months."* ([10]; p. 369)

The social benefits of IOCs are especially significant in emerging economies [31]. These benefits usually appear in different forms, such as availability of energy, electricity, heat, and irrigation water in previously remote areas, and economic-development opportunities in marginalized areas [6]. Local companies often implement social-responsibility programmes by investing in health and education for the employees and their families, and people living in the vicinity [5]. Moreover, IOCs in BioB often engage SMEs that expand employment opportunities, generate income, advance economies, and reduce poverty in the long term [5]. For example, in a period of 12 years, the expectation of poverty reduction because of BioB is 6% in Mozambique [7,47].

> *"Hosahalli village biomass gasifier in an agricultural community provided 20 kW electricity in 1997. The benefits of the project included cutting the walking distance of women to fetch water as water would be pumped to households whilst farmers were able to get irrigation water. A total of 20.2 acres was irrigated in 2002 enabling production of a variety of crops benefiting 17 farmers. Availability of evening lighting was also reported to benefit studying school children and the elimination of kerosene use."* ([6]; p. 1288)

In summary, IOCs in BioB are found to create wealth and social benefits for local populations, empower local communities, bring new employment opportunities, create social wealth, develop economies, and reduce poverty. As a result, IOCs in BioB are found to have higher value in emerging economies than in industrialised economies.

3.3. Sustainability Challenges

Despite several benefits, IOCs in BioB have been criticised for increasing risk and uncertainties.

The environmental challenges are the following. First, IOCs in BioB are criticised for aggravating land-use conflicts. The concentration of various industries needs large-scale use of local land, including land for energy-crop production [6], which escalates local land use conflicts [31]. BioBs have been strongly criticised for their intensive land use (*i.e.*, for energy crop production) [6,21]. Similarly, IOCs in BioB are criticised for the use of even more land. Large-scale production of energy crops may have a negative impact on water resources, cause soil erosion, and eventually require additional chemical fertilisers [5–7]. Second, IOCs in BioB are criticised for concentrating industrial activities at one geographical location. Concentration increases the pressure on the local ecology, and increases the risk of the ecological capacity being unable to deal with local pollution.

Economic challenges are related to capital intensity because of, for instance, huge investments required to form IOC, costs for waste quality standards, and costs for operation and maintenance of huge installations (e.g., a biomass gasifier). Capital intensity may cause financial difficulties [6,24,28,32]. These costs (e.g., high costs of the required infrastructure) are not always affordable for commercial companies without, for example, governmental support [10,24,39]:

> *"It was calculated that such a pipeline system would cost €112,700,000 and would require government funding for new infrastructure."* ([24]; p. 431)

Substantial capital is always needed to establish IOCs and often their large-scale approach has been economically unsuccessful [24]. For instance, Norwegian bio-energy firms had a loss in 2007, which was the result of high investment costs, lack of suitable techniques and technologies, and low electricity prices that decreased the competitiveness of bio-energy [28]. Additionally, IOCs in BioB can cause interdependency issues among collaborating organisations. Interdependency may lead to path dependencies and technological lock-in situations if the organisations link their businesses with other local companies for a long period [24,39]. Interdependencies in IOCs raise the risk of failure of the entire system if one collaborating company fails to fulfil its commitments [40]. Finally, IOCs in BioB are linked to transactional uncertainties, fluctuating prices of agricultural products, unstable quantities of yields, and unpredictable markets for waste and by-products leading to the risk of failure [31].

Social challenges are related to traffic congestion, odour nuisance, adverse visual appearance, and diminished recreational value due to the concentration and expansion of BioB at one location increasing social discomfort [7,31,39,40,48]. However, these critiques are raised in industrialised countries, such as the Netherlands, Norway, Sweden, and Germany, where the population density is relatively high [31].

In summary, IOCs in BioB are discussed to bring sustainability risks and uncertainties such as increasing land-use conflict and increasing pressure on the local ecology. Additionally, the operation and maintenance of IOCs in BioB are indicated to be capital-intensive, with increased interdependencies and transactional uncertainties. However, these challenges have been much less discussed in relation to emerging economies as compared to industrialised economies.

To integrate the findings in a transferable manner we developed a conceptual overview (presented in Table 4). Interestingly and presently not yet recognised in the core articles, we present the sustainability benefits and challenges by distinguishing between industrialised and emerging economies.

Table 4. Sustainability of IOCs in BioB in industrialized and emerging economies.*

Industrialised Economies (*31 Cases*)		
	Benefit	***Challenge***
Environ-mental	CO_2 reduction GHG reduction Waste reduction Less mineral fertiliser use	Ecological and human health risks
Economic	Synergies Cost reduction Competitive advantage Enhanced innovation Enhanced reputation	Capital intensive Interdependency Transactional uncertainty
Social	Enhances socio-economic life Local employment Generate income Social-responsibility programmes Secure energy supply Supports small-scale farmers	Aggregated conflict of land-use *Traffic congestion* *Odour* *Adverse visual appearance* *Decreasing recreational value* *Exceeding local ecological capacity*
Emerging Economies (*14 Cases*)		
	Benefit	***Challenge***
Environ-mental	CO_2 reduction GHG reduction Waste reduction Less mineral fertiliser use	Ecological and human health risks
Economic	Synergies Cost reduction Competitive advantage Enhanced innovation Enhanced reputation *Enhancement of local economy*	Capital intensive Interdependency Transactional uncertainty
Social	Enhances socio-economic life Generate jobs Generate income Social-responsibility programmes Secure energy supply Supports small-scale farmers *Poverty reduction* *Energy availability*	Aggregated conflict of land-use

* Concepts that are different across the blocks are presented in *italic*.

This conceptual overview indicates that the environmental benefits and challenges seem not to be geographically dependent. For instance, CO_2, GHG and waste reduction, and less use of mineral fertilisers are discussed as being similarly beneficial for emerging and industrialised economies. Likewise, the increasing pressure on local ecology and human health risks are discussed as challenging for emerging and industrialised economies. However, the patterns change if we consider the social aspect of sustainability. It turns out that scholars emphasise social benefits in emerging economies, such as poverty reduction and energy availability as typical social benefits. In contrast, scholars seem to emphasise more the social challenges, next to the social benefits in industrialised economies. The challenges of social aspects, such as traffic congestion, visual appearance, and decreasing recreational value, are typical in economically wealthy countries and are not perceived as challenges in emerging economies.

In summary, the results suggest a clear distinction between the individual cases from emerging and industrialised economies. IOCs in BioB are discussed as bringing more sustainability benefits in cases from emerging economies mainly due to the social aspects of sustainability.

4. Discussions and Conclusions

The objective of this paper was to find and integrate the available knowledge on sustainability of IOCs in BioB, while considering the three aspects of sustainability: environmental, economic, and social. In this section, we discuss the results and present the main conclusions.

BioB is recognised in the literature as playing an important role in sustainability enhancement, such as improved environmental performance of companies, developed socio-economic life [7], increased income for developing communities [28], and secured energy availability in a carbon-neutral way [5–7,28,31]. Meanwhile, BioB has been criticised for creating ecological and human health risks [6], for reducing biodiversity and for causing deforestation, soil erosion, and land-use conflicts [6–9].

By establishing IOCs in BioB organisations are presumed to respond to sustainability challenges of BioB through exchanging waste streams, sharing utilities, and integrating the production systems [5,10,32]. The core studies often investigate (eco-)industrial parks as a typical type of IOC in BioB. (Eco-)industrial parks are characterised by heterogeneity of collaborating organisations, and geographical, technological, and cultural proximity and complementarity among the collaborating organisations (Table 3).

From our systematic literature review, we found empirical evidence for both sustainability benefits and challenges studied by authors (Table 4). However, the authors have not investigated if the collaborations can mitigate all sustainability challenges of BioB, such as land use conflicts and soil erosion. As for the environmental aspect of sustainability, evidence has been found for reduced carbon and GHG emissions, reduced waste disposal, and reduced use of mineral fertilisers. As for the economic aspect, evidence has been found for synergy, cost reduction (e.g., of waste disposal), competitive advantage, enhanced innovative performance and enhanced reputation. As for the social aspect, evidence has been found for increased energy availability and energy-supply security, new employment opportunities, and improved living conditions. The latter of these is especially evident in individual cases from emerging economies. However, evidence has also been found for sustainability challenges, such as increased risk for the local ecology, the capacity of which might not be able to bear the concentrated production activities. Other challenges concern the capital intensity and the high operational and maintenance costs. Finally, IOCs in BioB seem to raise social discomfort due to traffic congestion, odour nuisance and diminished recreational value, which is especially evident in individual cases from industrialised economies.

Having explored the sustainability benefits and challenges, we discovered that scholars discuss different sustainability effects while studying cases from emerging and industrialised economies (Table 4). In particular, the social benefits of IOCs in BioB are more emphasized in cases from emerging economies, while they are challenged in cases from industrialised economies. In emerging economies, IOCs in BioB are argued to contribute to rural empowerment by generating jobs and income, eventually leading to the reduction of poverty. In industrialised economies, the authors' emphasis is more on the negative social aspects, such as traffic congestion and decreasing recreational value. Therefore, sustainability outcomes seem to be more positively presented in cases from emerging economies than from industrialised economies.

Although our study is preliminary in uncovering the sustainability effects of IOCs in BioB, the conclusion that IOCs provide a variety of sustainability benefits next to (region-)specific challenges supports pleas to pursue sustainability studies and develop political agendas on IOCs in BioB. We recognize the lower number of empirical studies on IOCs in BioB in emerging economies compared to industrialized economies (Table 4). Nevertheless, the substantial presence of individual case studies (within the articles) from two in many respects opposite extremes (six case studies from Sweden and four case studies from the United States) strengthens the representativeness of the conclusions.

Finally, the systematic literature review provided the surprising insight that, while the popularity of the topic of IOCs in BioB is growing (Figure 1), only a modest number of studies (24 articles) empirically investigated sustainability outcomes of IOCs in BioB, which may lower the reliability of the conclusions. Additionally, note that the studied articles were built with a cross-sectional design. Hence, the long-term perspective of sustainability and the interaction between its three aspects could not be found. Finally, the literature failed to give substantial quantitative evidence for the benefits and challenges of all three aspects of sustainability, making it impossible to assess the trade-offs between sustainability benefits and challenges. Articles typically focus on only one out of three sustainability aspects. Therefore, we recommend that future research consider more quantitative measures of all three aspects of sustainability when studying inter-organisational collaborations in bio-based business.

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Abbreviations

The following abbreviations are used in this manuscript:

BioB— bio-based business
CHP— combined heat and power plant
GHG—greenhouse gas
IOC— inter-organisational collaboration
SME— small- and medium-sized enterprise

Appendix A: Keywords and Search Strings

Keywords/Search Subsets		Search Strings
Inter-organizational collaboration		Alliance*, Coalition*, Collaborati*, Cooperati*, Eco-industrial park*, Supply chain, Industrial symbiosis, Inter$firm, In-ter$organi?ational, Inter$sector* relation*, Joint-venture*, Network*, Partnership*, Relation*
Sustainability outcome	*Social*	Community, Corporate social responsibility, Education, Employee health, Employment, Human right*, Labo$r condition*, Poverty, Social, Wellbeing, Working condition*
	Environmental	Eco-efficien*, Biodiversity, Carbon, Climate change, Cradle-to-cradle, Ecological, Emission*, Global warming, Life cycle assessment, Pollution, Resource use, Waste
	Economic	Company performance, Competitive advantage, Corporate performance, Cost*, Economic, Financial, Innovation, Profit*, Revenue* Sustainab*, Triple-bottom-line
Bio-based domain		Alga*, Bio$based, Bio$diesel, Bio$economy, Bio$electricity, Bio$energy, Bio$ethanol, Bio$fuel*, Bio$gas, Bio$heat, Bio$mass, Bio$material*, Bio$park*, Bio$plastic*, Bio$refin*, Bio$region*, Bio$resource*, Bio$tech*

Appendix B: Inclusion Criteria

Inclusion Criteria	Argumentation for Inclusion
Social Science Citation Index (SSCI) only	To limit the scope of the research to relevant social mechanisms at play.
English language	To make the process universally replicable.
As of year 1990	The first publication containing word "bio-based" is from year 1990.
Peer-review articles, review papers	To get a comprehensive overview of all relevant mechanisms that could play a role.
Qualitative and quantitative empirical studies, case studies	To get a comprehensive overview of all relevant mechanisms that could play a role.
Search "collaboration" in title and "bio-based" in topics	To collect the studies on inter-organisational collaboration in the bio-based domain, assuming that articles dealing with these topics may report on the sustainability outcomes of collaboration efforts.

Appendix C: Exclusion Criteria

Terms	_cell*, mobile, *oxid*, acid*, ad hoc network*, antenna, bandwidth, cataly*, DNA, equilibri*, ester, gene_, quantum, queu*, information system*, infra*, internet, IT, modif*, molecul*,multimedia, nano*, neural network*, neuro*, optic*, phone, polymer network*, polyurethane*, psych*, radio, react*, resist*, road network*, robotics, satellite, sensi*, senso*, software, switch*, television, transmi*, transport* network, video, wave, weight*, wireless.

Categories	public environmental occupational health, political science, anthropology, area studies, history philosophy of science, women's studies, psychology experimental, history of social sciences, psychology educational, history, agricultural economics policy, ethnic studies, cultural studies, philosophy, humanities multidisciplinary, agronomy.
Themes	Intra-organisational collaborations instead of inter-organisational collaborations, models without any empirical example, e.g., mixed-integer linear programming of supply chain optimisation, bilateral relations of science and commercial R&D, roles of academics and policy makers, and career network dynamics, red bio-technology.

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