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BUSINESS MODELS FOR INDUSTRIAL SYMBIOSIS: A GUIDE FOR FIRMS*

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Abstract

Industrial symbiosis (IS) is a collaborative approach concerning physical exchange of materials, energy, and services among different firms: accordingly, wastes produced by a given firm are exploited as inputs by other firms. This approach is able to generate economic and environmental benefits at the same time, the former for the involved firms and the latter for the collectivity as a whole. For these reasons, the implementation of IS is largely recommended. However, despite its huge potentialities, the IS approach seems to be actually underdeveloped and not fully exploited. Firms without any prior experience of IS exchanges suffer from lack of awareness about how to integrate the IS practice into their current business models and how to gain economic benefits from IS. Since the willingness to obtain economic benefits is the main driver pushing firms to implement the IS practice, this issue constitutes an important barrier to the development of new IS relationships.

In this paper, we contribute to this issue by identifying the different business models that each firm can adopt to implement the IS approach. In particular, we identify several business models for both firms producing waste and firms requiring waste. For each model, we highlight how firms can create and get economic value from IS. Moreover, from the interaction among firms, each of them implementing its own business model, several business scenarios at inter-firm level can arise. These scenarios are also presented: for each of them, strengths and weaknesses are identified and a short case study is discussed. The identified models can be useful at the company level since they provide indications about how to integrate the IS approach within their current business model.

Keywords: circular economy, industrial symbiosis, sustainable business models, value creation

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1. Introduction

Industrial symbiosis (IS) is a collaborative approach concerning physical exchange of materials, energy, and services among different firms: accordingly, wastes produced by a given firm are exploited as inputs by other firms (Chertow, 2000).

The IS approach allows to achieve environmental, economic, and social advantages (Mirata, 2004; OEDC, 2012). The environmental benefit is the result of the potential reduction in wastes, emissions, primary inputs, and energy (Chertow, 2000). The economic convenience comes from the savings due to lower costs for both wastes disposal and primary inputs purchase (Albino et al., 2016). Finally, from the social benefits point of view, the IS approach may foster the creation of new firms and new jobs (Mirata, 2004). Moreover, the European Commission (2011) explicitly recommended the adoption of the IS approach to boost production efficiency and resource productivity. As a result, policymakers of many countries have introduced the IS practice in their environmental agenda (Costa et al., 2010; OECD, 2012; Van Berkel et al., 2009).

Waste exchanges among firms can either be designed by adopting a top-down approach or, conversely, emerge from the bottom, as the result of spontaneous self-organized process undertaken by firms (Chertow, 2007). Empirical cases demonstrated that both these models can be successful (e.g., Jacobsen, 2006; Mirata, 2004). In fact, for both these approaches, firms are interested to collaborate exchanging wastes each other because driven by the willingness to obtain economic benefits (Lyons, 2007).

However, despite its huge potentialities, the IS approach seems to be actually underdeveloped and not fully exploited. In particular, several technical, economical, and organizational barriers to the creation of new IS relationships arise, discouraging firms to collaborate each other (Fichtner et al., 2005; Tudor et al., 2007). In such a context, firms with prior successful IS experiences tend to develop new symbiotic relationships more easily, as they profit from their earlier successes (Paquin et al., 2015). Alternatively, firms without any prior experience of IS exchanges suffer from lack of awareness about how to integrate the IS practice into their current business models and how to gain economic benefits from IS. This is recognized as one of the main factors hampering the development of the IS practice (Fichtner et al., 2005; Radtke, 2011; Sakr et al., 2011).

Many case studies have been analyzed by the literature with the aim to disseminate successful experiences of IS, which may be guide for firms interested to adopt the IS approach. However, since these experiences may be highly case-specific, not all findings can be generalizable. Alternatively, in order to foster companies to adopt the IS approach, general models are needed, describing the different strategies through which firms can create value and obtain economic benefits by IS.

In this paper, we contribute to fill the gap by identifying the different business models that each firm can adopt to implement the IS approach. In particular, we recognize several business models for both firms producing wastes and firms using wastes as inputs. For each model, we identify how the firm can create and get economic value from IS. Moreover, we found that from the interaction among firms – each of them implementing its own business model – several business scenarios at inter-firm level can arise. These scenarios are also presented; for each of them, strengths and weaknesses related to its implementation from strategic and organizational point of view are highlighted and a short case study is discussed.

The paper is organized as follow: Section 2 introduces the concept of business model. Business models supporting the IS practice at the firm level are presented in Section 3. Section 4 presents the business scenarios at the inter-firm level. Finally, discussion and conclusions are provided in Section 5 and Section 6, respectively.

2. Business models and Industrial Symbiosis

2.1. Business model: definitions and main elements

The business model is a conceptual tool providing an abstraction of how a firm do business (Eriksson and Penker, 2000; Magretta, 2002). It reflects the firm realized strategy, highlighting the combination of production factors needed to implement such a strategy and the functions of all the involved actors (Casadesus-Masanell and Ricart, 2010; Wirtz, 2010). The business model serves as a strategic tool for designing business activities as well as for a comprehensive, cross-company description and analysis.

Many formal definitions of business models have been provided by the literature (e.g., Zott et al., 2011). Though a comprehensive review of these definitions, Richardson (2008) proposed a consolidated view of which main elements should compose business models:

- *Value proposition*. What the firm will deliver to its customers, why they will be willing to pay for it, and the firm's basic approach to competitive advantage;
- *Value creation and delivery*. How the firm will create and deliver that value to its customers and the source of its competitive advantage;
- *Value capture*. How the firm will generate revenues and profits.

2.2. Sustainable business models

One of the key challenges to tackle the pressure of a sustainable future is designing business models able to ensure that firms capture economic value for themselves through delivering social and environmental benefits (Schaltegger et al., 2012). In this regard, sustainable business models are models that “*create competitive advantage through superior customer value and contributes to a sustainable development of the company and society*” (Lüdeke-Freund, 2010). In particular, the value proposition of a sustainable business model must include positive effects for society and environment in addition to the economic value for the firm. Firms can create such a proposed value by implementing technological, organizational, and management innovations (Boons and Lüdeke-Freund, 2013).

With the aim to support the development and the implementation of sustainable business models, Bocken et al. (2014) identified eight archetypes for these models, i.e., groupies of mechanisms and solutions that may contribute to building up the business models for sustainability. The archetypes are: i) maximize material and energy efficiency; ii) create value from ‘waste’; iii) substitute with renewables and natural processes; iv) deliver functionality rather than ownership; v) adopt a stewardship role; vi) encourage sufficiency; vii) re-purpose the business for society/environment; and viii) develop scale-up solutions.

2.3. IS as sustainable business model

Business models implementing the IS practice have been recognized as sustainable business models, classified under the archetype “create value from waste” (Bocken et al., 2014). In general, the value proposition by such an archetype is turning existing waste streams into useful and valuable inputs to other products. Moreover, the IS approach can also be related to the archetype “maximize material and energy efficiency”. In fact, by using waste α from production process A to replace input β in production process B, the amount of waste α landfilled per unit of output generated by process A is reduced; similarly, the amount of input β used to produce the same amount of output by process B is reduced. Accordingly, by adopting the IS approach, technical efficiency of both production processes and the industrial system as a whole is increased (Fraccascia et al., 2017).

The sustainability of business models oriented to the IS approach stems from the economic value created for firms simultaneously with the environmental benefits generated for the collectivity as a whole. In particular, the economic benefits are in form of lower production costs or higher revenues. As a result, the competitiveness of the firm can be increased by implementing such an approach (Esty and Porter, 1998). The environmental benefits come from the lower environmental pressure due to less amount of both wastes disposed of in the landfill and virgin input used in production processes (e.g., Jacobsen, 2006).

3. Business models supporting the IS approach at the firm level

According to the IS approach, wastes are used as inputs in production processes instead of landfilled. Two key actors are involved in waste exchanges: firms producing wastes and firms using wastes.

In this section, we identify the business models that each of these firms can adopt to implement the IS approach. In order to formalize these models, we used an inductive approach (Eisenhardt and Graebner, 2007): we reviewed secondary literature (academic literature, professional literature, companies' websites) about the implementation of IS projects and we analyzed business models adopted by the involved firms. To characterize the business models formalized in this paper, we use the framework proposed by Richardson (2008). Accordingly, for each model, we highlight the value proposition, the value creation, and the value capture.

3.1. Firms producing wastes

The IS approach is successfully implemented when the amount of wastes disposed of in the landfill is reduced. To avoid that wastes will be landfilled, firms producing wastes can implement two different strategies: i) using the produced wastes within the firm (*internal exchange*); ii) sending the produced wastes to other firms (*external exchange*).

Internal exchange. Firms can use wastes produced by a given production process to replace inputs in other production processes within the firm boundaries. The value proposition of this model is related to higher production efficiency, due to lower amount of wastes disposed of in the landfill per unit of output generated by the firm. Such a value can be created by implementing organizational innovations to manage the additional flows and stocks of wastes within the firm boundaries. Firms can capture the value in form of lower production costs, in particular due to the lower waste disposal costs. Moreover, the increased environmental sustainability of production processes may generate additional value in form of improved firm's reputation from stakeholders.

External exchange. Instead of using the produced wastes within the firm boundaries, firms can send their wastes to other firms, which will use them in their production processes. Also in this case, the value stems from higher production efficiency. However, differently from the previous model, the value is created by producing wastes with features making them able to be used by other firms (e.g., with adequate qualitative levels). Finally, from the side of value capture, the lower production costs and the higher firm's reputation from stakeholders can be backed up by additional revenues from selling wastes to other firms.

Table 1 shows value proposition, value creation, and value capture for both the models previously presented.

Table 1. Value proposition, value creation, and value capture for “internal exchange” and “external exchange” models

	<i>Internal exchange</i>	<i>External exchange</i>
Value proposition	Higher production efficiency (lower waste from output production)	Higher production efficiency (lower waste from output production)
Value creation	Organizational innovation	Producing wastes useful for other firms
Value capture	Lower production costs Better reputation from stakeholders	Lower production costs Better reputation from stakeholders Additional revenues from selling wastes

3.2. Firms using wastes

Firms can implement three different business models oriented to use wastes in their production processes: i) input replacement; ii) co-products generation; and iii) new products generation.

Input replacement. Firms can use wastes to replace inputs in their production processes. The proposed value is related to higher production efficiency, in form of lower amount of virgin inputs used to produce one unit of output. Such a value can be created by innovating the production process from the technical point of view, making it able to use the waste as input. Finally, the value is captured through lower production costs, in the form of lower virgin input purchase costs, and additional revenues from offering disposal service to firms producing wastes. Moreover, also in this case, the improved environmental efficiency may generate additional value, in form of better reputation from stakeholders.

Co-product generation. Firms exploit wastes to generate at least one new product, different to those currently generated, destined to be sold on the market. Two kinds of new products can be generated: i) products whose production process is more environmentally sustainable than traditional products, *ceteris paribus*; ii) products with some features better than traditional products, *ceteris paribus*. Therefore, products so generated can be considered as “differentiate products”, more profitable than the traditional one. The proposed value is related to the business enlargement allowed by the IS approach, since new products are added to the current product portfolio. So that such a value is created, firm needs to implement product and process innovation. In fact, firms have to design how to integrate wastes within new products and how to make production processes able to use these wastes. The created value can be captured by gains from selling the new products.

New product generation. New firms arise exploiting wastes to generate new products, which are sold on the market. This could sound quite similar to the previous model; however, since in this case the new products are the main business of the firm, the arisen firms are completely based on the IS approach. Hence, the value proposed by this model is to create new businesses by exploiting wastes. To create such a value, product and process innovations are needed. The value is captured by gains from selling the new products.

Table 2 shows value proposition, value creation, and value capture for all the models previously presented.

4. Business scenarios at inter-firm level

From the interaction among firms producing wastes and firm using wastes, each of them implementing its own business models, five business scenarios at inter-firm level may arise. In this section, we present these scenarios. For each of them, we highlight strengths and weaknesses related to the implementation from strategic and organizational point of view and we present a short case study. These scenarios are graphically depicted in Fig. 1 and discussed in the following sub-sections.

Table 2. Value proposition, value creation, and value capture for “input replacement”, “co-products generation”, and “new products generation” models

	<i>Input replacement</i>	<i>Co-product generation</i>	<i>New product generation</i>
Value proposition	Higher production efficiency (lower virgin input to produce output)	Business enlargement	Creation of new business
Value creation	Process innovation	Product innovation Process innovation	Product innovation Process innovation
Value capture	Lower production costs Better reputation from stakeholders	Gains from selling new products	Gains from selling new products

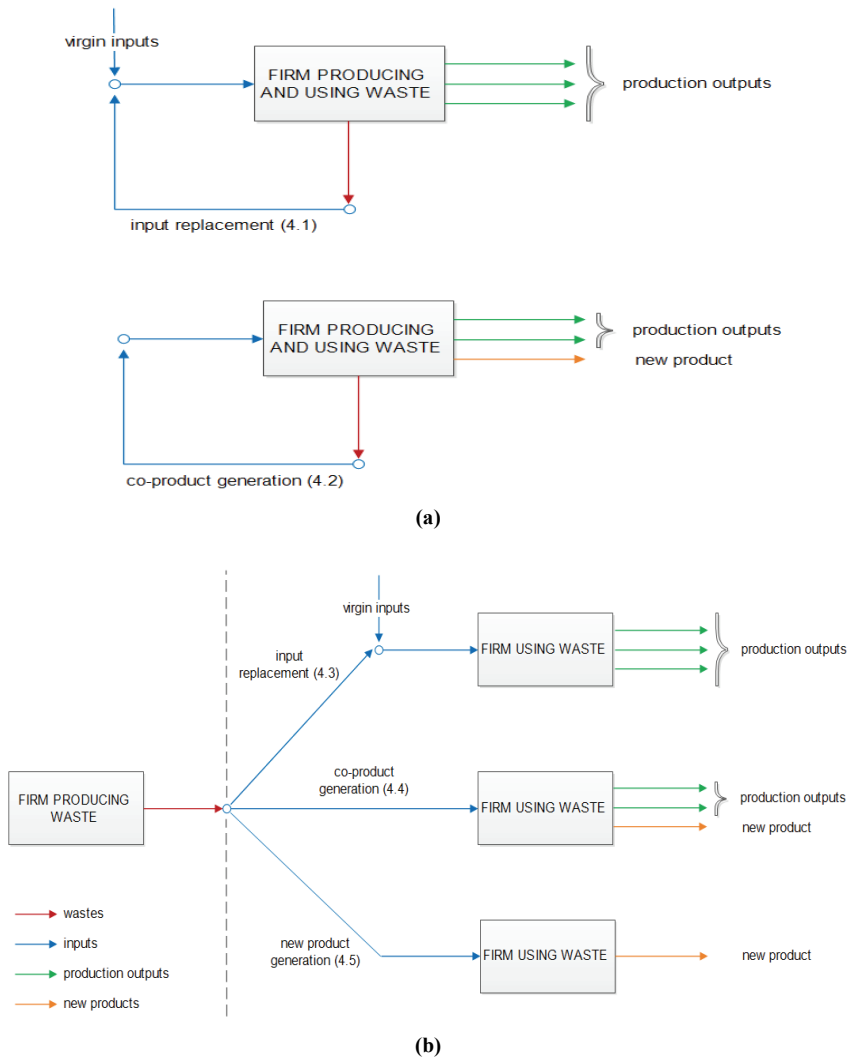


Fig. 1. Graphical representation of business scenarios at inter-firm level: a) in case of internal waste exchange; b) in case of external waste exchange. For each scenario, the number on the arrow indicates the sub-section presenting that scenario

4.1. Internal exchange + input replacement

This scenario arises when wastes are used within the firm's boundaries to replace production inputs.

Strengths. As main strength of such a scenario, no cooperation with partners is required. This means that firm does not need to disclose personal information or to negotiate the economic terms of the relationship, which is one of the strongest barriers hampering the adoption of the IS practice (e.g., Fichtner et al., 2005). Moreover, in the phase of input replacement, the firm is strategically independent because the amount of wastes that it can use does not depend on any other firm. Finally, from the economic point of view, two issues can be highlighted: i) the firm does not sustain any waste transportation costs; ii) the benefits from the IS approach have not to be shared with other firms.

Weaknesses. Symbiotic exchanges within the firm's boundaries may be limited in case of low diversity among production processes, not enough to allow technical match among wastes and inputs (Korhonen, 2001). Moreover, from the economic point of view, the additional costs needed to activate symbiotic processes cannot be shared with any partner. These weaknesses could make such a scenario hardly sustainable by small firms.

Case study. In UK, McDonald's produces biodiesel from the used cooking oil generated in its kitchens. The biodiesel so produced is used to fuel the company delivery vehicle. Hence, both fried oil disposal costs and fuel purchase costs are reduced. In 2013, 3,7 million liters of used cooking oil was converted in 3,1 million liters of biodiesel, fueling around 42% of the company delivery fleet.

4.2. Internal exchange + co-products generation

This scenario arises when wastes are exploited to create new products within the firm's boundaries.

Strengths. All the strengths of the previous scenario can be recognized also for this one. Moreover, we want to highlight that the amount of new products generated is dependent on the amount of available wastes. Therefore, the low waste supply risk is a particularly relevant strength for this scenario, since it makes the new product generation independent on contributions from other firms.

Weaknesses. This scenario suffers from all the weaknesses of the previous one. Moreover, since the amount of new products depends on the available amount of wastes, firms would be unable to satisfy demand of new products exceeding the highest amount that can be produced. Similarly, in case of reduced waste production, the amount of new products generated will be reduced.

Case study. Guitang Group, the largest sugar farm in China, has successfully applied this scenario. The group has exploited wastes from sugar production processes (molasses, bagasse, filtered sludge) to create new production chains (alcohol, paper, fertilizer) within the group boundaries. By implementing such an approach, from 1997 to 2004 Guitang Group increased its revenues by 153% (from 807 to 2.045 million CNY), due to the new products sold on the market, and its profit by 5.521% (from 3 to 170 million CNY), due to lower production costs and waste disposal costs (Yang and Feng, 2008).

4.3. External exchange + input replacement

This scenario arises when wastes generated by a given firm are used to replace input in another firm.

Strengths. Potential additional costs arising from IS can be shared among firms: for this reason, such a scenario could be sustainable even by small firms. Moreover, both firms

can gain additional benefits than those arising from internal use of wastes: the firm producing wastes from selling wastes whereas the firm using wastes from selling disposal service.

Weaknesses. Firms need to find economic agreements related to waste exchange and to negotiate the cost-sharing policy (Albino et al., 2016). Moreover, since the economic benefits that each firm can obtain depend on the willingness to cooperate of the other firm (Yazan et al., 2012), a strong cooperation among firm is needed in order to implement such a scenario (Lambert and Boons, 2002). Transaction costs arise from such a cooperation, eroding the gross economic benefits created by using wastes in place of inputs.

Case study. DENSO Manufacturing UK produces automotive air conditioning units and engine cooling systems for the automotive industry. Potassium aluminum fluoride is generated as hazardous waste by its production processes. Instead of be disposed of in the landfill, such a waste is used by Mir-Ver Metals, a company working in metal industry, as inputs for its production processes. Cooperation between these firms allows to divert from landfill 15 tons of waste per year, creating 45.000 euro of economic benefits shared among firms. This synergy has been implemented under the National Industrial Symbiosis Programme (NISP) in UK.

4.4. External exchange + co-product generation

This scenario arises when wastes generated by a given firm are exploited by another firm to create additional products to its main business.

Strengths. This scenario may support cooperation among firms belonging to very different sectors (that would be unable to cooperate otherwise), playing an important role for enhancing environmental innovations (Mirata and Emtairah, 2005).

Weaknesses. As highlighted in the “internal exchange + co-product generation” scenario (Section 4.2), the amount of new products generated depends on the amount of available wastes. In this case, the amount of available wastes may also depend on cooperation among firms. If the symbiotic relationship was interrupted, firm using wastes will no more be able to produce its new products. For this reason, the structure of bargaining power among firms could be unbalanced, negatively affecting the cooperation among firms (Yazan et al., 2012). Moreover, in case the waste should have fixed qualitative features to be used in new product generation, it may be difficult for firm using waste to find adequate waste supplier. Finally, high R&D investments may be needed to create the new product.

Case study. CSC is an Italian firm producing and supplying concrete to the local construction industry. Since the financial crisis in 2008 negatively affected the firm business by reducing final demand of its products, the firm decided to introduce new products within its current portfolio in order to enter in new market segments and increase revenues. It developed a new concrete product that mixes a percentage of chopped plastic into the concrete mix in place of conventional aggregate. In fact, plastic is 50% less weight than aggregate and has positive performance about impact resistance and noise absorption. Moreover, plastic used for concrete production stems from urban wastes. CSC founded a joint venture company collecting urban wastes, in order to reduce supply risk by directly managing the supply chain. By adopting this model, CSC reduced its production costs because of lower amount of virgin aggregates used in concrete production, increased its revenues by selling the new product, and finally obtained additional gains because of payment from the municipality for managing the waste (Short et al., 2014).

4.5. External exchange + new product generation

This scenario arises when a new firm is created *ad hoc* to generate new products exploiting wastes from another firm.

Strengths. All the strengths recognized for the “External exchange + co-product generation” scenario (Section 4.4) can be recognized also for this one.

Weaknesses. All the weaknesses recognized for the “External exchange + co-product generation” scenario (Section 4.4) can be recognized also for this one. However, differently from the previous case, the business model of the firm using wastes is completely supported by the IS relationship. Hence, the new firm has high economic and strategic dependency from the firm producing wastes. In fact, in case of lack of cooperation, the new firm will be unable to sustain its main business. This aspect may generate an additional displacement of bargaining power.

Case study. Kazmok is a Dutch company started in 2010, producing bags from end-of-life conveyor belts used in flower industry, postal depots, distribution centers, and the recycling industry. Conveyor belts mainly comprise PVC and rubber, an incredibly strong material that produces bags to last a lifetime. Bags so produced are not only environmentally sustainable but they are unique products, for which customers are willing to pay premium price. So doing, firm differentiated from the competitors and gained the reputation of sustainable firm.

Table 3 resumes all the scenarios at inter-firm level and the case study discussed for each of them.

Table 3. Case study discussed for each business scenario at inter-firm level.

FIRM PRODUCING WASTES		FIRM USING WASTES		
		Input replacement	Co-products generation	New products generation
	Internal exchange	McDONALD’S	GUITANG GROUP	---
	External exchange	DENSO + MIR-VER	CSC + waste plastic suppliers	KAZMOK + end-of-life conveyor belt suppliers

5. Discussion

Firms can adopt the IS approach by implementing different business models. However, the choice of what model to implement may be affected by at least three factors: i) technical factors; ii) economic factors; and iii) strategical factors.

From the technical point of view, two aspects should be considered: the possibility to internally replace inputs with wastes and the typology of both produced wastes and required inputs. Only firms whose wastes are able to replace internal inputs can implement the “internal exchange” model: if McDonald’s did not use trucks, it could not internally use the biodiesel produced from fried oil but it should sell such a biodiesel on the external market, implementing in such a case the “External exchange + co-products generation” scenario. Moreover, not all wastes can be used to generate new products but some wastes can only replace inputs. In these cases, the “co-product generation” model as well as the “new products generation” one cannot be implemented.

From the economic point of view, firms can choose to implement the more profitable business model for themselves. For instance, McDonald’s could sell the biodiesel from the fried oil on external markets, hence adopting the “internal exchange + co-product generation” scenario instead of the “internal exchange + input replacement” one. However, since it prefers to use biodiesel internally, we may suppose such a use more profitable.

Moreover, the internal models may be more difficult to adopt for small firms because of the impossibility to share costs with partners.

Finally, from the strategic point of view, not all the business models have the same implementation risks. In particular, the “co-product generation” as well as the “new product generation” model seem having high risks related to waste supply. Firms could be not willing to sustain high risks, preferring to adopt a less risky model.

6. Conclusions

This paper firstly identifies and discusses business models supporting the IS approach at the firm level. We found that two different models can be implemented by firms producing wastes, whereas firms using wastes can implement three business models. For each of these models, we discuss how the firm can propose, create, and capture value. Moreover, from the interaction of firms, business scenarios at the inter-firm level have been identified. For each of these scenarios, strengths and weaknesses have been discussed and a short case study has been presented.

These models show all the possible strategies that can be implemented to adopt the IS approach. Hence, they can be useful to force both bottom-up (where each firm decides the business model to adopt) and top-down (where business models of firms are designed *a priori*) IS relationships. Hence, this paper can be a guide for firms interested to implement the IS approach as well as for policymakers interested to design new symbiotic exchanges within a given geographic area.

Further development of this guide may include how to overcome barriers arising from each model as well as how to reduce the identified weaknesses.

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