Industrial Symbiosis Incentives: Mitigating risks for facilitated implementation

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Abstract

Industrial symbiosis (IS) is considered as a business model of the circular economy. This business model proposes symbiotic exchanges, also known as synergies, between companies, allowing the flow of resources, wastes and utilities. In recent years, the IS initiatives (Eco-industrial parks, Urban Industrial Symbiosis and symbiotic exchanges) have been exponentially growing around the world. This increase is related to raising environmental awareness and the opportunities to obtain economic, environmental and social benefits through the implementation of this model. Despite the exponential growth of IS initiatives, the companies are still facing problems in the achievement of reliable and permanent synergies, especially those without antecedents and IS background. Over the years the literature has identified several factors in the IS emerging process. Incentives are among these factors, being defined as unlocking tools or mechanisms related to diverse areas such as: economic, political, social, intermediaries, process, technology, etc. Authors believe that the large-scale implementation of IS incentives has not been properly addressed. In order to promote facilitated IS implementation and achieve a replicator effect, incentives should be fully addressed. In many case studies, it has been observed that the incentives for IS can be threatened by risks, compromising the implementation and hindering the emerging process. The aim of this paper is to contribute to unlock the emerging IS process, based on incentives identification, implementation risk identification and proposal of mitigation actions. With this purpose, this study developed an incentive identification framework based on the best practices of IS; a risk assessment model, based on internal and external risk factors and finally, a set of mitigation actions directed to the stakeholders. The main result of this study is a risk assessment model for IS implementation. The proposed methodology in this study, can be a useful tool for companies aiming to start symbiotic exchanges. This model might allow companies to have a facilitated implementation, allowing companies to prevent waste of resources in the emerging IS implementation process.

Keywords: circular economy, industrial symbiosis, incentive, assessment model, risk mitigation.

1. Typifying Industrial Symbiosis and its emerging process

Industrial Symbiosis (IS) is a concept of industrial ecology introduced in the early 70s (Short et al., 2014). Making reference to an environmental metaphor, in practical terms, this concept aims to create an ecosystem represented by a group of industrial actors sharing waste, resources and utilities (Chertow, 2000). The principle behind IS is quite simple, instead of being thrown away or destroyed, surplus resources generated by an industrial process are captured and redirected for use as a 'new' input into another process by other industries providing a mutual benefit or symbiosis (Lombardi et al., 2012). The firms involved through theses synergies can obtain economic benefits by sharing resources, wastes, information, knowledge, expertise, political support, supplying networks and distribution markets (Taddeo et al., 2012). In most cases, these benefits translate into reduction in the operational costs (Albino et al., 2016), reduction of greenhouse gas emissions (Johnsen et al., 2015), increases in knowledge and skills, jobs creation (Sun et al., 2016), tax benefits (Fraccascia et al., 2017) and economic profit. In the last 20 years, IS has been incorporated with greater importance in the industrial context due to the increasing concern about climate change (Boons et al., 2017), especially in the European Union (Domenech et al., 2019) , United States (Neves, et al., 2019) and China (Yu et al., 2015). As a consequence, the European Commission (European Commission, 2018b) and other countries have promoted legal frameworks, programs and plans that support the facilitated implementation of circular economy and its business models (Mirata, 2016).

Several authors have identified and characterized the IS emerging process (Mirata, 2004; Islam et al., 2016; Neves, et al., 2019), having a strong focus on understanding the early stage and promotion of IS synergies. These studies have also recognized the key factors that appear in this process. Over the years, literature categorizes these key factors in different groups: enablers, drivers, challenges, barriers, etc. Regardless of which classification and denomination literature suggests, these factors can intervene in three perspectives: factors that promote and facilitate the development of IS supporting or unlocking (enablers, drivers) (Golev et al., 2014; Islam et al., 2016); factors that hinder or constrain the implementation of this practice (barriers, challenges) (Golev et al., 2014) and factors that ignite the implementation (triggers) (Vladimirova et al., 2018). From these factors, one of the extensively studied in recent years has been the enablers (Corder et al., 2014; Islam et al., 2016). It was observed in literature that most of the studies do not discern between incentives and enablers. As a consequence, enablers and incentives are constantly confused, several times those concepts are put in the same category. Nevertheless, the authors consider that the incentives for IS are in a different category due to the different scope and context.

Enablers are factors that support the emerging process of industrial symbiosis. Incentives on the other hand, are instruments or mechanisms supporting the consolidation of the enablers (Henriques et al., 2019). These incentives must have a principle of replicability, meaning that they can be applied under different conditions and different national realities. For example, existence of regulations and policies that allow symbolic exchanges has been identified in various studies as a fundamental enabler for the promotion of IS (Islam et al., 2016; Leong et al., 2017; Neves, et al., 2019). This policy is typically supported by instruments, such as, landfill taxes (Mirata, 2004), environmental taxes (Bruvoll et al., 2009; Johnsen et al., 2015) and industrial symbiosis plans (Mirata, 2016). All these instruments are incentives for IS.

The purpose of this paper is to advance the understanding of IS emerging process through the comprehensive identification and characterization of IS incentives. For this reason, we consider that it is necessary to analyse the incentives and correlate with their implementation risks. The final contribution of this study is the promotion of mitigation actions that encourage the reduction of these risks. These actions will contribute to the promotion of synergies in a more efficient manner.

This study has an empirical approach that is supported by implementation cases experiences, stakeholder consultations and external observation. The research was developed and structured in order to answer the following questions:

- What are the main incentives for IS implementation on a large scale?
- What are the risks related with the incentives and what is the nature of the risk factor?
- What are the actions that could be promoted in order to mitigate the risk associated to the incentives?

This research arises in the sequence of an extensive study developed in the context of the project SCALER (*SCALER-Scaling for Industrial Symbiosis and Efficiency Resource Project*, 2017), which envisages the promotion of industrial symbiosis practices in the European process industry.

2. Research methodology definition

The first step in this study was to define a methodology research that would allow the achievement of the proposed objectives. In this sense, Figure 1 represents the proposed methodology research model. This research methodology consists in two main phases; the first phase dedicated to the incentive identification by literature review and expert consultation. The second phase is dedicated to the incentive analysis in a detailed perspective by the development of a risk assessment model for risks evaluation, finally resulting in a full set of proposed mitigation actions.

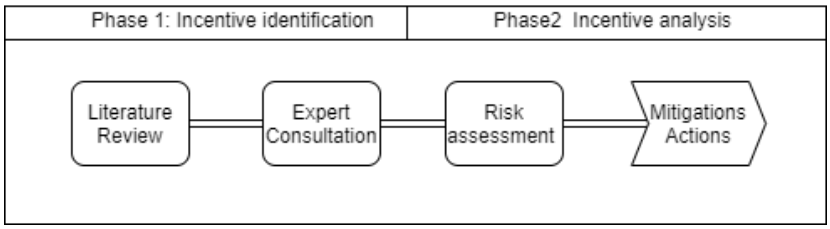

Figure 1. *Research Methodology*

Phase 1: Incentive identification

The IS incentives identification was conducted initially through a literature review and expert consultation. The main objective of this review was to identify IS implementation cases and their associated incentives. The identification was developed through searches in the Web of Science and Scopus search engines selecting scientific peer reviewed journal papers. Nevertheless, other publications were also considered, such as technical reports of EU countries, official documents of the EU, statistics, case studies and the best practices for industrial symbiosis (Vladimirova et al., 2018). A complementary method used for incentives identification was expert consultation through dedicated enquiry. The aim of this enquiry was to obtain the opinion of the experts in industrial symbiosis about their perspective on the role of incentives and their critical areas. The combination of the main findings from literature review and the expert enquiry, result in a final incentive identification.

Phase 2: Incentive analysis

Once the incentives were clearly identified, it was necessary to assess their associated risks. This assessment was promoted by a risk assessment model. This assessment is based on the basic principles of risk management, consisting of 3 main steps risk identification, risk analysis/ evaluation , and risk treatment (*ISO 31000 - Risk management*, 2009). Figure 2 represents the risk assessment model proposed for the purposes of this study.

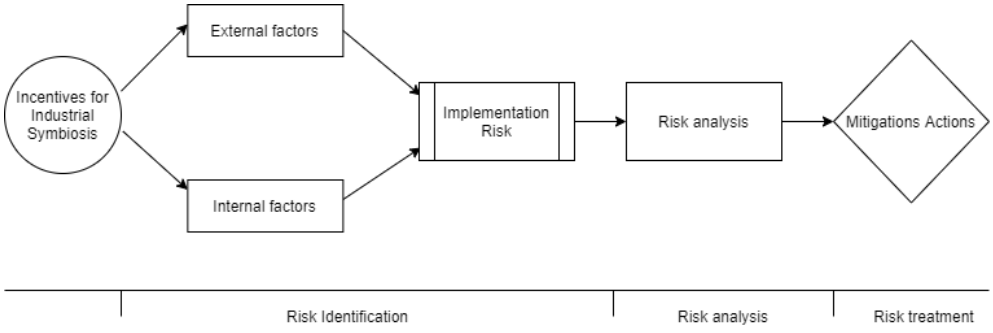

Figure 2. *Risk assessment model steps used*

The risk assessment model is structured in three sequential steps: (a) the first step called risk identification allows the identification of implementation risks through the analysis of external and internal factors by documentation review techniques (*IEC/ISO 31010 - Risk assessment techniques*, 2009); (b) the second step is the analysis of the implementation risks. This procedure allows to evaluate the factors associated, in order to propose measures for the risk treatment and (c) the third step defines mitigation actions associated to risk treatment.

It should be noted that the study is mostly based on an empirical approach, and supported by implementation cases experiences, stakeholder consultations and external observation. The approach used to regard the mitigation actions was developed in the generic perspective of avoiding and reduce the implementation risks. Mitigation actions implementation are highly dependent on case study specificities and slight adaptations based on empirical practices are advised.

3. Assessing implementation risks: New model proposal for IS incentives

Identifying incentives for IS

Regarding incentive identification, they were grouped by areas recognized as critical in the literature review. These areas are: financial, policy related, social, information related, process and technology. Through the expert inquiry (Vladimirova et al., 2018), the relevance of these areas was also validated by results crosscheck In general terms, the enquiry results considered that the critical aspects for developing and implementing IS are: economic aspects (economical gains, financing); ability of willing partner (social factors); and unblocking policies. We can conclude that in the incentive identification framework, there is great presence of political, financial and social incentives. Table 1 presents the final incentive identification framework, bringing together the identified areas and incentives.

Table 1. *Incentive identification framework*

Area	**Incentive**
Financial	• Co-funding investment Programs • Common Waste Market • Integrated method to calculated the overall benefits • Premium Tariff Energy • Biofuels Tariff
Policy-related	• Disaggregated industrial waste policy framework • Landfill Tax • Environmental and Energy Taxes • Improving the Energy Efficiency and Resource Efficiency • Green criteria as key element for public procurement
Social	• Training programs (Build awareness) • Collaborative networks • Sectorial clustering • Social Corporate Responsibility programs (SCR)
Information-related	• Knowledge and training (Institutional) • Networking initiatives • Dissemination initiatives (community)
Technology	• Transition to Industry 4.0 Programs • Databases and ICT tools
Process	Promotion of formal agreements and protocols

Regarding financial incentives, special tariffs rewarding companies that pursue the incorporation of renewable energies have proven to be important incentives in Nordic countries (Johnsen et al., 2015). The financing programs are also essential for IS on large scale implementation, especially programs supporting the purchase of infrastructure, utilities and services (Costa et al., 2010), helping to overcome barriers such as financial limitations of the companies to develop the initiatives by themselves. Other valuable instrument is the waste market or waste fund that works as a trigger for the purchase and sale of waste (Costa et al., 2010).

Regarding policy related domain, the most effective and predominant instrument has been the waste policy framework. Specifically disaggregated industrial waste policy (National, regional and local) that allows the synergies implementation between industries, through the simplification of industrial waste declassification procedure. Other important tools/instruments are taxes in several areas such as landfills, greenhouse gas emissions, footprint, etc. Regarding taxes, they can be separated in two main approaches; those that penalize environmental pollution or excessive and inefficient use of resources, such as

Norwegian CO_2 tax (Bruvoll et al., 2009) and those taxes that promote the use of alternative methods with less environmental impact. The Finish reduced taxation is one of the most influential cases in this approach (Johnsen et al., 2015). There are also other political incentives that have great relevance, which are the strategies for green growth, such as the Green Public Procurement (European Commission, 2016), resource/ energy efficiency programs (Adamides et al., 2009) and circular economy plans (European Commission, 2018a). These instruments gradually change consumption habits and mindset within the industrial sector.

Social and information-related incentives had also an important presence/role in results identified, mainly by those instruments and programs that support the creation of awareness at the community and institutional level. Some of the most popular instruments are collaborative networks (Raabe et al., 2017), clusters (Taddeo et al., 2012), training initiatives (Massard et al., 2013), dissemination programs, green marketing and action plans (Mirata, 2004). These instruments help to overcome barriers such as lack of trust and social inertia through the creation of awareness.

Regarding the technological incentives, they complement the other areas previously mentioned as they play a fundamental role in the implementation of IS on large scale initiatives. The programs for the transition to I4.0 allows the automation of the industry and consequently the control and monitoring of the production processes in an optimized way. Tools such as cyber-physical systems, cloud manufacturing and Internet of Things (IoT) are essential in this process (Kang et al., 2016). The shared databases and ICT tools are also important since the integration of datasets and geolocation data is crucial for matchmaking and mimicking methodologies (Holgado et al., 2018). Regarding process incentives, the promotion of protocols and formal agreements helps define terms of negotiation and execution times, facilitating the implementation process (Costa et al., 2010).

Assessing incentive implementation risks

In a risk management process, it is important to consider the context of the risks and their associated factors, where those can be internal (social, cultural, legal, regulatory, etc.) and external (strategy, capacities, norms, relationships, etc.). The purpose of any risk analysis is to understand the nature of the risk and its characteristics. The focus of the present risk assessment model was to analyse the internal and external risk factors from the companies' perspective. In this sense, the first part of the risk assessment model was dedicated to the risk identification, followed by their associated risk factors (internal/external) and finally by their associated implementation risks. Table 2 presents the risk factors and implementation risks.

Table 2. *Risk factors and implementation risks*

Incentive	Risk factors		Implementation risks
	Internal	**External**	
Co-funding investment Programs	• Dependence on state funds for the implementation of IS initiatives • Lack of receptivity • Lack of knowledge regarding available funding programs and lack of technical competences to prepare /submit proposals	• Lack of national funds to promote and maintain platforms that promote business links • High level of bureaucratic processes of co-financing programs and lack of standardized environmental regulation to support their implementation • Low receptivity of large companies	Low adherence rate to financing programs Loss of funding and programs
Common Waste Market	• Low waste quality in the residues, lack of controls and standards to guarantee the quality of the materials • Resistance of companies to initiatives/ projects that necessarily change their operations • Lack of knowledge of possible uses of available waste • Insufficient knowledge of technological capability and data management by companies	• Waste price instability, compared to the virgin raw materials market • Vulnerability at the Supply Chain level regarding Waste / by-products, • Partner location and logistics. Long distances and lack of transport might compromise the viability of synergies • Lack of funding to promote and maintain this initiative • Different national realities regarding waste management, classification and recovery	Low adherence rate to waste transaction initiatives Loss, discontinuation or cancellation of Waste Market initiatives

Integrated method to calculated benefits	• Insufficient knowledge and technological capacity • Lack of interest and awareness in the principles of industrial sustainability • Lack of data management by companies	• Different national realities regarding waste management, classification and recovery • Lack of regulation at a national or European level that forces the companies to participate in the implementation of a shared waste database	Low application/use by the end-users (industrial actors)
Premium Tariff Energy	• Inability to manage the responsibilities associate to adaptation process in order join this tariff • Dependence on state funds to cover the initial investment • Technological unviability	• Lack of national funding to promote and maintain this initiative • Low development level of regulation and policies that promote this tariff • High level of bureaucratic processes to acquire this tariff • Lack of standardized environmental regulation to support the tariff implementation	Low adherence rate of the end-users to the tariff (industrial actors)
Bio fuels Tariff	• Inability to manage the responsibilities associate to adaptation process in order join this tariff • Dependence on state funds to cover the initial investment • Technological unviability	• Lack of national funding to promote and maintain this initiative • Low development level of regulation and policies that promote this tariff • High level of bureaucratic processes to acquire this tariff • Lack of standardized environmental regulation to support the tariff implementation	Low adherence rate of the end-users to the tariff (industrial actors)
Landfill Tax	• Business scepticism about new environmental challenges and social barriers (resistance to change) • Lack of interest due to the low prices of land fill gates (In some countries)	• Low development level of regulation and policies that promote this tariff • High level of bureaucratic to effectively implement the land fill taxes • Lack of standardized environmental regulation to support the tax implementation	Alteration of landfill taxes for a less favourable approach for the IS promotion
Desegregated industrial waste policy framework	• Problems in adapting to new policies approach • Alteration of operations in order to achieve the new targets • Lack of initial investment to adapt the industrial process	• Long distances and lack of transport might compromise the viability of synergies • Lack of suitable partners for the synergies implementation • Limited diversity of waste /by-product streams due to the high homogeneity of surroundings companies • The bureaucratic complexity associated with transition and adaptation to new policies	Stagnation of policies that do not allow or hinder the development of IS initiatives
Environmental and Energy Taxes	• Business scepticism about new environmental challenges and social barriers (resistance to change) • Lack of initial investment to improve the industrial process	• Lack of funding to promote and maintain this initiative • Low development level of regulation and policies that promote energy and resource efficiency • Low development level of regulation and policies that promote these taxes	Alteration of energy/environmental taxes for a less favourable approach for the IS promotion
Green criteria as key element for public procurement	• Business scepticism about new environmental challenges and social barriers (resistance to change) • The resistance of companies to initiatives/ projects that necessarily change the method they operate at different levels (Social inertia)	• Lack of regulation at national or European level that stimulates the companies to participate in this kind of initiative • Problems in the purchasing process due to insufficient or unstable product offer	Low adherence rate by the companies that will continue consuming the same products
Improving the Energy Efficiency and Resource Efficiency through policy	• Lack of technical competences to prepare /submit proposals • Financial limitations for initial investment • Lack of motivation to apply / participate in these initiatives	• Lack of regulation at national or European level that stimulates the companies to participate in this kind of initiative • Lack of funding to promote and maintain the programs promoted for this policy • The bureaucratic complexity	Low adherence rate of the industrial actors in these initiatives Loss of funding and programs for energy and resource efficiency
Training programs (Build awareness)	• Lack of receptivity, trust and motivation among employees due to resistance to change • Business scepticism about new environmental challenges and social barriers (resistance to change)	• Lack of funding to promote and maintain the training programs • Reduced government presence as a driving agent	Low attendance and participation by the community and business actors
Collaborative networks	• Business scepticism about new environmental challenges and social barriers (resistance to change) • Lack of motivation and collaborative approach to join the network	• Lack of funding to promote and maintain this initiative • Reduced government presence as a driving agent	Low attendance and participation by the community and business actors

Sectorial clustering	• Mistrust due the fact that clusters normally are dominated by a few firms • Lack of receptivity due to resistance to change (complex cross-sector relationships)	• Lack of funding to promote and maintain this initiative • Reduced government presence as a driving agent	Low attendance and participation by the community and business actors
SCR programs	• Lack of funds to develop an SCR plan • Lack of trust and social inertia at various levels of the institution	• Lack of community interest • Lack of intermediaries to support this type of programs	Low implementation of SCR plans by companies
Networking initiatives	• Business scepticism about new environmental challenges and social barriers (resistance to change) • Reduced "circular" company culture can affect the implementation of IS practices • Lack of receptivity, trust and motivation among employees due to resistance to change	• Lack of cooperation between the scientific community and companies • Lack of receptivity of knowledge agents and business actors	Low attendance and participation by the business actors, scientific community
Knowledge and training	• Reduced "circular" company culture can affect the implementation of IS practices • Lack of receptivity, trust and motivation among employees (Social inertia)	• Lack of knowledge agents and entities trained to support and accompany this initiative	Low implementation of knowledge and training initiatives in the companies
Dissemination initiatives	• Lack of receptivity, trust and motivation among employees • Reduced "circular" company culture can affect the implementation of IS practices • Lack of employees with skills and knowledge to develop these initiatives	• Lack of community and business actors' interest • Lack of financing to disseminate IS appropriately	Low attendance and participation by the business actors, scientific community
Transition to Industry 4.0 programs	• Inability of the company to face new technological challenges • Insufficient knowledge of technology capability and data management by companies • Inability to manage responsibilities associated to this initiative • Confidentiality issues	• Lack of financing that generates dependence on state funds, such as, programs and projects • Low industry receptiveness or inability to make the necessary technology investments • Dependence on government participation as the main driver	Low attendance and participation by the companies Loss, discontinuation or cancellation of I4.0 programs
Share data bases and tools	• Lack of confidence in the availability of data, confidentiality issues • Inability of the company to face new technological challenges • Lack of knowledge and equipment for data collection and treatment	• Lack of financing to promote this initiative • Lack of trust from companies to share their data	Low adherence rate of the end-users to the databases (industrial actors)
Promotion of protocols and formal agreement	• Lack of personnel to take the responsibilities that the development of this type of documents implements • Lack of knowledge to develop protocols	• Mistrust in accepting commitments that could have legal consequences • Conflicts of interest due to the competitive nature of the industrial sectors	Low implementation of formal agreements and protocols in the emerging phase of synergies

It is important to highlight that most of the risks identified were caused by means of economic, social, political and institutional capacity risk factors. The social risk factors were those that had the greatest presence in our analysis. We consider that these can be divided into two perspectives; institutional (companies, industry, etc.) and community (business agents, community government entities, etc.). On the company side the lack of confidence in ecological concepts, trust environment and uncertainties in the return on investment (Taddeo, 2016), lack of motivation at various levels, self-interest nature of the industries (Tan et al., 2015), confidentiality issues (Kosmol et al., 2020) and the business as usual mind-set have turned out to be the most predominant. In terms of the community, factors such as lack of intermediaries, lack of industrial symbiosis expertise, low awareness about the opportunities provided (Johnsen et al., 2015), lack of environmental awareness, non-existent or low presence of the government as a driver were the most prominent. These risk factors mainly translate into low attendance in the initiatives.

Economically, most of the risk factors are related to the financial inability of companies to acquire the infrastructure, utilities and services that are required to implement some of the incentives (Costa et al., 2010). This incapacity generates dependence on state funds that are provided through plans, projects and credits. These financing instruments often do not have a continuity nature, which generates uncertainty in their refinancing and puts the continuity of the initiatives at risk (Vladimirova et al., 2018).

In policy terms most of the identified factors are related to the absence or ambiguity of regulations and the existing legislation regarding industrial waste management (Costa et al., 2010; Allard et al., 2012). It should be emphasized that in some cases, even if there is an industrial waste policy framework, they do not often effectively support the creation of synergies. Another important political factor were the uncertainties that exist regarding the direction and approach that new national policies will take, which stipulate new requirements, needs and regulations (Vladimirova et al., 2018).

Mitigating implementation risks for facilitated implementation

The last step of the presented risk assessment envisages the formulation of mitigation actions that minimize the risk associated to the implementation of incentives (Henriques et al., 2019). The aim of this set of actions is to reduce the frequency, magnitude, and severity of the risk impact. The mitigation actions are completely based on the main findings of the risk analysis. Since most of the risk factors identified in the previous step were economic, social, political and institutional capacity, a structure of actions was promoted that responds directly to these risks and the actions that must be taken by the diverse stakeholders involved. We considered stakeholders as: national entities (ministries, agencies, authorities, etc.); regional / local government (Chambers, regional agencies, business councils, associations, etc.); intermediaries (clusters, consultancies, etc.); knowledge agents (R&D organizations, universities, etc.); businesses (companies, industries, etc.). In this sense, the following set of mitigation actions are proposed regarding the different stakeholders in order to avoid and reduce risks on incentives implementation.

Table 3. *Set of mitigation actions*

Stakeholder	Mitigation actions
National Entities	• Promote new policies and legal frameworks that support the transition to a more sustainable industry, aligned with a clear European legislation (standardized) • Reinforce the participation in IS initiatives and programs, the role of the state cannot limit itself as a funding entity but should also be incorporated as a promoter • Reinforce the allocation of sufficient national funds for IS incentives, which must necessarily have a character of continuity to overcome the barriers associated with uncertainty • Promote and prioritize supranational initiatives that are aligned with the collective efforts to tackle the climate change (e.g. European Green Deal) (European Commission, 2019)
Regional/ local government	• Reinforce the commitment in dissemination of IS and its benefits, greater participation and involvement in the promotion of the Circular Economy and its business models, through conferences, workshops, action groups, or regional communication plans • Increase engagement through actively participating in IS programs, clusters, initiatives in progress. It is fundamental that the industrial sector feels their support of the local/regional authorities • Increase the community awareness in environmental problems and sustainable development through the knowledge transfer • Prioritize industrial symbiosis strategies within the scope of Research and Innovation Strategies for Smart Specialization,
Intermediaries	• Reinforce the dissemination of good practices, anchors companies' experiences, circular economy and other topics that help creating awareness in the industrial sector • Reinforce the negotiation process through the creation and development of protocols, agreement of timing (with stakeholders), formal partnership, etc. • Development and promotion of mechanisms (methodologies, tools, etc.) that allow to measure which benefits involves the incorporation of symbiotic synergy

Knowledge Agents	• Reinforce the participation in clustering and networking initiatives, this will help to overcome the social barriers related to the different approaches of the two sectors (Industries actors and scientific community) • Encourage a close relationship with the industry, developing applied research linked with real industry needs and practical problems
Businesses	• Boosting the training & dissemination initiatives in topics such as the circular economy, their business models, green thinking and green growth. These actions have the main objective of overcoming social barriers • Reinforce the technological investment areas, such as purchase of utilities, IT skills improvement and training among employees • Boosting the participation in initiatives such as clustering/ networking and really engage with partners and initiatives • Build trust environment in the initiatives, promoting open mindedness to receive anchor companies, knowledge agencies, local authorities' representatives and other intermediaries • Reinforce the transfer of knowledge will be fundamental to mitigate the risk associated with the loss of key players and high turnover culture • Reinforce the participation in associations and industrial clusters, due its supportive role in the IS emerging process

4. Conclusions

In recent years, the exponential growth of IS initiatives around the world has generated the need to deeply understand the IS emerging process and its different factors. The current study has analysed the incentives that contribute to the industrial symbiosis implementation. This paper has systematically reviewed the incentives for IS, its implementations risks, and promoted mitigations actions. In order to achieve the initial objectives this article promoted an incentive assessment for industrial symbiosis, with a special focus on understanding how implementation risks can be mitigated.

In general terms, companies are encouraged to develop synergies mainly for economic reasons. Whether for direct gains, such as reduced operating costs or revenues from the incorporation of new business models, or on the other hand, indirect gains such as government funds, credits, projects, etc. Concerning implementation risks, it was possible to verify that most of the implementation risks that were revealed through this study are related to economic, social, political and institutional capacity risk factors. The source of these risk factors is varied but they are mainly due to barriers such as economic inability, lack of trust environment, uncertainties, lack of interest/motivation, etc. In order to promote measures to mitigate these risks, the mitigation actions from the perspective of various stakeholders were derived. In general terms, the actions are directed for business practice, policy transition, awareness-raising and engagement reinforcement.

Without disregarding the results obtained in this study, we consider that this study had some limitations due to its nature. The risk assessment model was based on methods such as observation, literature review and expert consultation. The mitigation actions were proposed in order to avoid the impacts of risks, nevertheless, a real case validation will strengthen the present mitigation actions. For future studies the proposed methodology should be supported by real case implementation scenarios, which will help validating the full methodology and preliminary results.

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