


# How to improve the process of forming biobased R&D collaborations

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**Abstract:** The transition towards a biobased economy requires innovations. In addition to the usual challenges of innovation trajectories, the characteristics of biobased innovations cause extra difficulties. To lower the failure rate of innovation trajectories in general, companies tend to form R&D collaborations. Choices made during the formation of such R&D collaborations play a key role in the project's success. Here, one may benefit from the social sciences. This paper presents a perspective on what the social sciences may bring to analyze and improve the formation process of biobased R&D collaborations. The paper also provides an overview of relevant innovation and transition models, and lists the dominant variables in such formation processes (biobased characteristics and general determinants), and the guidelines that seem useful. Although each model has its advantages, none of the innovation and transition models studied addresses both the *phases of a formation process* of a biobased R&D collaboration and the *variables* involved in each phase. Concerning the formation process of biobased R&D collaborations, the literature addresses social, organizational, technological, economic, and environmental variables. The key determinants of multi-partner R&D collaborations are partner properties, motives to join a consortium, appropriability of a firm, and project properties. The descriptions of their influence on an R&D collaboration presented here can be used as guidelines, as recommendations, in processes for the formation of relatively less complex R&D collaborations. The influence of biobased characteristics – such as type of innovation (drop-ins versus novel materials), biorefinery, biomass supply and technological challenges – on R&D collaboration have not been studied systematically as yet. © 2020 The Authors. *Biofuels*, *Bioproducts*, and *Biorefining* published by Society of Chemical Industry and John Wiley & Sons, Ltd

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## Introduction

The biobased economy is defined as an economy where biomass is used to produce not only food and feed but also energy, materials, and chemicals.<sup>1</sup> For the transition towards such an economy, technological innovations are necessary, and diverse stakeholders – especially government, research, and industry – have to join forces to develop the necessary technologies, products, and processes.<sup>2,3</sup> The European Commission alone has already invested over 5.5 billion euro in over a thousand biobased innovation projects, for the period 2015–2020.

Innovation projects in general show low success rates, and biobased innovations seem to perform no better. Concerning product development, in general, the literature indicates a wide range of failure rates (30%–80%).<sup>4</sup> In addition to the common difficulties in innovation trajectories, biobased innovations are part of the wider transition from a well-established and efficient fossil-based economy to a biobased economy. This transition requires complex, interdependent development of technologies, value chains, and societies.<sup>5</sup> The first hurdle already is the fact that there are problems with the availability of biobased resources that fulfill certain criteria at reference prices, and which could serve as feedstocks for biobased processes. Many biobased innovations focus on applying side streams, avoiding the use of food crops. For these kinds of feedstocks, in particular, availability and mobilization can pose serious problems. One may think of side streams that offer good potential as biobased resources, but they are spatially scattered (such as palm kernel wastes, coffee residues, or pellets of new lignocellulose sources such as reed or miscanthus) and are difficult to certify, for instance in terms of quality or sustainability.<sup>6,7</sup>

The challenges to biobased innovations are multiplied when pondering collaborations on innovations by two distinct industries; we refer to the chemical sector and the agro-food sector, each with its unique industrial, if not sectoral, culture, fully optimized production scales, and routinized business practices. For example, a conventional chemical company that intends to change from fossils to biobased raw materials is a novice when it comes to contracting, transporting, processing, and storing non-homogeneous biomass-based raw materials. A collaboration between such a chemical company and an agro-food company could then be a way forward, notwithstanding the challenges such a cooperation poses. As already pointed out in the corporate strategy-classic by Ansoff,<sup>8</sup> for innovations with more than one major uncertainty (in the case of biobased innovations, novel market, new products, new raw materials, new technology, etc.) a way of reducing uncertainties is a collaboration with the right

partners. A study on bioplastics<sup>9</sup> recognizes these complexities and recommends addressing not only technological and economic variables in biobased innovation projects, but also social variables (e.g. societal benefits of bioplastics, the stakeholders of the value chain, public communication), and environmental variables (e.g. environmental impact, Life Cycle Analysis (LCAs), accountability systems).

To lower the failure rate of complex innovation projects, companies tend to form research and development (R&D) collaborations.<sup>10,11</sup> These interorganizational R&D collaborations – more specifically R&D consortia – are defined as relationships between three or more R&D partners to pursue both individual and shared goals.<sup>11</sup> Regular subcontracting is thus not core to our study. Prime motives for joining a specific R&D consortium are cost sharing, risk sharing, and skill sharing.<sup>12,13</sup> The success rate of joint R&D projects depends on the motives of the partners to join, and the type of partners.<sup>10,14,15</sup> Even during the formation process of R&D projects, therefore, the partners have to make important decisions such as partner choice (consortium composition), goal of collaboration, and contract conditions, which will play a key role in the project's success. Sometimes the formation process of an R&D collaboration and the corresponding decisions are orchestrated by a triggering entity, a so-called orchestrator or innovation broker.<sup>16–18</sup> In practice, the role of such an orchestrator is directed at lowering the failure rate of the formation process of complex R&D collaborations.

The authors of this paper, working for applied research institutes and universities, have decades of experience as researchers and business developers (orchestrators) with biobased R&D projects and their formation processes. To lower the failure rate of these projects we arrived at models and guidelines from the social sciences to improve the process of forming R&D projects. The aim of this paper is to show the core of what the social sciences have to offer to analyze and improve the formation process of a biobased R&D collaboration. With this paper we provide support to researchers and orchestrators by giving an overview of useful models, critical variables and guidelines, and a perspective on their usefulness during the formation process. In this way we come up with an action perspective for those setting up biobased R&D consortia. The usefulness of several models and guidelines will be illustrated with cases, indicated in italics.

The formation process for an R&D collaboration generally consists of several phases, from idea generation, partner search / selection, proposal and consortium development, to signing the contract. Our study focuses on the phases between idea generation and signing the contract.

We conducted a review study to investigate whether the literature provides useful models, lists of critical variables, and guidelines that improve the formation of biobased R&D collaborations. The literature contains a vast number of studies on R&D collaboration in general, but offers surprisingly little systematic information on their formation process. The first step of the review study was a literature search using the academic journals / databases Scopus and Web of Science, using combinations of the following keywords: consortium, formation, innovation, R&D, model, network, multi-partner alliances, and biobased. Second, the long resulting list of publications was screened; publications strictly reporting technological innovations, or social aspects of an innovation after the formation process, were excluded. Third, trimming the still large amount of shortlisted papers and topics led to the exclusion of studies regarding intellectual property rights, public policies, and contracts. The fourth and final step was a forward and backward reference search to arrive at the most relevant publications.

The literature search resulted in over a hundred relevant publications, which were divided by the topic addressed, such as the characteristics of a biobased collaboration, transition and innovation models, and determinants of collaboration. The models are subdivided into transition models, describing the context of the innovation, and innovation models, describing the innovation process. Following the bioplastics innovation-study by Iles and Martin<sup>9</sup> we also look into relevant variables of the formation process of a biobased R&D collaboration, divided in biobased characteristics and general

determinants. Finally, based on the way these variables affect the success rate of a project we form a list of guidelines, being recommendations not rules, for partners / brokers useful for improving the process of formation of R&D collaborations.

The remainder of the paper is organized as follows (Fig. 1). The next section presents a short description of the biobased characteristics. An overview is then given of the core of relevant transition and innovation models available in the literature. The paper then focuses on the general determinants influencing R&D collaborations, between two partners and in multi-partner consortia, respectively. Consideration is then given to the way in which variables affect project success, and to guidelines for partners / brokers, which are recommendations rather than rules, useful for the orchestration of the process of formation of an R&D collaboration. The concluding section summarizes the findings, and proposes areas for future research.

## Biobased characteristics

The increasing scarcity and insecurity of fossil resources and the problems of fossil-related climate change have led to a search for alternative resources, which has intensified in recent decades.<sup>5</sup> If we only take technological feasibility into account, all chemicals and materials based on fossil resources can be substituted by biobased resources.<sup>19</sup> But such biobased innovations require collaborations. In this section, we describe the characteristics of a biobased R&D collaboration: biomass supply, bio-refinery, technological challenges, type of

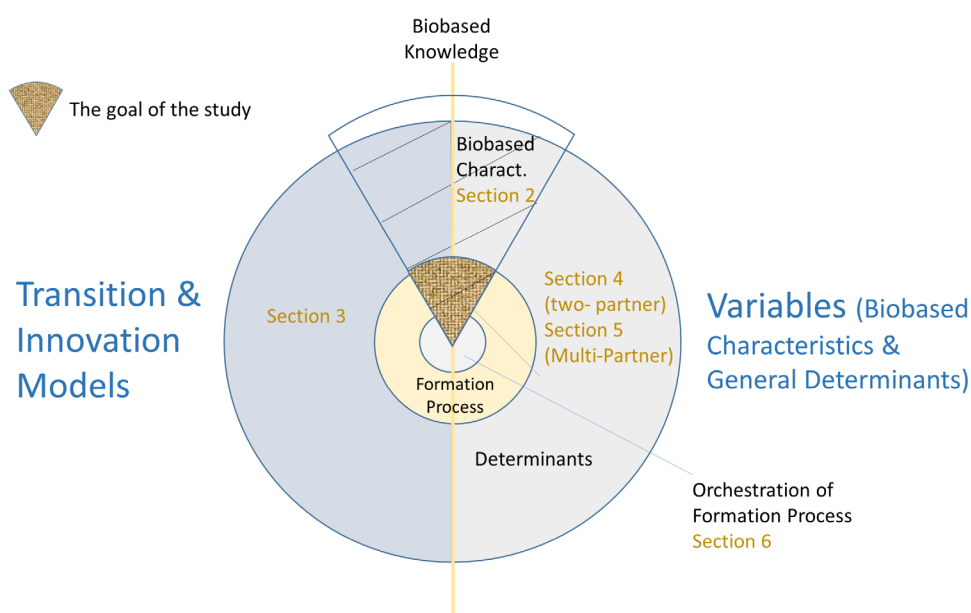


Figure 1. Knowledge to improve the process of forming biobased R&D collaborations.

innovation, new chains / collaborations, and society-sensitive issues.

## Biomass supply

Evidently, an important factor for the success of a biobased innovation is the availability of biomass with the right specifications and price.<sup>20</sup>

## Bio-refinery

The fractions of raw materials and corresponding applications of the products of a bio-refinery are more diverse than an oil refinery; biobased raw materials consist of a broader range of chemical compounds, and they are applicable to an even wider variety of markets (e.g. food, feed, materials, and chemicals). As a consequence, choosing the combination of the most suitable applications, sources, and corresponding bio-refinery processing steps is more complex than for a petrochemical refinery. In an ideal situation, the biomass is fully used, leaving no residues, in applications obtaining the highest aggregate value.<sup>1</sup>

## Technological challenges

The biobased economy has to address three technological challenges:<sup>21</sup>

1. Breakthrough technologies: It is a research-intensive field, where fundamentally new knowledge and capabilities have to be created and acquired.
2. Cross-sectoral collaboration: Interdisciplinary approaches are required because it has a cross-sectoral character, drawing upon a variety of sciences and technologies.
3. Acceptance rate: Acceptance of its new products and technologies may become difficult, because of higher risk perceptions among users.

## Type of innovation

Biobased innovations can be divided into two groups, namely drop-ins and novel materials.<sup>1</sup> First, drop-in innovations are based on the substitution of the fossil-based building blocks in products and processes by (essentially) identical biobased building blocks. *A case example is the substitution of fossil-based ethene by the biobased alternative, ethene from sugar cane, in the production process of poly-ethene by the Brazilian company Braskem.*<sup>22</sup> Drop-in innovations are, in general, incremental innovations, because no changes or only small changes of the formulation are necessary, the end product is in general exactly the same as the product it replaces, and

it can be used in the same applications, so no additional product development is needed. However, the production and sourcing of the identical biobased building block will require new raw materials and new production processes, and can therefore extend beyond an incremental innovation. A major challenge for the substitution of inputs by biobased feedstocks is the size of the already existing market and the cost of production of the drop-in in a novel biobased process, which still needs industrial optimization in comparison with an already established fossil-based industrial process. This is certainly the case if one has to compete with larger players benefitting from economies of scale in their processes and / or markets, and in their lobbying to governments.

Biobased innovations related to novel materials, the second group of innovations, exploit the broad range of chemical functionalities for the development of new building blocks, from which new materials may be developed, generally with new technical functionalities. Compared to fossil-based raw materials (petrochemical hydrocarbons), biobased raw materials consist of a broad range of chemical compounds (e.g. carbohydrates, proteins, and fats) and an even broader range of chemical functionalities, properties. Such an innovation is called a radical innovation. *A case example is biobased packaging material based on polylactic acid (PLA). The production of PLA required the development of new production processes and a new production plant: PLA is not only a biobased alternative for fossil-based packaging material but it also gives an added value to the functionality of the product. The added value in this case is that PLA and its monomers are non-toxic, in some applications replacing a toxic monomer of polystyrene, while in certain applications PLA also has the advantage that it is biodegradable.* Other examples of added value may be lower carbon dioxide emissions during production or in use, less harmful for human health, and better technical functionalities (e.g. biodegradability, solubility, barrier properties, strength, UV resistance).

## New chains / collaborations

In some cases the whole supply chain must be developed, from biomass production, biorefinery, production of materials, product development, up to market introduction. In that case new market players and major investments may be necessary.<sup>23</sup> For biobased applications the agro-food and forestry sectors are the main sources of biobased raw materials. Companies (e.g., chemical and energy companies) that switch from fossil to biobased raw materials have to build relationships with biobased raw-material suppliers, typically unfamiliar to them.<sup>9</sup> Furthermore, these switching companies are used to storing, transporting, and handling fossil-based

resources, but they are not used to the diverse biobased resources that often need to be sourced from many small production locations.<sup>9</sup> The transition towards a biobased economy is often expected to require radical innovations and new supply chains linking, at best, remotely related sectors.<sup>24</sup>

### Society-sensitive issues

The transition to a biobased economy is a complicated trajectory, touching upon societally sensitive issues, such as the use of genetic modification and the food versus fuel discussion.<sup>25</sup>

Depending on their characteristics, specific biobased R&D collaborations can differ in complexity. A collaboration with a large number of partners will be less complex when these companies just want to share risks in exploring a new technology. It will be evident that an R&D collaboration with three partners, developing an incremental, drop-in innovation, based on mature technology, is less complex than a collaboration, which we have experienced, with more than 10 partners coming from different industries and with different interests, developing both radical and incremental innovations, based on immature technologies.

### Transition and innovation models

This section gives an overview of the core of the relevant transition and innovation models that may relate to the process of forming biobased R&D consortia. The first subsection addresses transition models, typically used to analyze and to facilitate major transformations in societal functions towards, in our case, the biobased economy. The second subsection considers innovation models. The initial presentation of general innovation models is extended by the presentation of models specifically suited for the process of forming an R&D collaboration.

### Transition models

A transition model describes major transformations in societal functions, such as transportation, communication, housing, and feeding.<sup>26</sup> Examples of such transitions are the transformation from sailing ships to steamships, and from an oil-based economy to a biobased economy. A transition involves technological innovations, but also innovations in user practices, regulations, industrial networks, infrastructures, and symbolic meaning or culture. We arrived at, and will describe, two transition models useful for the analysis of the processes necessary for the transition to a biobased economy: strategic niche management (SNM)

with a multi-level perspective (MLP), and technological innovation systems (TIS).

### Strategic niche management

Strategic niche management (hereafter SNM) claims that an innovation can be facilitated by creating technological niches. A niche is a protected space that allows experimentation with the co-evolution of technology, user practices, and regulatory structures. The assumption is that, if such niches are constructed appropriately, they can act as building blocks for broader societal changes towards sustainable development.<sup>27</sup>

In the set of articles developing SNM, one article added and elaborated a multilevel perspective to SNM (Fig. 2),<sup>26</sup> distinguishing the following three levels: the sociotechnical landscape level, regime level, and the level of the niches. The landscape level is formed by the material and immaterial context of societies.<sup>28</sup> In other words the landscape level is the macro context, and items at this level are natural resources (e.g. fossil fuel, biomass), climate (international), political practices, and social cultures. Climate change and related agreements are objectives at the landscape level. The regime level can be defined as the grammar or rule set, embedded in a complex of engineering practices, production process technologies, product characteristics, skills and procedures – the ways of handling.<sup>28</sup> For the biobased economy, the literature recognizes several regimes – typically the chemistry regime, the agricultural regime, and the energy regime.<sup>5</sup> The objects at the third and most specific level are niches. A

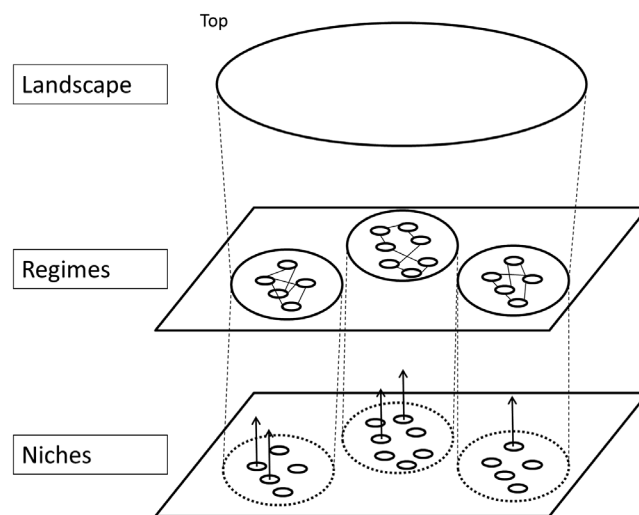


Figure 2. Multilevel perspective model.<sup>26</sup> Innovative developments, represented by the small circles at the niche level, may cluster and lead to changes at the regime level. Many changes at the regime level may lead to changes at the landscape level and thus to a transition.

biobased innovation can be labeled as a niche. To become a successful innovation and to evolve from niche level to maturity at regime level, a niche must execute three processes: Voicing and shaping of expectations, building social networks, and the learning process.<sup>29</sup> *A case example of an analysis of these three processes in a biobased application is the study of biofuels by van der Laak et al.*<sup>30</sup>

Applying the multilevel perspective to a technological innovation, technological change occurs by linkages between levels, and changes at the levels.<sup>29</sup> Changes at the landscape level – for instance a sharp rise or fall in oil prices – can put pressure on the energy regime or the chemistry regime, and may result in changes at the level of these regimes. *For instance, under rising oil prices chemical companies that do not possess naphtha crackers for the production of their feedstock from oil may be willing to look for feedstock diversification, and thus consider biomass as a raw material. Next, less stable regimes may create market momentum for new technologies, like biochemicals developed earlier in niches.*

Strategic niche management in a multilevel perspective can be useful during the process of the formation of an R&D collaboration. For example, information about stakeholders in the chemical industry, at the regime level, can be useful for an R&D consortium partner search at niche level. However, as SNM cannot be used to give an analysis of the status of an innovation and possible shortcomings, such as the consortium composition, one has to resort to another transition model: Technological innovation systems (TIS).

## Technological innovation systems

A TIS is based on the innovation system concept introduced by Dosi *et al.*<sup>31</sup> and Lundvall<sup>32</sup> in the 1980s. According to a TIS, an innovation is not determined merely by variables within one company but it is simultaneously part of a larger innovation system, which includes the market, government, and research institutes. A TIS is a type of innovation system that can be used to analyze and evaluate the development of a particular technological field.<sup>33</sup> A TIS can give an overview of the functioning of an innovation system, and its failure at a certain time. The TIS-analysis can be conducted by using the following set of seven functions: entrepreneurial activities, knowledge development, knowledge exchange, guidance of the search (selecting between various technological options that could be developed), formation of markets, mobilization of resources, and counteracting resistance to change.<sup>34</sup> These functions address technological, economic, and social variables of an innovation system. The TIS analysis shows per function if the development of the function is sufficient or if an adjustment is necessary. *The TIS was used to analyze and evaluate several renewable energy cases (hydrogen, biofuels, natural gas).*<sup>35,36</sup> *The*

*conclusion was that realizing a virtuous cycle in an innovation system requires functions to reinforce each other over time. The Netherlands' biofuels innovation system was considered to be driven by the function's entrepreneurial activities, support from advocacy coalitions, and resource mobilization.*<sup>36</sup>

We can conclude that transition models can give a broad perspective on an innovation. This can be used during the process of forming an R&D consortium. A TIS analysis complements the SNM analysis by providing the status of an innovation system at a certain moment in time. A TIS can, for example, be used to analyze the status at a certain moment in time of a biobased R&D consortium in formation, and it may, for example, indicate missing stakeholders in this consortium.

Having presented, in brief, the essentials of the broader transition models, the SNM and the TIS, which may provide the wider overview of the relevant variables that impact innovations and R&D collaborations, we now turn to the more specific innovation models, to study the formation processes of an R&D collaboration.

## Innovation models

This subsection presents core lessons from the established innovation management literature, namely the linear innovation model and the circular innovation model, complemented by specific models for the process of the formation of an R&D collaboration. An innovation can be defined as the invention, development, and implementation of new ideas into products and processes.<sup>37</sup> A vast amount of research has been done on the development of innovation models, in general providing variations on a simplified figure or flow-chart representation of an innovation process.<sup>38</sup> These models can be useful for the formation process of an R&D consortium because they give insights into the sequence of steps an innovation goes through. We will discuss the different types of models most relevant for this paper, going from the simple linear models to more complex models, ending with circular models.<sup>38</sup>

One of the first, but still informative, innovation models is the *linear innovation model*,<sup>39</sup> which presents a sequence or chain of key steps, from basic research, applied research, via development to diffusion, necessary for an innovation. An offspring of it is the method of estimating the maturity of technologies on the basis of nine technology readiness levels (TRLs), developed by NASA in the 1970s, and in use by, for example, the EU. Over time, different versions of this linear model were developed and used (see Godin)<sup>39</sup> such as the innovation funnel to prioritize ideas repeatedly, and resource allocation to R&D projects.<sup>40</sup>

Although these linear innovation models are still in use because of their simple, convenient representation of

the sequence of activities, they have also been criticized. First, not all activities in the model are always needed for an innovation. Second, in the early 1970s the innovation process within a firm became more integrated with other functions of the firm; for example R&D became linked with marketing.<sup>41</sup> As a result more integrated innovation models were developed for the innovation process (essentially) within a single firm.<sup>42,43</sup>

Since the turn of the century *circular innovation models* have begun to appear.<sup>38,44,45</sup> These models explicitly reflect that an innovation process is a perpetual process, along a path of activities that has no fixed starting or ending point, stretching out beyond the boundaries of a single firm. For example, the cyclic innovation model (CIM)<sup>44</sup> is a circular innovation model that can be applied to an innovation with two or more partners (see Fig. 3). The model replaces the linear and the integrated models by a circle with four areas of activities similar to the steps in a linear model, namely scientific exploration, technological research, product development, and market transition, but is connected by four related cycles. The interaction between scientific exploration and technological research is depicted by the technically oriented science cycle. The development of new technologies takes place in this cycle, using both scientific and technological knowledge. Recall, for example, the development of the genome editing technology CRISPR/Cas, which allows permanent modification of genes within organisms. The integrated engineering cycle

represents the interaction between technological research and product development. New product development takes place in this cycle, using both technological knowledge and product requirements. *The optimization of the biotechnological production process of a novel biochemical by using strain modification technologies such as CRISPR / Cas is an example of such new product development.*

The interaction between product development and market introduction is depicted by the differentiated service cycle. In this cycle, innovation takes place based on information obtained from customers and the service sector. *An example is the development of a small-scale fermenter, based on criteria set by farmers, who want to use agricultural rest streams as raw material for biotechnological methane production and energy.* Finally, the interaction between market transitions and scientific research is depicted by the socially oriented science cycle. In this cycle, the systematic development of new insights into socioeconomic trends and market transitions takes place. *An example is the development of a model addressing the socio-economic aspects of a biotechnological innovation.* Figure 3, as a whole, sets the innovation arena for the relevant activities, processes, and related stakeholders (that is, manufacturing and processing industry, public and private service sector, soft knowledge infrastructure and hard knowledge infrastructure).

Circular models provide insights concerning the type and sequence of the determinants and activities of an

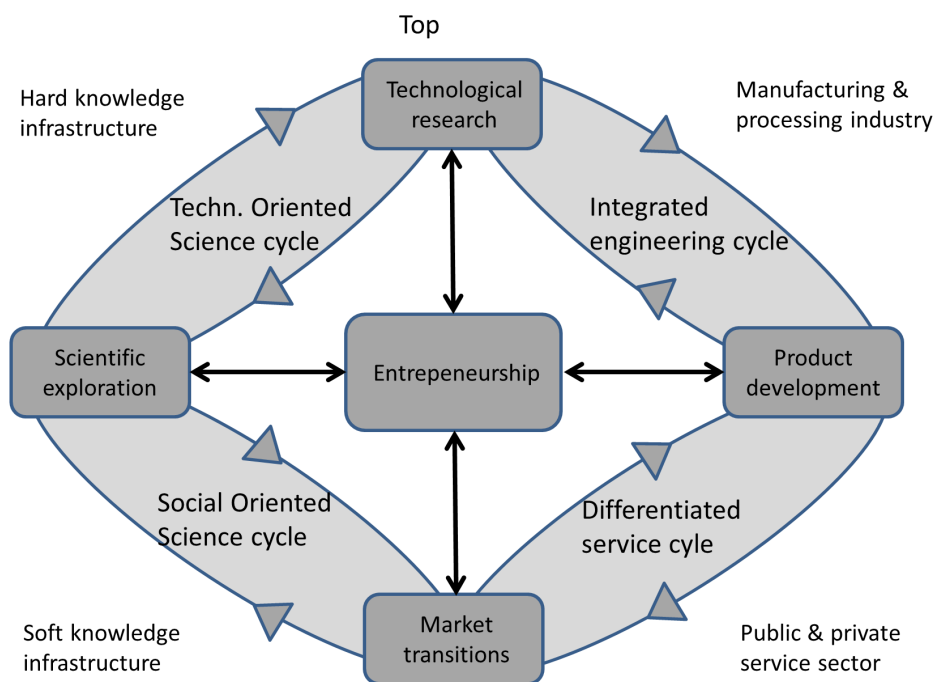


Figure 3. Cyclic innovation model (CIM).<sup>44</sup>

innovation. However, even the circular innovation model does not address the process of formation of an innovation consortium, the main reason being that most of the models are still focused on improving intrafirm, not interfirm, innovation processes.

In sum, the linear and circular innovation models presented provide useful insights into the type and sequence of the determinants and activities of an innovation, but we still need more dedicated literature to address the formation process of an R&D collaboration.

### Models for the formation process of an R&D collaboration

This sub-subsection provides an overview of the innovation models that target the formation process of an R&D collaboration. Interestingly, the literature review resulted only in the model by Ring and Van de Ven<sup>46</sup> (see Fig. 4), which had been developed on the process of forming inter-organizational relationships in general.

This closed-cycle model consists of an ongoing sequence of three phases in the formation process, namely negotiation, commitment, and execution. Doz and Baburoglu<sup>47</sup> elaborated on this more general model to arrive at the following

nine activities, which they call preconditions, for an R&D collaboration:

1. Identifying interdependencies.
2. Developing shared norms of problem solving.
3. Triggering cooperation: The need for a focal entity.
4. Selecting participants.
5. Making the shadow of the future visible.
6. Securing the participants sustained ability to contribute.
7. Designing cooperation.
8. Learning and adjusting over time.
9. Expansion of scope and deepening of commitments.

An R&D collaboration can vary in consortium structure and in contract explicitness.<sup>47</sup> The multi-partner R&D collaboration could be based on explicit commitments and contracts or it could be founded on less formal, common ground. Next, at the start of the collaboration, the partners can either be asked to join a well-specified structure, or the structuring process will emerge over time from their interactions. Figure 5 summarizes the four different resulting types of collaboration, using the dimensions *forms of collaboration* and *enablers of collaboration*.<sup>47</sup>

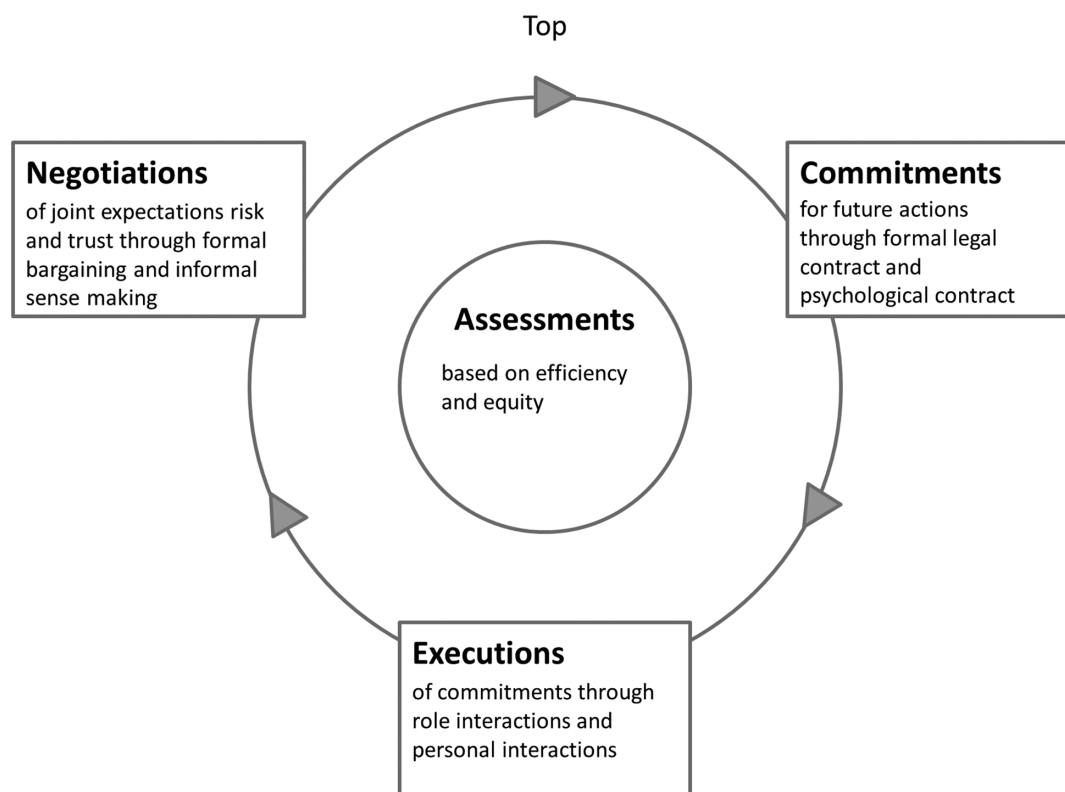


Figure 4. Formation process of an inter-organizational relationship.<sup>46</sup>



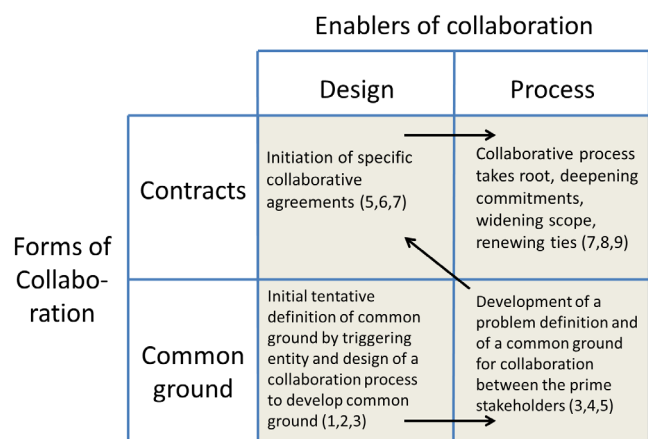


Figure 5. Formation process model by Doz and Baburoglu.<sup>47</sup>

Although Fig. 5 has no ‘one best pathway’, a collaboration seems likely to evolve through several phases as depicted by the arrows.<sup>18</sup> At the start of a collaboration there is often a tentative definition of common ground and relatively little structure (process). This can then evolve into more explicit contracts with a structural design.<sup>47</sup> The numbers in Fig. 5 refer to the nine activities mentioned above. The first three activities are initial conditions, and the other six are activities related to network emergence.<sup>18</sup> As far as we are aware, the model in Fig. 5 is the only model describing the activities and structuring of a formation process of an R&D collaboration. Unfortunately, this model does not address relevant variables (e.g. economic, social, and technological) per phase of the formation process.

In addition to this model with nine steps,<sup>47</sup> scholars describe the phases generally necessary for the process of forming a collaboration between the focal firm and a partner:<sup>48,49</sup>

1. Defining the firm’s goals.
2. Selecting the partner.
3. Establishing the collaboration agreement / contract.
4. Implementing the partnership.

Other scholars address the formation process when describing the phases of the life cycle of an R&D collaboration between two partners:<sup>50,51</sup>

1. Initiation phase.
2. Partner selection phase.
3. Formalization phase.
4. Implementation phase.
5. Evaluation phase.

Interestingly, there seems to be no similar, recognized literature addressing the variables per phase for the formation process of a multi-partner R&D collaboration (consortium).

It is justifiable to conclude that there are some models in the literature for the process of forming a multi-partner R&D consortium, addressing the activities, phases, and structuring of a formation process. However, they do not address the relevant variables (e.g. economic, social, and technological) per phase of the innovation process. More generally, we conclude that, so far, no innovation model seems to exist addressing both the phases of an innovation process and the relevant variables for each phase.

Returning to our objective of finding models for the process of forming biobased (multi-partner) R&D collaborations, so far we have reviewed both transition and innovation models. Although each model has its advantages, we have to dig deeper to find models that may inform us regarding both the formation process phases of a biobased R&D collaboration and the variables involved.

## R&D collaboration between two partners

Scholars have extensively studied the performance of R&D collaborations between two partners, often using the technological alliance framework.<sup>52-54</sup> A technological alliance is a cooperative agreement between two partners (e.g. R&D cooperation) for achieving a durable technological competitive advantage.<sup>55</sup> In this section and the next we describe the key determinants of an R&D collaboration between two (respectively multiple) partners, based on the literature on alliances.

The key determinants of an R&D collaboration can be divided into three groups: partner properties, motives, and appropriability.<sup>56</sup> The appropriability of a firm is the ability of that firm to apply the knowledge obtained from an R&D collaboration in such a way that it profits from the knowledge. Table 1 provides short descriptions of the determinants of an R&D collaboration, and their influences on an R&D collaboration.

The prime motives for firms to join an R&D collaboration are resource sharing, cost sharing, risk sharing, shortening the innovation process, and entry to foreign markets.<sup>55,57,58</sup> These prime motives can be summarized in a resource-based view: A firm wants to access necessary resources it does not already possess.<sup>57,59</sup> The potential of a collaboration between two partners will be positively influenced by the level of complementarity of the resources that are brought into the collaboration by the partners.<sup>59</sup> The resources can be divided into four groups: financial (e.g. cost sharing), technological (e.g. knowhow and R&D), physical (e.g. materials and facilities), and managerial resources (e.g. internationalization skills). The risks can be divided into relational risk (e.g. trust

**Table 1. Determinants for the formation process of a collaboration between two partners and their influences.**

Determinant	Description	Description of the influence
Partner firm properties		
Size	The number of employees within the partner firm	A positive impact on a collaboration, <sup>56,67,68</sup> except for Doz and Baburoglu. <sup>47</sup>
Collaboration between a large and a small firm	<ul style="list-style-type: none"> <li>• Divergence of mutual purpose in time</li> <li>• Consistency of the position of the R&amp;D collaboration within the large firm</li> <li>• Interface between top management and middle management in large firm</li> </ul>	<ul style="list-style-type: none"> <li>• Negative impact on collaboration</li> <li>• Positive impact on collaboration</li> <li>• Good interface has a positive impact on collaboration<sup>62</sup></li> </ul>
R&D intensity	The annual R&D investments divided by the sales in that year	Positive impact on the propensity of a firm to form R&D collaborations. <sup>47,63</sup>
Prior experience	The amount of experience of a firm with R&D collaborations	Positive impact on the propensity of a firm to form R&D collaborations. <sup>45,48,64</sup>
Type of partner	Relation of two partners: Two competitors, supplier and customer, or public research organization (PRO) and firm	A collaboration between competitors or between public research organization and a firm is more likely to fail or to be delayed than a collaboration between supplier and customer. <sup>61</sup>
	Type of industry: For example chemical, food, energy	A radical innovation has more chance to succeed if the partners come from a different kind of industry. <sup>49,50,64</sup>
Geographic position	The geographic distance between the two partners	The more distant a partner, the less likely a firm will start a collaboration. For an incremental innovation a diversity of the geographic position of the partners is a benefit. <sup>47,64</sup>
Motives		
Motives	The motive (resource sharing, cost sharing, risk sharing, shortening innovation process, and entry to foreign markets) influences the R&D collaboration.	Based on the resources necessary and the risks taken, a framework was developed to understand the prime considerations in forming an R&D collaboration (Table 2). <sup>51,52</sup>
Appropriability of both firms		
Spillovers	The knowledge obtained from the partner during the project	The more a firm expects positive spillovers the more likely it will join a collaboration. <sup>56,65</sup>
Lead time	The time necessary to get from an idea to a new product	The shorter the lead time the better. Lead time is a major determinant for a collaboration between a customer and a supplier. <sup>56</sup>
Tacit knowledge	Knowledge that is difficult to transfer from one firm to another	The ability of transferring tacit knowledge is positively related to collaboration with professional research Organizations. <sup>56,65</sup>
Ability firm	The ability of a firm to appropriate research findings	The success rate of an R&D collaboration is positively related to the ability of a firm to appropriate research findings. <sup>56,61,65</sup>

in relationships) and performance risk (trust in a positive outcome of the collaboration).

Based on the stated necessary resources in an alliance and the two types of risks, a framework was developed (see Table 2) to understand the prime objectives of a partner in the process of forming their R&D collaborations.<sup>57</sup> For example, when a firm (box 2 in Table 2) contributes financial resources and expects high project performance risks, that is low success rates, it is more likely that it will join the collaboration when the anticipated profits are high, and there are exit provisions

in the contract. In contrast, for example, when a firm (box 3 in Table 2) contributes technological knowhow to the project, and expects high relational risks, such as unwanted spill-overs, it is more likely that it will join the collaboration when it can safeguard its knowledge by patenting.

An R&D collaboration can be divided into two types of collaboration, namely horizontal and vertical. A vertical R&D collaboration is essentially a collaboration between a supplier and a client. A horizontal collaboration is a collaboration between two competitors.

**Table 2. Strategic alliance making orientations.<sup>57</sup>**

Alliance resources	High relational risk	High performance risk
Financial	Box 1 Objective: Share of equity	Box 2 Objective: Exit provisions
Technological	Box 3 Objective: Patent safeguard	Box 4 Objective: Licensing
Physical	Box 5 Objective: Embeddedness	Box 6 Objective: Recurrent contracts
Managerial	Box 7 Objective: Key positions	Box 8 Objective: Alliance managers

Next, we move from listing the relevant determinants to formulating the guidelines, which are themselves recommendations, not rules, based on how these relevant determinants affect the success rate of an R&D collaboration project. From Table 1, the descriptions of the influences of the determinants can be used as a guideline in the process of forming an R&D collaboration between two partners. For example, it has been concluded that the size of a firm, and its prior experience with R&D collaborations, have a positive impact on the propensity of a firm to form R&D collaborations. It implies that, when you are in the position to choose between two otherwise similar firms, you are advised to start the formation process with the larger firm that has more experience on collaborations. Table 2 can be used to categorize a firm's prime considerations in the process of forming an R&D collaboration.

Among the inter-organizational collaborations that have been studied there are many collaborations between two partners, but can we also apply the above findings fully to a multi-partner collaboration, important for biobased innovations? We will address this question in the next section.

## Multi-partner R&D collaboration

This section addresses the relevant literature on multi-partner R&D collaborations. It is divided into four subsections: determinants of a multi-partner R&D collaboration, conflicts in the literature addressing these determinants, complexity of projects, and biobased R&D collaborations.

### Determinants of a multi-partner R&D collaboration

This subsection gives an overview of the determinants of a multi-partner R&D collaboration, including publications

concerning multi-partner alliances and networks. Note that we stay away from the literature on the alliance portfolio of individual firms<sup>66</sup> to focus instead on multi-partner R&D collaborations. A multi-partner alliance brings additional complexity, on the one hand, going beyond the mere summation of the collaborations between two partners.<sup>67</sup> On the other hand, such alliances focus attention more narrowly, thus only on a subset of all the ties that comprise an innovation network.<sup>18</sup> An innovation network can be defined as a loosely tied group of organizations that may consist of members from industry, government, and research institutes collaborating to achieve common innovation goals.<sup>68</sup> The formation processes of multi-partner R&D collaborations can be enriched by studying the collaborations as an innovation network forms.<sup>69</sup> We divided the determinants for the formation process of a multi-partner R&D collaboration into the same three groups as in the previous section: partner properties, motives, and appropriability. Project properties are added as a fourth group, which the literature describes as determinants for a multi-partner R&D collaboration. In Table 3 we give a description of all the determinants mentioned above and their influences on the process of forming a multi-partner R&D collaboration.

In general, the literature is clear on individual determinants, and the influence on the process of forming collaborations is straightforward. The studies regarding R&D intensity, prior experience, and the degree of industry competition give conflicting results (Table 3).

### Conflicts in the literature addressing determinants

This subsection addresses the three conflicting results in literature regarding determinants for the formation process of a multi-partner collaboration and their influences. According to a Japanese case study, the R&D intensity of the firms in the consortium is positively related to the process of forming an R&D consortium.<sup>70</sup> This is comparable to the results regarding collaborations between two partners (Table 1). However a Taiwanese case study concluded that R&D intensity has no significant influence on the behavior of firms joining a multi-partner R&D collaboration.<sup>71</sup> Another case study also focused on the determinants influencing the creation of new resources.<sup>72</sup> The results of the latter study show that firms with strong internal capabilities (R&D intensity) and linkage of their assets and goals to the collaboration develop resources (e.g. products, patents, prototypes, competences).<sup>72</sup> Based on the foregoing literature, we derive that the effect of the R&D intensity of a firm on an R&D collaboration can

**Table 3. Determinants for the formation process of a multi-partner collaboration and their influences.**

Determinant	Description	Description of influence	Contrasting results
<b>Partner properties</b>			
Size	The number of employees within a firm	Positively related to the formation of an R&D consortium <sup>70</sup>	
Firm age	The number of years the firm exists	Positively related to the formation of an R&D consortium <sup>70,71</sup>	
R&D intensity	The annual R&D investments divided by the sales of that year	Positively related to the formation of an R&D consortium <sup>71</sup>	No significant influence on formation <sup>70</sup>
Prior experience	The amount of experience of a firm with R&D collaborations	Positively related to the formation of an R&D consortium <sup>71</sup>	No significant influence <sup>70,73,74</sup>
Prior experience	The partners know each other from previous projects	Positively related to the formation of an R&D consortium <sup>74</sup>	
Network capabilities	The ability of a firm to build networks	Positively related to the formation of an R&D consortium <sup>71,73</sup>	
Type of partner	Horizontal versus vertical collaboration	An horizontal R&D consortium is hard to establish. Severe circumstances are necessary for competitors working together. <sup>14</sup> R&D consortia consisting of both horizontal and vertical collaboration (horizontal-vertical collaboration) appear to be stronger than pure horizontal or pure vertical collaborations <sup>14</sup>	
Type of partner	The degree of industry competition a firm is part of	The higher this degree the more there is a tendency to join an R&D consortium. <sup>70</sup>	Contrary results <sup>71</sup>
Type of partner	The degree of product market competition among consortium members	The degree is negatively associated with the outcome of an R&D consortium <sup>64,77</sup>	
Type of partner	Type of industry: for example chemical, food, energy	A diverse portfolio is positively related to the formation of an R&D consortium <sup>70,71</sup>	
Type of partner	Type of industry: for example chemical, food, energy	A diverse portfolio in partners is better for the performance of a collaboration. Only the performance of multinationals is lower. <sup>78</sup>	
Geographic position	The geographic distance between the two partners	Negatively related to the formation of an R&D consortium <sup>74,79</sup>	The formation of high-tech industrial clusters on a location can nullify the advantage of a local partner because of the lack of privacy <sup>80</sup>
<b>Motives</b>			
Motives	The motive of a firm to join an R&D collaboration	Cost sharing, risk sharing, and skill sharing <sup>13,64</sup>	
<b>Appropriability</b>			
Appropriability condition of a firm	The number of patents filed by the firm	Positively related to the rate of R&D consortia formation <sup>70,71</sup>	
Spillover	The knowledge obtained by a partner from the other partner during the project	Positive influence on the outcome of an R&D consortium <sup>77</sup>	

**Table 3. (Continued).**

Determinant	Description	Description of influence	Contrasting results
Project properties			
Type of R&D	Type of project: Basic research, applied research, and development	Collaborations have more impact when they conduct relatively basic, rather than relatively applied R&D <sup>64,77</sup>	
Type of project	Exploitation versus exploration project	The factors, size of the consortium, type of partner, density and intensity of the network, are different for exploitation projects than for exploration projects <sup>81</sup>	

vary depending on the phase of the collaboration. The R&D intensity had little effect on the formation process<sup>71</sup> but has serious effects on the resources created.<sup>72</sup>

The Japanese case study mentioned above also showed a positive relationship between prior experience and the formation process of an R&D consortium. However, other more recent studies could not find a significant influence of prior experience on the formation process of an R&D collaboration.<sup>71,73,74</sup>

Finally, regarding industry competition, we find that an R&D consortium with competing partners (horizontal consortium) is hard to establish. Difficult circumstances are needed for competitors to work together<sup>14</sup> – for example, when the development of a next-generation product is far too risky and too expensive for a single firm to carry on its own. The higher the degree of industry competition, the more there is a tendency to join an R&D consortium.<sup>71,75</sup> The differences in the findings of similar studies have been explained by differences in actions between well-established firms and emerging firms.<sup>70</sup> In the earlier Japanese case study<sup>70</sup> only a minority of the partners were emerging firms. In contrast, from a study on firms that catch up on emerging technologies it is clear that, in that case, a collaboration between emerging competitors is really necessary.<sup>71</sup>

## Complexity of projects

In this section we look at complexity of a foreseen multi-party project in relation to the conflicts in results described in the previous section. How can we explain these conflicts? The complexity of an R&D project depends on several determinants, such as the type of partners, type of project, type of consortium and type of innovation. Table 4 specifies these determinants and their influence on the formation process of multi-partner R&D collaborations.

The information in Table 4 can be used as a guideline, consisting of recommendations rather than rules, for the process of forming an R&D collaboration. For example, if one wants to set up a consortium to develop an incremental

innovation, that consortium preferably consists of firms involved across stages of the value chain. However, it becomes a different situation where both options of one determinant are applicable. For example, when the project involves both exploration and exploitation, it is not clear which study result is applicable: The influences of the factors size of the consortium, type of partner, density and intensity of the network, are different for exploitation projects and exploration projects. The more both options of the determinants of an R&D collaboration are applicable, the higher the degree of complexity of an R&D collaboration, and the less applicable is the information in Table 4 as a guideline during the process of forming a multi-partner collaboration. This can also be the reason for the conflicting results in Table 2. Further research is necessary on this matter.

## Biobased multi-partner R&D collaborations

In addition to the complexities of a multi-partner collaboration, biobased collaborations may have characteristics, described above, that make a collaboration more complex. The influence of the type of innovation (drop-ins versus novel materials), biorefinery, biomass supply, and technological challenges to the collaboration have not been studied as yet. Variables regarding new collaborations (like strong and weak ties) and new chains (like network wholes) have been addressed in network theory studies,<sup>76,81,82</sup> but the effects of these variables on a biobased R&D collaboration have not been studied. This leads to the following overall conclusion: the complexity of biobased R&D collaborations can differ. So if we apply the above presumption to biobased R&D collaborations, the information in Tables 2 and 4 can be used as a guideline for relatively less complex collaborations. It does not, however, apply straightforwardly to complex collaborations. These collaborations may require an orchestrator as a triggering entity. Further research into these issues is needed.

**Table 4. Determinants influencing the complexity of an R&D collaboration.**

Determinants and options	Description of the influence
Type of partners	
Well-established versus emerging technologies	Catching up on emerging technologies: a collaboration between competitors is necessary. Well-established technologies: No influence of the type of partners. <sup>70,71</sup>
Partners with state-of-the-art technology versus others	A partner with state-of-art technology tends to join an R&D collaboration because by joining the collaboration it can decrease the R&D expenditure and increase the R&D capacity. A partner with outdated or no technology needs to scale up its own R&D activities. <sup>12</sup>
Type of project	
Exploitation versus exploration	The influences of the determinants, size of the consortium, type of partner, density and intensity of the network, are different for exploitation projects vs exploration projects. <sup>81</sup>
Type of consortium	
Horizontal versus vertical	R&D consortia consisting of both horizontal and vertical collaborations (horizontal-vertical collaboration) appear to be stronger than purely horizontal or purely vertical collaborations. <sup>14</sup>
Type of innovation	
Incremental versus radical	A radical innovation has a higher chance to succeed in a horizontal consortium or if the partners come from a different kind of industry. An incremental innovation has a higher chance to succeed in a vertical consortium and / or more geographically distributed partners. <sup>14,52,82–84</sup>

## Orchestration of the formation process

The process of forming an R&D consortium and the corresponding decisions can be orchestrated by a triggering entity. Doz and Baburoglu<sup>47</sup> describe two types of formation processes: emergent and engineered processes. In an emergent process a collaboration is driven by interdependencies (e.g. common threats, finding access to similar resources) and similar interests of the partners. An engineered process is led by a triggering entity. This entity may have great added value for the formation process by taking the lead in three main functions: innovation initiation, network composition, and innovation process management.<sup>16</sup> This orchestrator therefore affects the type of partners (size, diversity), network structure (density, autonomy) and network position (centrality, status).<sup>17</sup>

Table 5 gives an overview of the characteristics of emergent and engineered formation processes and the differences between the two. These characteristics can be used to categorize the formation process of a collaboration to better understand the process itself and the orientation of the final consortium. Consortia formed through engineered processes may be more likely to have an explorative orientation. On the other hand, the orientation of consortia formed

through emergent processes is more likely to be focused on exploitation.<sup>18</sup> Although engineered collaborations are not likely to involve competitors, a neutral party like an orchestrator can help to account for competitors being able to collaborate on a specific project while remaining competitors elsewhere.<sup>12</sup>

Over time, one type of formation process can transform into the other type.<sup>18</sup> For instance, as the partners in a collaboration created by an engineered process improve their relationship and see that they have similar interests, then the context may be created for an emergent process to develop. For the survival of an R&D collaboration over time it is important to realize a balance between efficiency and innovation, and therefore a balance between characteristics from both emergent and engineered processes.<sup>12,18</sup>

Based on the two types of processes (engineered and emergent) and the motivation to join an R&D consortium (network cooperation or risk sharing), four types of partners (see Table 6) can be described with appropriate success rates: community builders, gamblers, visible hands, and opportunists.<sup>15</sup>

The information in Tables 5 and 6 can be used *ex ante* to better understand the formation process of a multi-partner R&D collaboration by categorizing the formation process (emergent or engineered) and the motives of the partners

**Table 5. Differences between emergent and engineered processes.<sup>18</sup>**

Activity	Emergent process	Engineered process
Characterization of network	Competitive collaboration	Options exploration
Environmental interdependencies	Strong effect	Less pronounced effect
Similar interest	Strong effect	Less pronounced effect
Triggering entity	No direct effect may not be required	Necessary for formation process
Open solicitation	Open to interested parties, likely to be similar organization – snowball effect	Triggering entity targets diverse members – hub and spoke effect
Seeking domain consensus	Defining boundaries	Aligning interests
Expectations of continuity	Strong, until opportunity or threat is dealt with	Very low at onset
Formal structure	Tight coupling to constrain opportunism	Filling structural holes, loose coupling
Escalation of commitment and satisfaction	Tight of escalation and disappointment	Unmet expectations unless transformed
Evidence of learning	Contingent on nature of the context	Likely to be low

**Table 6. Types of partners in an R&D consortium.<sup>15</sup>**

		Motive
Process Emergent	Network cooperation	Risk sharing
	Community builders No dominant player and no one player can do it alone	Gamblers Fears over appropriability of R&D need to be balanced over the lack of resources
Engineered	Visible hands Concerns for legitimacy outweigh lack of technological democracy	Opportunists Pay or bribe firms to share vision or have firms pay to explore that vision

(network cooperation or risk sharing). Again, if the formation process becomes more complex, showing characteristics of both an engineered process (orchestrator) and an emergent process (environmental interdependencies), Table 5 is less useful for the process of forming a multi-partner R&D collaboration. Moreover, if the partners of the collaboration have different motives (e.g. network cooperation, risk sharing), the typification of partners (Table 6) is also less useful for the process of forming a multi-partner R&D collaboration. Thus, the conclusions in the previous section regarding the complexity of a biobased R&D collaboration also apply to the orchestration of the formation process.

## Conclusions

This paper provided an overview of the relevant transition and innovation models that can be used to analyze and improve the process of forming an R&D collaboration. Transition models can give a broader perspective on an innovation and the variables involved. In addition to the type and sequence of steps of an innovation, a transition model analyzes the world around it at landscape and

regime level. An SNM/MLP analysis gives a description of the niche, regime, and landscape level relevant for a specific innovation and the variables involved. For example, information about the stakeholders at the regime level is useful for the partner search during the formation process. For instance, in situations of globally expected rising oil prices, chemical companies without ownership of a naphtha cracker for the production of their feedstock from oil may be more willing to look for feedstock diversification and thus consider biomass as a raw material. These companies are potential partners for biobased developments. Changes in the landscape and regime level can thus create opportunities and threats for the innovation. A TIS analysis can be used to analyze the status of the R&D consortium during the formation process at a certain moment in time based on seven functions (entrepreneurial activities, knowledge development, knowledge exchange, guidance of the search, formation of markets, mobilization of resources, and counteracting resistance to change) and point out the possible underdeveloped functions. Innovation models give a useful insight into the type and sequence of the steps of an innovation – the steps that one needs to take before market

introduction. Based on these steps, choices have to be made by firms / brokers during the process of forming a biobased R&D consortium. We conclude that, although each model has its advantages, as far as we know, none of the transition and innovation models in literature addresses both the formation process phases of a biobased R&D collaboration and the variables involved.

A vast amount of research has been done on the general determinants of an R&D collaboration. Partner properties, motives to join a consortium, and appropriability of a firm are the main determinants of an R&D collaboration between two partners. The literature describes another group determinant for a multi-partner R&D collaboration: project properties. The influence of biobased characteristics such as type of innovation (drop-ins versus novel materials), biorefinery, biomass supply, and technological challenges on the formation process of an R&D collaboration is not addressed in the literature.

Table 7 gives an overview of the variables (biobased characteristics and general determinants) addressed in the literature regarding biobased R&D collaborations based on the well-known Social, Technological, Economic, Environmental, Political variables (STEEP) categorization. The literature has given little attention to the effect of political variables on the process of forming an R&D collaboration. The effect of legal variables like subsidies and contracts on the other hand has been studied extensively. This is a major topic on its own and therefore we did not address it in this paper.

These variables from a wide range of categories affect a biobased R&D collaboration. A model describing the process of forming a biobased R&D collaboration should therefore address these variables. Such a model is not yet available in the literature. The description of the influences of the variables in Tables 1, 3, and 4 can be used as a guideline, as recommendations, and the information in Tables 2, 5 and 6 can be used to better understand the formation process of an R&D collaboration. However, we also recognize that the more complex an R&D collaboration, the more the influences of the determinants of the R&D collaboration may counteract each other, and the less clear-cut the information is for the process of forming the R&D collaboration.

Doz and Baburoglu<sup>47</sup> describe two types of formation processes: emergent and engineered processes. An engineered process is led by an orchestrator. An orchestrator may have great added value for the process of forming an R&D collaboration by taking the lead in three main functions: innovation initiation, network composition, and innovation process management. Especially for biobased R&D collaborations, where partners from different sectors often need to collaborate, an orchestrator can play a vital role.

Further dedicated research into complex multi-partner R&D collaborations in specific biobased collaborations and their determinants is essential, to better understand the formation processes of these R&D collaborations.

**Table 7. Variables for the formation process of a biobased R&D collaboration.**

Category	Variables
Social/consortium	<p><b>Biobased characteristics:</b> Type of innovation, new collaborations, technological challenges, new chains/ market players and societal sensitive issues</p> <p><b>Partner properties, motives, appropriability and type of partner</b> (Tables 1–4)</p> <p><b>Project properties:</b> Type of R&amp;D, type of project, resources and risks) (Tables 2–4)</p> <p><b>Type of consortium:</b> horizontal versus vertical (Table 4)</p>
Technological	<p><b>Biobased characteristics:</b> Type of innovation, bio-refinery, biomass supply, technological challenges</p> <p><b>Project properties:</b> type of R&amp;D (Table 3)</p> <p><b>Type of innovation:</b> incremental versus radical (Table 4)</p>
Economic	<p><b>Biobased characteristics:</b> Type of innovation, bio-refinery, new collaborations, biomass supply, technological challenges, new chains and market players</p> <p><b>Partner properties, motives, appropriability and type of partner</b> (Tables 1–4)</p> <p><b>Project properties:</b> Type of R&amp;D, type of project, resources and risks) Tables 2–4</p> <p><b>Type of consortium:</b> Horizontal versus vertical (Table 4)</p> <p><b>Type of innovation:</b> Incremental versus radical (Table 4)</p>
Environmental/biobased	<p><b>Environmental characteristics:</b> CO<sub>2</sub> reduction, renewable resources</p> <p><b>Biobased characteristics:</b> Type of innovation e.g. environment friendlier alternatives</p>



Furthermore, the formation process influences the success of a multi-partner R&D collaboration, but, as far as we know, there is no model in the literature addressing the relevant variables (e.g. economic, social, and technological) per phase, to analyze and improve this formation process. Finally, further research is needed to determine the influence of biobased characteristics on the process of forming a multi-partner R&D consortium. We want to pursue this research agenda and invite others to join in, to the benefit of a successful transition to the biobased economy.

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