sustainability

Project Report

Co-creating Science Commercialization Opportunities for Blue Biotechnologies: The FucoSan Project

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Abstract: We report the experience of the FucoSan InterReg project that had the ambition to generate commercialization opportunities for biotechnology research in a marine environment. Fucoidan, a promising biomarine polysaccharide extracted from seaweed, offers a broad array of potential applications; however, the supporting innovation value chain is still under development. We explore how the use of business modelling tools can contribute to building a shared understanding of commercialization opportunities across a diverse range of research and development actors. We analyze data (interviews, workshops, and surveys) from a German-Danish network of actors involved in the FucoSan InterReg project to identify how the tools contribute to setting up a base to support future activities across a potential innovation value chain. The results point towards the direct and indirect positive effects of engaging in the co-creation of a shared understanding of the functionality and possibilities of promising biomarine products. The findings support the idea that interdisciplinary and multilateral interactions help actors to identify the necessary connections and interdependencies to build a sustainability-driven innovation value chain.

Keywords: biotechnology; science commercialization; fucoidan; sustainability; business model

1. Introduction

Sustainability has taken center stage in public discourse as well as in research funding [1]. Since the approval of the UN's Agenda for Sustainable Development and the 17 Sustainable Development Goals (SDGs) there has been increased interest across industries in how to advance towards these objectives [2], even if it means sacrificing economic returns or profitability in the short term [3–5]. This shift has a substantial impact on how we approach and assess science commercialization, as scientists' discoveries should not only have an impact on scientific progress, but also on society [1]. The FucoSan InterReg project (www.fucosan.eu) had the ambition to contribute to this challenge.

FucoSan is a four-year (2017–2020), cross-border (German-Danish), research and innovation project in Europe (funded by the European Union). It is focused on a promising biomarine product: fucoidan. Fucoidan is a seaweed polysaccharide found in species such as *Laminaria digitata*, *Saccharina latissima*, *Fucus vesiculosus*, or *Fucus distichus subsp. evanescens* (formerly *Fucus evanescens*) among other brown macroalgae [6,7]. It is known for its potential medical applications [8–13]. Interestingly, most of the potential from the natural product is still unexploited, requiring still substantial progress in both research and development. In this context, we built upon the suggestion to use business modeling tools to bridge the scientific and societal impact dimensions [14,15] in order to generate sustainable commercialization opportunities.

For the duration of the project, we studied the researchers' interest to further engage in collaboration with non-academic actors and to transfer their research into new products and services. The researchers identified and assessed potential opportunities but also stressed the need for further support mechanisms that could compensate for the weaknesses of the current knowledge and technology transfer process. We use this research context to contribute to the current discussion on how business models may help to address the sustainability and transfer challenges [14]. Overall, we found support for the idea that business modelling tools can help to trigger change in the researchers' perceptions and expectations in relation to science commercialization. Our results provide guidance to other organizations interested in exploring science commercialization opportunities, in particular when combining societal, economic, and environmental impacts.

The article is organized as follows: first, we start with a review on the concept of science commercialization and how it is changing in light of sustainability and business modeling. Second, we describe the project as our research setting as well as the method that has been used to collect and analyze the data. Third, we present the results of the different measures and activities conducted during the project. Finally, we discuss the results and highlight the implications for the management of the commercialization process, further research in this topic, and for policy makers.

2. Theoretical Framework

2.1. Impact as a Motivator for Science Commercialization

An important discussion on science commercialization focusses on the question of whether we are actually measuring its impact correctly since a too narrow focus on economic aspects neglects the broader long-term impact perspective. [16]. Science commercialization is defined as "the process of converting scientific knowledge into new or improved products or services that are made available in the market" [16]. However, the impact of these products or services is not only the economic return they can generate but also their societal and environmental contributions. The intriguing question is to what extent the "commercial" view of science commercialization has limited the scientists' motivations to engage in transferring their knowledge into new products and services that can have an impact in these broader terms.

Individual and organizational aspects influence how scientists consider the scientific and societal (social/economic/environmental) impact of their research [17]. Thus, in addition to the dilemma between economic, social, or environmental impact, scientists have to consider the impact that their work has in the scientific community. Some research projects might have a high potential in relation to social or environmental goals, but they might not be fitting for a journal publication in the research field of the scientist. This requires some balancing to address the tension between scientific and societal goals giving shape to different degrees of academic engagement.

Academic engagement "represents inter-organizational collaboration instances, usually involving 'person-to-person interactions' that link universities and other organizations, notably firms" [18]. It includes aspects that go beyond the commercialization or patenting of research, also embracing social and economic impact at large [19]. The extent to which a researcher decides to engage with other organizations can have a positive impact on the ability to identify potential applications of research findings and the understanding of the problems faced by practitioners. However, it can also negatively impact on the researchers' autonomy and delay or preclude the dissemination of significant scientific results [20].

2.2. Scientists Engagement in Commercialization and Sustainability

The decision to allocate more or less effort to engaging with non-university actors (for commercial or non-commercial activities) is at an individual (researcher) level. There are organizational and institutional influence factors, but it is mostly determined by the perceived impact of the research on the potential scientific beneficiaries [21]. Prior research has explored what motivates researchers to engage in university-industry collaborations and how such collaborations would relate to previous industry experience or how they would influence future scientific performance [18,22].

A recurrent observation is that the alignment of researchers' scientific and societal impact is not an anomaly among "successful" researchers [18]. There is a positive interaction between achieving scientific breakthroughs and being able to communicate them to other actors or engage in collaborative projects with industrial partners. This can further extend the impact of the scientific advancement. Such an observation creates a highly attractive proposition: what if we could motivate researchers to strive for societal goals related to their scientific interests and research capabilities? Empirical studies on the overlap between science and societal interests suggest that the alignment does not necessarily happen automatically. For instance, it has been found that research on agribusiness does not prioritize research problems that could contribute to improve food availability or alleviate hunger [23]; similarly, in medical research, the economic objectives of the pharmaceutical industry determine the prioritization of topics and transfer approaches [24].

However, there are new forces that might reshape this relationship. Under the generic theme of sustainability there is an increasing visibility of the Sustainable Development Goals (SDGs) (UN's Sustainable Development Goals - https://sustainabledevelopment.un.org/) proposed by the United Nations and the Societal Challenges (Europe 2020 – Societal Challenges, https://ec.europa.eu/programmes/horizon2020/en/h2020-section/societal-challenges) described by the European Union. These new forces aim to influence science and industry orientation when engaging in research and innovation activities, with the ambition to accelerate the progress towards sustainable societal outcomes. The SDGs put stress on goals that do not necessarily sustain an exclusive monetary view of science commercialization, thus it requires a different approach to explore scientists' perceptions of their impact [21], potentially making it more attractive for them to engage in such activities. Still, we know little about the type of interventions or processes that could stimulate this shift in researchers' interests.

2.3. Developing Sustainable Science Commercialization Opportunities with Business Models

When we observe how entrepreneurs develop their projects, we can see that there is a process of interaction and co-creation within the context in which they operate [25]. From the initial idea to the development of a business opportunity it is not a linear process, but an often complex and time-consuming venture with high uncertainty [26]. While most of the prior research on the activation of science commercialization opportunities has focused on the phenomenon of academic entrepreneurship in the form of university spinoffs [27], our focus is set on what happens before the researcher decides to become an academic entrepreneur or to participate in similar academic engagement activities. Studying the ideation and initial generation of potential opportunities to pursue in the future [28]. The challenge is, then, how to promote, facilitate, and activate this process. If we combine the entrepreneurship perspective on science commercialization and the insights from the academic engagement research stream, we identify that a potential key aspect is the generation of interdisciplinary interactions between the scientists, potential users and researchers from more distant fields like management and economics. Productive interactions are expected to offer the possibility to "enable researchers to resolve the tensions between the demands to produce scientific and societal impact" [17]. These interactions ideally need to be conducive to generating, refining, and co-creating science commercialization opportunities that contribute to sustainability and to societal goals. If there is a favorite, generally accepted, mediating framework for this type of interactions in entrepreneurship, it is the business model [29].

Business models have become a popular tool for designing and specifying a potential future business [30] and have been popularized in practice as part of the design thinking movement. They are mainly used to approach complex problems by making them more tangible and engaging multiple actors in the process [31,32]. Furthermore, they are suggested to facilitate the creation of business cases for sustainability opportunities as the use of a business model helps to balance economic, social, and ecological aspects [14]. Given the promising potential of business models as a mediating instrument in this specific context, we are left with the research question of: how could business modelling tools frame science commercialization perceptions among scientists?

3. Research Design

3.1. Research Setting: The Fucosan Project

The activation of science commercialization opportunities is a process which is slow and difficult to observe [16,33]. Prior research studying successful technology or science commercialization cases often ends up suffering from survival bias, as most such projects only become visible if they are successful. This has often been a shortcoming of prior research in this area [34].

In order to overcome such shortcomings, the FucoSan project (www.fucosan.eu) (EU InterReg Project) included specific activities to allow for the study of early-stage factors that can potentially give room to the activation of future science commercialization. It also offered the possibility to assess the impact of the business modelling and market discovery activities into the activation of research commercialization opportunities.

The four-year project (2017–2020) is by definition a cross-border collaboration project (in this case Germany and Denmark). It includes, also by definition, academic and industrial research participants from diverse fields from the production of biomaterials to pharmaceutical and medical research. The academic research partners had no prior experience in commercializing research results (via licensing or creation of academic spinoffs) and had limited information on how fucoidans were being sold as nutrition supplements, but no personal knowledge on whether and how market opportunities in the medical market could be actually developed. The private companies involved in the project had experience commercializing cosmetic (skins creams) with biomarine extracts, but no prior experience on using fucoidan as an active element in their natural cosmetic products or medical applications. Thus, the project's main aim was to identify and develop high-value opportunities for fucoidan, a compound that has been identified as a high potential candidate for several biomedical applications thanks to its bioactivities like anti-inflammatory, antioxidant, anti-cancer, or anticoagulant effects [10–13,35].

We did not influence the composition of the project team as participants were selected based on their interest and research activity on the promising biomarine brown-algae extract of fucoidan. The final list of participants in the project, that configured our research setting, is described in Table 1. The combination of different profiles and interests along the key activities of the potential innovation value chain offered a unique context for our research on science commercialization.

Table 1. Project participants' profile and role.

Type of Participant		Role in the Innovation Value Chain	Main Activity
Project members	Research University A	Research on the extraction processes from the brown algae.	Scientific research—extraction
	Research University B	Research on the extraction methods using enzymes to advance the purification process.	Scientific research—purification
	Research University C	Research on the characterization of fucoidan and bioactivity standardization.	Scientific research—pharmacology
	Research University D	Research on medical applications of promising biomarine products (in animals).	Scientific research—medical area
	Research University E	Research on medical applications of promising biomarine products (in humans).	Scientific research—medical area
	Research institute—public/private centre	Exploration of fucoidan application by testing its properties and bioactivity.	Scientific research—testing and exploration of applications
	Private company	Harvesting and extraction of the raw fucoidan material from the brown algae.	Process innovation development
	Private company	Application in cosmetic and other direct consumer markets of products with fucoidan.	Product innovation development

Table 1. *Cont.*

Type of Participant		Role in the Innovation Value Chain	Main Activity
Project stakeholders	Regional biomarine business association	Activation of collaborations across actors involved in biomarine research.	Support and advice
	Regional Biomedical cluster organization	Activation of partnerships and collaborations with the medical industry.	Support and advice
	Private company	Support in the commercialization of natural medical products.	Advice and market insights

3.2. Method

In order to explore the project participants' responses to the different business modeling tools and how their science commercialization perceptions evolve over time, we adopted an inductive qualitative method to approach this research question. We combined different sources of data in our analysis, including interviews, survey data, direct observation, as well as workshop notes [36,37]. Such an approach fits with our research question to explore the science commercialization interests but also to study the effects of being exposed to the market discovery and business modelling activities. This could also be described as a processual approach, in which we observe and capture the changes in perceptions and expectations, and what is driving them [38]; see Figure 1 for an overview of the research approach.

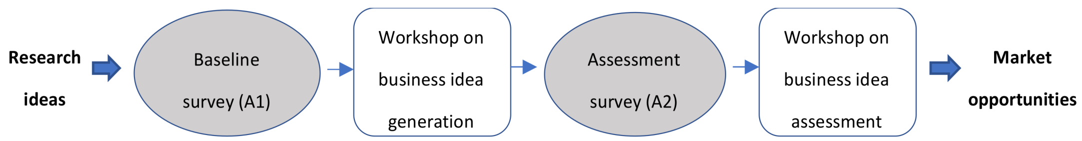

Figure 1. Description of the project research approach.

Therefore, our data collection efforts started with a baseline interview survey (Appendix A) that provided a starting point for developing activities exploring business opportunities. A second assessment using another survey (Appendix B) was conducted to establish how the participants perceived different characteristics of the market opportunities directly related to the project. Finally, additional workshops and activities with the participants helped to enrich the insights and to capture a broader picture of how their views had changed within the 18 months of our study (see Table 2 for a detailed timeline).

Table 2. Timeline of the main data collection activities.

Type of Data Collection	Description of the Data Collection Activity	Date
Survey (Appendix A) responses	Administration of baseline survey (Appendix A) to the project participants and individual interviews.	February 2018
Qualitative inputs and feedback (workshops minutes)	Survey results presentation and discussion on the meaning of the results and specific concerns and challenges. Initial identification of possible business opportunities.	February and May 2018
Survey (Appendix B) responses and group discussion	Administration of survey (Appendix B) in a project workshop, with discussion of the results to clarify responses.	February 2019
Qualitative inputs and feedback (workshop minutes)	Workshop to validate and refine possible business model designs and their potential.	June 2019

3.3. Data

Consistent with the processual view, we collected different types of data across time. As described in Table 2, we collected the initial data from a survey administered with the project participants. This was then complemented with clarificatory comments and examples to support the survey responses.

The same data collection protocol was followed for the second survey aiming to assess market opportunities. All participants (Table 1) completed the surveys, with a minimum of one respondent from each organization.

In more detail, the first survey (Appendix A), also described as the baseline survey, helped to capture the current perceptions of the participants in relation to five main themes: (1) experience on university-industry collaborations that could help to activate science commercialization activities, (2) perceived barriers for further university-industry collaborations, (3) participants' intention to engage in university-industry collaborations, and (4) participants' interests in engaging in different types of science commercialization. Each of the questions captured different variables that could provide inputs to assess the starting point of the project participants. For specific details see Table 3.

Table 3. Baseline survey (Appendix A) to capture intentions and experience of science commercialization.

(Theme) Questions	Variable Measurement (Reference, if Any)
(1) What type of university-industry collaboration (UIC) activities have you done or been involved in in the past (last 5 years)? (see annex for further details)	Types (listed) of university-industry collaboration [18].
(1) What is your overall satisfaction with your prior experiences on university-industry collaborations?	Very positive–Very negative, using a Likert scale (1–7).
(2) In your opinion, what are the challenges in making university-industry collaborations work? (see annex for further details)	Orientation vs. transaction (listed) barriers [22,39], using a Likert scale (1–7).
(3) Please indicate your level of agreement with the following sentences on intentions, knowledge, perceptions, plans on engaging in UIC. (see annex for further details)	UIC intentions and perceptions [40] using a Likert scale (1–7) adapted from Linan & Chen [41].
(4) How likely is it that you attempt or engage in the following activities (licensing, starting a company, consultancy ...)? (see annex for further details)	Intentions to engage in formal and informal research commercialization [42] using a Likert scale (1–7).

The second main activity in the data collection was the assessment of the potential market opportunities related to the science commercialization project. Therefore, we relied on the work of Gruber and Tal [43] who propose to first understand the potential values (functions) of a technology, in this case fucoidan, to then identify and assess the different possible application opportunities. The generation of the opportunities was done using the inputs of each of the different participants (including the stakeholders), aiming to cover the different activities in the innovation value chain, from the sourcing of raw material, the extraction, the purification, the enzymatic modification, the characterization, and the final application in different possible contexts.

We transformed the items proposed by Gruber and Tal [43] into questions to get a collective assessment of the different items in relation to each market opportunity for the application of the technology (fucoidan in our case). The different items and questions are described in Table 4.

To refine and expand the results of the assessment from Survey Appendix B we conducted a workshop to further discuss and revise the potential business models behind each of the opportunities. This also allowed us to introduce specific aspects related to sustainability or other elements that are unique in biomarine innovation settings. The business model canvas template [32] was used as a tool to guide and structure the discussion with the participants.

Table 4. Questions (Appendix B) used for the assessment of the commercialization opportunities.

Questions	Variable Measurement (Reference)
Is there a compelling reason to buy? (unmet need/effective solution/better than current solutions)—ReasonToBuy	The measured variables are the complete list suggested by Gruber & Tal [43] to assess the market opportunities. For each question a Likert scale (1–5) is used.
How large is the market? (current market size/expected growth)—MarketSize	
Is there economic viability? (margin/customer stickiness)—Viability	
What about implementation obstacles? (produce development or sales and distribution difficulties/funding challenges)—Implementation	
Time to Revenue (development time/from product to market readiness/length of sale cycle)—Time2Revenue	
What about external risks (competitive threats/3rd party dependencies/barriers to adoption)—ExternalRisk	

4. Data Analysis and Results

We structure the results section in two parts: first, we report the main results from the survey activities (Appendixes A and B); then, we describe how the different workshops contributed to move the project discussion closer to the development of commercialization activities with societal and economic impact.

Survey Results

The results of the surveys are presented as empirical evidence of how the variables could be captured and measured, but without statistical significance ambitions. The objective is to provide an illustration of how this could be done at a larger scale.

The first survey (Appendix A) was used to set the baseline of the participants on university-industry collaboration (UIC). It allowed us to capture descriptive aspects such as the prior experience participants had in UIC activities. As it can be seen in Figure 2, the participants had mostly been involved in joint research projects or research contracts with industry. Yet, none of them had directed an academic spinoff or engaged in licensing of their research.

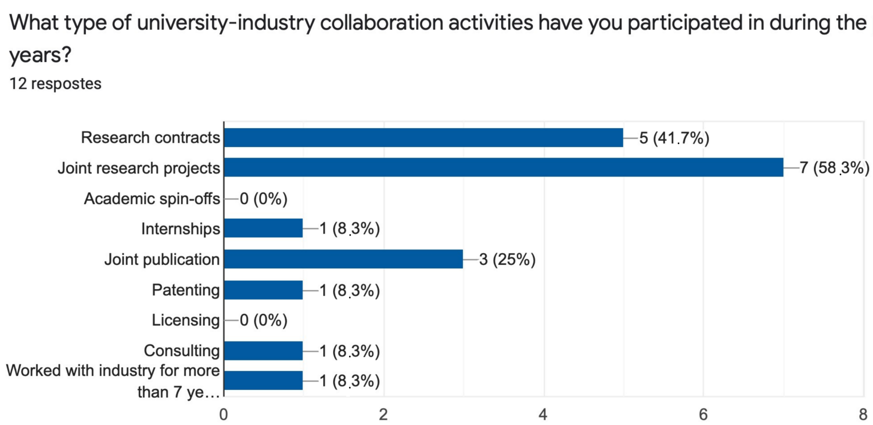

Figure 2. Detail on participants' prior university-industry collaboration (UIC) experience (Appendix A results, n = 12).

The variables measured in this baseline survey covered three main areas. First, participants' prior UIC experience (+/– *UIC experience*) and their perceptions regarding orientation and transaction barriers, as measured in Bruneel et al. [39] using: (1) *orient. research*, capturing the perception that university is too focused in pure research; (2) *orient. diff*, capturing whether the sense of urgency and priorities are too different between university and industry; (3) *orient. underst.*, describing whether the perception is that the problem is a different understanding of expectations and working practices; (4) *orient.oversell*, identifying whether the university has a tendency to oversell or create unrealistic expectations; (5) *trans.IP conf*, measuring whether there is a perception that the problem is intellectual property (IP) as conflict between the involved parties; (6) *trans. rules*, capturing when the perceived problem is related to the different rules and regulations in university and industry; and (7) *trans. intermed*, to identify if the problem is that there is an absence of valid intermediaries for collaboration. The descriptive results of this first group of variables can be seen in Table 5.

Table 5. Results from baseline survey (Appendix A) on UIC experience and intentions.

	Mean	**sd**	**Min**	**Max**
+/− UIC experience	5.5	0.67	4	6
Orient. research	4	1.34	2	6
Orient. diff	4.16	1.33	2	6
Orient. Underst	4.42	1.67	2	7
Orient. oversell	4.25	1.65	2	7
Trans. IP conf	4.41	1.56	2	6
Trans. rules	5.08	0.79	4	6
Trans. intermed	3.83	1.64	1	7
UIC attract	5.92	0.51	5	7
UIC advantage	5.92	0.67	5	7
UIC positive	5.08	1.24	2	6
UIC knowledge	4	1.76	1	6
UIC success	4.58	1.44	2	6
UIC intention	3.75	2.18	1	7
Licensing	3.25	1.36	1	5
Startup	1.75	1.14	1	5
Consulting	2.75	1.29	1	6
prof develop	2.17	0.94	1	4
contract res.	3.58	1.31	2	6
engage UIC	4.42	1.68	2	6
N		12		

Second, the baseline survey covers the participants' perceptions of the UIC behavior measuring aspects such as how attractive (*UIC attract*), advantageous (*UIC advantage*), and positive (*UIC positive*) the behavior is. Additionally, other aspects related to whether participants have knowledge on how to manage this type of collaboration (*UIC knowledge*), their success expectation (*UIC success*), and the intention to engage in them in the short term (*UIC intention*) are included. Interestingly, the results show (see Table 6) that although this behavior is seen as highly attractive and advantageous (both showing 5.92/7), the intention to get actively involved in this behavior is the lowest of the reported answers (3.5/7).

Table 6. Basic descriptive statistics of the variables from the assessment survey (Appendix B).

	Mean	sd	Min	Max
ReasonToBuy	3.9	0.99	1	5
MarketSize	4.05	0.88	2	5
Viability	3.77	0.91	2	5
Implementation	3.49	1.27	1	5
Time2Revenue	3.54	1.28	1	5
ExternalRisk	3.2	1.09	1	5
N		16		

Third, the specific questions on commercialization activities offered a glimpse of how licensing (3.25), contract research (3.58), and research engagements in the contexts of an UIC (4.42) were more likely than other high commitment activities such as commercializing research by creating a startup (1.75) or offering professional training activities to the industry (2.17). See Table 6 for further details.

After the initial baseline survey, a workshop (done in two sessions in February and May 2018) was conducted with the participants to identify possible business opportunities related to science commercialization. While the first session was used to clarify and validate the results of the survey (Appendix A), the second was mainly focused on the different activities of the partners—represented as a value chain (see Figure 3)—and identifying opportunities.

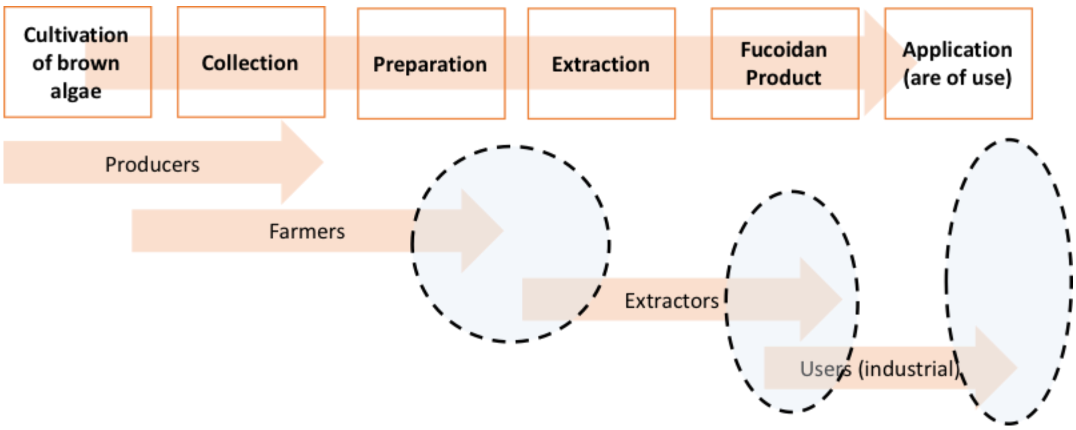

Figure 3. Workshop result—roles and activities in the potential value chain.

The representation of the value chain, interlinking the activities of the project participants from the research centric action to the market focused applications, helped the participants to get a broader view of their contributions to a future innovation value chain [44] and also to identify the key areas (circles in Figure 2) that connect the different actors in the industry. This representation was the result of a workshop where the project participants described their core activities, identified what inputs they needed, what outputs they produced, and where they thought that the overall chain needed to become stronger if we wanted to increase the biomarine product's innovation activity.

In this exploration workshop up to five potential business opportunities were identified for further fucoidan market applications research: (BM1) new sustainable harvesting, (BM2) new purification methods, (BM3) fucoidan for macular degeneration (AMD) treatment, (BM4) fucoidan for tissue/bone regeneration, (BM5) fucoidan for cosmetic application (as skin moisturizer). It is, however, important to highlight that the number of possible opportunities, especially related to application fields, could have been much higher. The current research interests and experience of the participants influenced their selection process [45]. As such, opportunities related to food applications, like food supplements or animal nutrition [9] for example, were not selected. This was done on purpose, as the objective was to further elaborate on business opportunities that the participants could relate to (and activate) in the future.

Thus, the second survey (Appendix B) had the objective to measure the participants' assessment of the different business opportunities. Using a multi-criteria assessment tool (see previously presented Table 4 for details) that relies on six different variables [43], each of the above-mentioned opportunities has been assessed. The variables used are: "*ReasonToBuy*", measuring whether there is a compelling reason to buy the product/service; "*MarketSize*" and "*Viability*", both regarding the economic margin and the possibility to retain customers; "*Implementation*", capturing the perceived product development, funding, or other challenges; "*Time2Revenue*", the expectation on the time necessary to establish the product on the market; "*ExternalRisk*", measuring the perception of potential competitive threats, barriers to adoption, or other external risks. See Table 6 for different variables' descriptive statistics.

The results of the assessment for each potential business opportunity are shown in detail in Figure 4. Again, the data is offered as an example of the results of the application of such measurements, but there are no causal claims or inferences regarding the actual market potential of each of the opportunities. However, the results show that, in general, BM3, fucoidan for macular degeneration (AMD) treatment, shows higher values than other of the assessed opportunities in terms of compelling reason to buy (4.56/5), attractive market size (4.5/5), and potential economic viability (4.06/5). Nevertheless, the participants also stated that the medical application cases (this includes BM4, fucoidan for tissue/bone regeneration) have the highest potential challenges when it comes to implementation, time to first revenues, or being exposed to external risks.

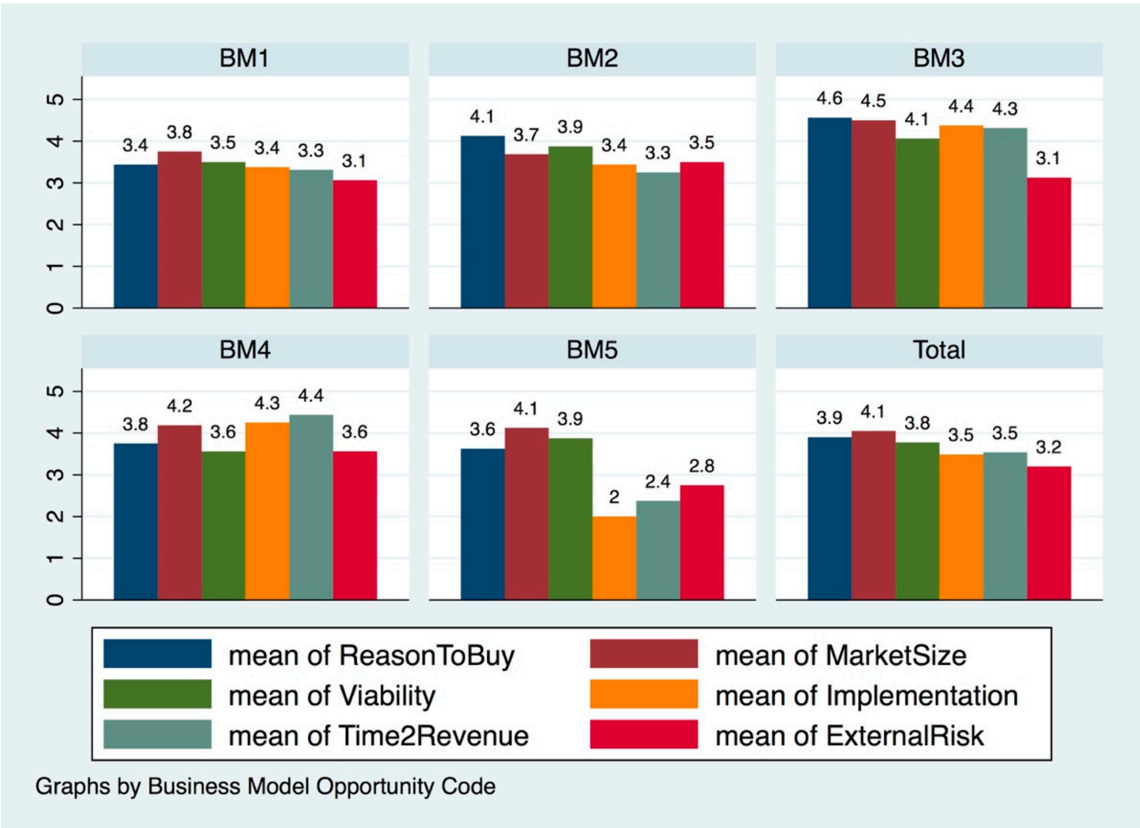

Figure 4. Comparison of the different criteria for each business model.

Following this assessment, we conducted additional workshops (including project stakeholders) to refine and clarify the possible business model behind each of the opportunities. As an illustrative example of the outcomes of applying the business model canvas [32] we show the results for BM2, new purification methods, that shows how the fucoidan extraction activities could open sustainable business opportunities to commercialize ongoing research work (see Figure 5 for an illustrative example).

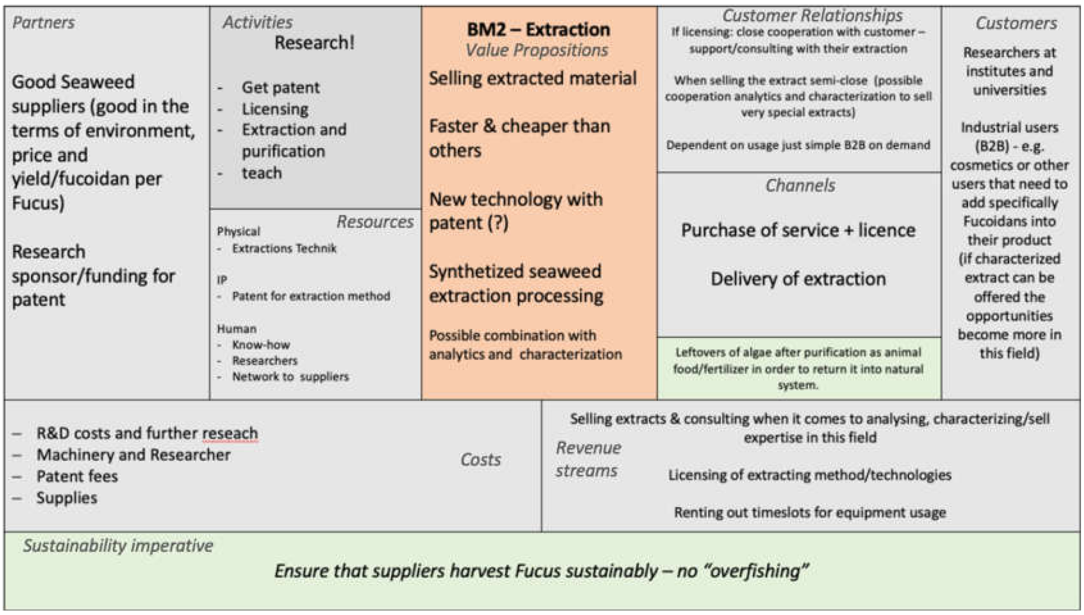

Figure 5. Example of business model representations developed for each opportunity.

The final outcome of the process is the assessment of each business opportunity and the corresponding business model that could be used to activate it. Overall, the results represent the commercialization potential that the project participants identified, as well as the necessary interactions between the different actors involved in elevating research from the lab to the market.

5. Findings and Discussion

The FucoSan project had the ambition to explore opportunities for sustainable commercialization of fucoidan research. By doing so, the project has not only advanced the state-of-the-art research regarding fucoidan research in ophthalmology or other medical applications [46], but also introduced changes in the participating scientists' science commercialization expectations and perceptions. In particular, it has helped to understand whether and how business modelling tools could help to shape science commercialization perceptions among scientists. The results show that a project intervention can help to reveal potential opportunities and could pave the way to further commercialization initiatives.

5.1. Science Commercialization as a Desirable But Not Necessarily Intended Behavior

The results of the initial baseline survey (Appendix A) point to the core of the challenge to trigger more science commercialization activity. Even though researchers know about the positive perception of the behavior, they do not plan to engage in it in the short term. Such results are in line with other research on scientists' behavior. The existing pressure to sustain a scientific career requires a strong focus on advancing scientific research (publications) and securing external funding for their future research projects [47]. As a result, additional activities are seen by the project participants as interesting and attractive but not necessarily feasible. Our results also resonate with the observation that highly successful researchers have fewer difficulties in combining scientific and societal impact [22], yet, to get into the virtuous circle might be quite a challenge. In such situations, the absence of prior experience in university-industry collaborations could be a strong inhibitor to engaging at all with non-university actors [18].

5.2. Sustainability as the Glue to Tie Scientific and Societal Impact

The projects' workshops and additional survey to assess the business models on the identified opportunities offer a unique glimpse into what a first attempt to explore science commercialization looks like. In line with research on how the prior knowledge of participants influences the identification of opportunities [45], our results show how through a process of productive interactions a first mapping of opportunities can be completed.

The opportunities identified by the participants show different combinations of potential impact dimensions, defined as economic, social, environmental, and scientific impact. We can observe that the economic impact dominated in ideas such as *(BM5) fucoidan for cosmetic application* (skin moisturizer) but also that a combination of environmental and economic impact has helped to shape *(BM1) new sustainable harvesting*. (*BM3) fucoidan for macular degeneration (AMD) treatment* or *(BM4) fucoidan for tissue/bone regeneration* aimed at social, scientific, and to some extent economic impact, and finally, (*BM2) new purification methods* captured the scientific and economic impact possibilities.

The sustainability theme that encompasses the whole idea of finding valuable applications from a brown-algae extract does not necessarily translate into only environmental impact opportunities. Instead, the participants expressed how the motivations to start a new project can involve a multiplicity of impact dimensions [48], suggesting that this combination can make opportunities more attractive to outsiders; in our setting, researchers without prior experience in commercialization of research.

5.3. An Attractive Science Commercialization Opportunity Is Not Enough

When taking a broader perspective of the case under study, our results reinforce the perception that novel science commercialization projects require a long-term approach. It has been identified and described that novel technologies take years to reach the market [34]. The path is even harder and longer for scientific breakthroughs that do not have a short-term economic return, even when they have potential societal benefits (e.g., high value added medical products) [49]. The results of the participants' assessment (Appendix B survey) of the different fucoidan business opportunities show how the participants felt that the most compelling opportunities might also be the risker and more difficult ones to implement. This brings us to the importance of broadening the angle to assess the opportunities, instead of making a case-by-case assessment. It is necessary to consider the portfolio of possible options and evaluate the interdependencies across them.

The concept of the innovation value chain helped the participants to relate to the interdependencies between the opportunities. We used it in the workshop discussions, as well as when presenting some of the survey results to the participants. This generated a further understanding of how some business opportunities are dependent on others. For instance, the activation of the highly attractive medical applications (BM3/4) for fucoidan depends on the advances on the extraction and purification methods (BM2). Furthermore, the participants identified that the whole development of a sustainable value chain around fucoidan relies on the possibility of harvesting it (BM1) without affecting the environment, and ideally generating a positive effect on the overall biomarine sustainability. Therefore, the project helped to identify the need to take a broader perspective to identify but also to execute the different business opportunities in the future.

6. Implications

Our research offers a new perspective on the challenges behind science commercialization initiatives. The FucoSan project explores the potential of a biomarine extract (fucoidan), but it also has offered a context to experiment on the identification of potential science commercialization opportunities using business modeling tools. While prior research has suggested that the use of sustainable business models could help to bridge societal and economic tensions [14], our research provides empirical evidence of how such tools can be used to accelerate the identification of business opportunities. Furthermore, we show how these tools can guide scientists and stakeholders in the activation of what has been proposed as productive interactions [17] across interested parties.

Contrary to what is commonly expected, we also identify that scientists have a high interest in engaging in activities that could be conducive to the activation of university-industry collaborations or commercialization of their research. However, our findings suggest that besides the orientation and transactional barriers for this type of collaborations [39], the most challenging obstacles remain in the lack of experience and support. The engagement with non-university actors requires additional efforts and has less clear returns for the scientific career of a researcher [50]. There is a need for specific resources and mechanisms that could accelerate the commercial development of science-based business ideas.

Thus, for policy makers, it is important to highlight that the call to address the global sustainability challenges (be it as part of UN's SDGs or EU's Societal Challenges) is helping to redefine the social vs. economic duality in science commercialization. The increasing visibility and importance given to the societal impact (including the environmental impact) of researchers, does increase the overall interest in exploring options to advance towards such goals. However, such progress requires also an adjustment of the measures and incentives that govern scientific research. Otherwise, we risk pushing researchers to chase goals that are invisible in their professional and institutional assessment [1].

7. Limitations and Next Steps

Our work is not absent of limitations. This project aims to provide a first step towards a more active involvement of researchers in science commercialization. While we have provided examples of survey tools that can be used in this context (Appendices A and B), we lack detailed information about the underlying motives and the nature of the relationships beyond the established borders of industries. Further research with larger groups or with several projects will be able to pinpoint the relationships between individual researchers' characteristics and their science commercialization attitudes and consequent actions.

Furthermore, the scope of the project has limited our ability to follow up on the further activation of the opportunities. Additional research could analyze cases over longer periods and where there are options to observe how the market conditions evolve, and whether the interactions of the scientists result in the creation of academic spinoffs or collaboration agreements with established players in the industry.

This is a project that has a rather specific setting: the exploration of applications for a biomarine extract. It could be argued that there might be differences in the early-stage commercialization of natural origin products, in particular comparing them to the development of other technological products that have required substantial research efforts (see for example the case of nanotechnology [51]). Studies that compare how the nature (natural versus artificial) of the technology has influenced the development of the science commercialization opportunities and the overall ecosystem around it could help to further explore the effects of such differences.

8. Conclusions

The global shift towards sustainable development goals is also permeating the discussions on science commercialization. There is an explicit demand to further accelerate scientific research that could contribute to progress towards the sustainability goals. However, when taking the perspective of the scientists we observe that they are already subject to the tensions of finding a balance between the scientific, economic, and societal impact of their research. The introduction of sustainability demands will increase the complexity of the researchers' decisions, despite the new option to transfer their research results.

Using the context of FucoSan, a cross-border project on a promising biomarine compound, fucoidan, we explore how the introduction of business modelling tools can help to trigger a change in science commercialization. We provide empirical measures and evidence of the challenges that scientists perceive to make the journey from the lab to the market. However, we also identify that there is a high interest in engaging in collaboration with non-university actors.

Our results call for the need for further support in the first steps that scientists take to explore applications of their research. While there is growing interest and openness to such collaborative activities, the scientists' career assessment and incentives need to be redefined to promote and reward the sustained engagement necessary to activate sustainable societal impact.

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Appendix A

Table A1. Survey details (Survey tool used in the study).

Question	Response Type (Response Options)
Name of your organization/department	Open field
What type of organization is it?	Select one (from multiple option field)
SME	
Start-up	
Large Company	
University	
Research Centre	
Institution (local or regional)	
What type of university-industry collaboration activities have you done or been involved in the past (last 5 years)? Research contracts Joint research projects Academic spinoff Industry training (secondment) Joint publication Patenting Licensing	Multiple choice [18,52]
What is your overall satisfaction with your prior experiences on university-industry collaborations?	Very positive–Very negative Likert scale (1–7)
Any comments or thoughts you would like to share from your prior experiences?	Open question
In your opinion, what are the challenges in making university-industry collaborations work?	Likert scale (1–7) [22,39] (For the barriers questions, we use Bruneel et al. comments [39], also using [53] for the wording.)
University research is too orientated towards pure science.	
Differences in the sense of urgency between university and industry researchers.	
Lack of shared understanding about expectations and working practices.	
Tendency to oversell research outcomes or create unrealistic expectations.	
Potential conflicts regarding patents or other intellectual property rights.	
Different rules and regulations in university and industry.	
Absence of valid intermediaries that facilitate the collaboration.	

Table A1. *Cont.*

Question	Response Type (Response Options)
Other	Open question
Please indicate your level of agreement with the following sentences (total disagreement 1, total agreement 7):	Likert scale (1–7) Adapted from Linan & Chen [41]
Developing a university-industry collaboration is an attractive option.	
I see advantages in engaging in university-industry collaborations.	
In my organization there is a positive perception towards university-industry collaborations.	
I know the necessary details to start a university-industry collaboration.	
If I start a university-industry collaboration, I expect a high probability of success.	
In the short term (next months), I have as a goal to activate a university-industry collaboration.	
I am determined to start a university-industry collaboration in the near future (next year).	
How likely is it that you will attempt or engage in the following?	Very unlikely to Very likely. Likert scale (1–7). Assessing commercialization intentions [42]
License technology based on your research in the next 2 years?	Formal commercialization
Start a company based on your research in the next 2 years?	Formal commercialization
Engage in contract consultancy in the next 2 years?	Informal commercialization
Offer continuous professional development (training) in companies in the next 2 years?	Informal commercialization
Engage in contract research in the next 2 years?	Informal commercialization
How likely is it that you will engage in collaborative research in the next 2 years?	Informal commercialization
Others	Open field
Contact name	
Contact email	

Appendix B

Table A2. Survey details (Survey tool used in the study).

Question (For Each Business Model Opportunity)	Response Type (Response Options)
Is there a compelling reason to buy? Unmet need/effective solution/better than current solutions	Very low to Very high. Likert scale (1–5). Scale adapter from Market Opportunity Assessment tool [43].
How large is the market? (current market size/expected growth)	
Is there economic viability (margin/customer stickiness)	
What about implementation obstacles (produce development or sales and distribution difficulties/funding challenges)	
Time to Revenue (development time/from product to market readiness/length of sale cycle)	
What about external risks (competitive threats/3rd party dependencies/barriers to adoption)	

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