# Complementarity of Strategic Assets: A Symbiotic Evolutionary Model for Open Innovation

***Complementariedad de activos estratégicos: un modelo evolutivo simbiótico para la innovación abierta***

***Complementariedade de Ativos Estratégicos: Um Modelo Evolutivo Simbiótico para Inovação Aberta***

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ARTICLE




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### Abstract

This article proposes a theoretical model that simulates the propensity to establish mutualistic symbiotic relationships between corporations and startups on open innovation programs. Inspired by the concept of symbiosis, the Evolutionary Model of Symbiotic Relationships for Innovation identifies the pairs with the major complementarity of strategic assets necessary for the generation and capture of the value of innovation projects and determine if this relationship promotes gains for both parties. The model has been applied in a single case study, subunits of analysis incorporated. The results show a correlation between the propensity indicated by the model and the selection actually performed.



***KEY WORDS***

Open Innovation, Corporate Engagement with Startups, Strategic Assets, Complementarity, Symbiosis.



### Resumen:

Este artículo propone un modelo teórico que simula la propensión a establecer relaciones simbióticas mutualistas entre corporaciones y startups en programas de innovación abierta. Inspirado en el concepto de simbiosis, el Modelo Evolutivo de Relaciones Simbióticas para la Innovación identifica los pares con la mayor complementariedad de los activos estratégicos necesarios para la generación y captura del valor de los proyectos de innovación y determina si esta relación promueve ganancias para ambas partes. El modelo se aplicó en un solo estudio de caso. Los resultados muestran una correlación entre la propensión indicada por el modelo y la selección realmente realizada.



**PALABRAS CLAVE:**

Innovación abierta, Compromiso corporativo con nuevas empresas, Activos estratégicos, Complementariedad, Simbiosis.



### *Resumo*

Este artigo propõe um modelo teórico que simula a propensão a estabelecer relações simbióticas mutualísticas entre corporações e startups em programas de inovação aberta. Inspirado no conceito de simbiose, o Modelo Evolucionário de Relações Simbióticas para Inovação identifica os pares com maior complementaridade de ativos estratégicos necessários para a geração e captura do valor dos projetos de inovação e determina se esse relacionamento promove ganhos para ambas as partes. O modelo foi aplicado em um único estudo de caso, com subunidades de análise incorporadas. Os resultados mostram uma correlação entre os resultados do modelo e a seleção efetivamente realizada.

***Palavras-chave***

Inovação Aberta, Engajamento Corporativo com Startups, Ativos Estratégico, Complementariedade, Simbiose.

## 1. INTRODUCTION

The intense process of technological disruptions, globalization, among other changes, has generated greater market complexity, growing competitiveness (Bennet & Bennet, 2004), structural changes in the economy and the emergence of new trade spaces and types of products (Teece, 1998). In this scenario, the role of innovation is an increasingly important topic in the debate on economic growth, competitiveness and sustainability (Tidd, 2006).

In this new scenario, startups have proven to be powerful engines of knowledge creation and come to play a key role in innovation processes (Spender et al., 2017). To achieve a desirable innovative performance, corporations have sought to establish forms of engagement with startups as part of their open innovation efforts.

Startups have a huge competitive advantage over large corporations in terms of agility. On the other hand, large corporations have resources that startups can only dream about. The combination of entrepreneurial activity with corporate capacity seems to be a perfect combination, but that can be difficult to achieve (Weiblen & Chesbrough, 2015).

To better understand the dynamics of these cooperative relationships between startups and corporations, the 'Resource-Based Theory of Competitive Advantage' (Grant, 1991) offers a rich field for the understanding of strategic assets for innovation, defined by Teece (2004) as the set of resources that can generate competitive advantage for the company in its innovative process.

In the search for inspirations that help understand the establishment of cooperative relationships between such different actors and given the complexity of a wide range of attributes that describe their natures, it is observed that computational models inspired by biology offer a wide range of opportunities for representation, analysis and simulation of various problems (Watson & Pollack, 1999), such as the relationship of organizations in open innovation programs.

This article proposes an Evolutionary Model of Symbiotic Relationships for Innovation. It simulates the propensity to establish mutualistic symbiotic relationships between corporations and startups on open innovation programs. Inspired by the concept of symbiosis, the goal is to identify the pairs with the major complementarity of strategic assets necessary for the generation and capture of the value of innovation projects and determine if this relationship promotes gains for both parties.

## 2. THEORETICAL FOUNDATION

The theoretical foundation that sustains the present article was built based on correlated studies that discuss the corporate engagement with startups on open innovation programs, strategic assets for innovation, evolutionary algorithms, and symbiotic relationships. Therefore, the following topics are the most relevant aspects that are necessary to understand the proposed model.

### 2.1. CORPORATE ENGAGEMENT WITH STARTUPS IN OPEN INNOVATION

Corporations are defined as large and formal organizations controlled by a technostructure of professionals (Hillman, 1970), considered in this study as private companies, with more than 5 years of existence, of large size, operating in traditional economic sectors and with mature business models. These organizations are characterized by conditions that slow or hinder innovation (Freeman & Engel, 2007; Leonard-Barton, 1998; Spender et al., 2017; Thieme, 2017; Weiblen & Chesbrough, 2015)this study aims at deepening our understanding of the theme and at providing directions for future research. Design/methodology/approach – By using an explicit method for the review (Pittaway et al., 2004, often arising from their own trajectory and, paradoxically, due to factors that were at the origin of their competitive advantages in the past (Leonard-Barton, 1998).

In contrast to the constraints faced by corporations to innovate, startups are organizations created to conceive and develop new business models in a typical process of creative destruction. These are organizations with dynamic capabilities related to agility in developing new value offerings for the market, with reduced cost, networking and greater dynamism. The intrinsic capabilities of startups allow them to play an important role in innovation processes. Although there is no universal definition, startups are temporary organizations that aim to find a new business model that can generate value for its clients and enable this value to be captured in a reproducible, scalable and profitable manner (Blank & Dorf, 2012), in extremely uncertain environments (Ries, 2011).

Spender et al. (2017) observe that open innovation is an important way for large corporations to achieve greater agility in the development of new value offers for the market, with lower costs and greater dynamism in the face of an intense ongoing technological revolution. On the other hand, the existence of relationships with external partners is a priority for the success of startups, given the lack of tangible and intangible resources for the development of innovation processes (Spender et al., 2017).

Corporate engagement with startups is a concept that emerges from the field of Open Innovation and is seen as its subset and a form of its implementation (Thieme, 2017).

Throughout this uncertain and dynamic process of open innovation, which begins at the conception of new knowledge, ideas, products, business models, and ends with its introduction into the market, the complementarities present themselves and can generate mutual gains (Spender et al., 2017; Thieme, 2017; Weiblen & Chesbrough, 2015).

### 2.2. STRATEGIC ASSETS FOR INNOVATION

Understanding a company as a broad set of strategic resources available for the formulation of competitive strategies is a way to understand the factors that can influence the motivation and barriers observed for the establishment of strategic alliances between startups and corporations with a view to innovation. The 'Resource-Based Theory of Competitive Advantage' is a perspective that has grown considerably in recent years as a result of the understanding of the balance between the dimensions internal and external to the companies in the formulation of competitive strategies (Grant, 1991). The company is understood as a broad set of resources (tangible and intangible), i.e., assets, which are available for the formulation of strategies for facing the market in search of competitive advantages that allow them to achieve economic income or above-normal rates of return (Das & Teng, 2000). Therefore, a resource is considered valuable if it helps the company to create strategies that capitalize on opportunities and ward off threats.

According to Teece (1998), companies are repositories of knowledge that are embedded in processes and routines that support the assets and specific competencies of these companies. However, superior technology alone is rarely sufficient for competition in the current day. The competitive advantage can be attributed not only to ownership of (1) Knowledge Assets but also to the combination of these with others; (2) Complementary Assets, necessary to create and capture the value of knowledge; and (3) Dynamic Capabilities, characterized by enabling the identification of opportunities to obtain competitive advantages and by organizing resources to exploit their potential in the face of these opportunities (Teece, 1998).

## 2.3. EVOLUTIONARY ALGORITHMS

Assembling the taxonomy tree of the research algorithms, the genetic algorithms, and the algorithms based on symbiotic processes – 'compositional evolution' - are in the branch called Evolutionary Algorithms. These are methods that simulate, through algorithms, natural (biological) evolution processes, mainly aiming to solve optimization problems (Barcellos, 2000).

An evolutionary algorithm is a procedure that interacts over a set (population) of data (individuals) for a number of times (generations). Additional biological concepts apply, such as the evaluation of the fitness of the individual and its genes, as the defining element of the attributes of these individuals. The set of genes of an individual is called the chromosome (Sampaio et al., 2018; Lacerda, 2018).

Genetic algorithms form a class of research algorithms based on natural evolution (Barcellos, 2000). However, a key aspect that is not captured by a model based on genetic algorithms is the processes that occur above the species level, that is, between different 'species'. The variation offered by symbiosis is qualitatively different from the sexual crossing, as it offers the possibility of joining two sets of genetic materials (Mills & Watson, 2007; Watson & Pollack, 1999).

## 2.4. SYMBIOTIC RELATIONSHIPS

Symbiosis, in its general definition, is the collaboration between different organisms. Frequently, the term is used to refer to the special case of mutualism, where symbionts (organisms in symbiotic relationships) mutually benefit from the established relationship (Watson & Pollack, 1999).

The present study considers that all organisms in an ecosystem interact with each other, establishing relationships, regardless of whether they are genetically close or distant. The interactions may be short, medium or long term, and the relationships may involve distant or close individuals. They may be intraspecific, within the same species, and interspecific, between different species. These relationships, in turn, can lead to co-evolutionary processes or result in little or no apparent consequence to the adaptive process (Asima & Rajat Kumar, 2018).

Additionally, relationships may or may not result in mutual gains for those involved. In this sense, the representation of these interactions can be expressed by mathematical symbols, representing the impact on the involved parts; for example, the expression '+/+' represents a situation when both parties gain from the interactions (Asima & Rajat Kumar, 2018).

In addition to Mutualism [+/+], other categories of relationships can be observed in the field of symbiosis, such as Commensalism [0/+], Parasitism [-/+], Amensalism [-/0] and Neutralism [0/0] (Asima & Rajat Kumar, 2018; Martin & Schwab, 2012).

Symbiosis can be recognized as a key source in the evolutionary process. In its strongest form, symbiosis can lead to symbiogenesis: the genesis of new species through the genetic integration of symbionts. For example, eukaryotic cells, from which all plants and animals descend, have a symbiotic origin (Watson & Pollack, 1999).

In these eukaryotic cells, the relationship with the mitochondria offers a rich example of the symbiotic relationships that resulted in adaptive evolutionary processes and that inspire the present study. Mitochondria are cellular organelles present in most eukaryotic cells (that have their own genetic structure) and are responsible for processing and generating energy for the host cell (Embley et al., 2003).

## 3. EVOLUTIONARY MODEL OF SYMBIOTIC RELATIONSHIPS FOR INNOVATION

The Evolutionary Model of Symbiotic Relationships for Innovation (EMSRI) aims to evaluate the propensity to achieve mutualistic symbiotic relationships between a corporation and startups, considering evidence of the complementarity of strategic assets for innovation of these organizations.

It is a heuristic model of symbiotic evolution that aims to describe the behavior of the factors that influence the formation of symbiotic relationships between startups and the corporation and therefore does not intend to have a deterministic character. Its conception provides a method to support decision-making that corporate managers involved in open innovation programs, or even entrepreneurs of startups, can consider when evaluating potential partners with whom they can cooperate in open innovation programs.

The starting point was inspired by the Monteiro et al., (2015) model, based on his PhD thesis (Monteiro, 2012)om a \u001cnalidade de failitar a difusão do onheimento e, omo onsequênia, aumentar a ompetitividades das empresas omponentes do APL. Para tanto, foram: (i, in addition to other related works (Sampaio et al., 2018; Lacerda, 2018; Carneiro, 2014; Monteiro et al., 2014).

All of these works studied the impact of affinity on the relationships of cooperation and diffusion of knowledge. Monteiro (2012) has mature companies as its object of study and application from the same sector. Carneiro (2014) studies the dissemination of knowledge, based on the technological profile of students. Lacerda (2018) and Sampaio et al., (2018) investigates the process of creating and disseminating knowledge of a certain organizational competence among employees of the same company.

In the same way, previous studies have addressed the formation of networks by entities of the similar nature and consider the similarity between them a condition for their affinity.

However, none of them discussed the propensity to establish relationships between individuals of different natures. EMSRI was distinguished, throughout the development, for its application in a new context formed by different entities, such as startups and corporations, characterized by distinct and complementary attributes.

In this context, the understanding of the formation of symbiotic relations between entities of different natures emerges with the complementarity of attributes as a primordial condition for the formation of cooperative relations, differently from the similarity understood in the other studies addressed.

To assess the propensity to form mutualistic symbiotic relationships between startups and corporations in open innovation programs, the complementarity of strategic assets for innovation of the studied actors is considered (Teece, 1998; 2004). The goal is to identify pairs of organizations that have complementary strategic resources necessary for the generation and capture of the value of innovation projects and for this relationship to generate gains for both parties.

The main contribution of the model is the creation of an environment conducive to the study of the establishment of mutualistic symbiotic relationships between corporation and startups, i.e., the formation of cooperative relationships involving actors of different natures, an unprecedented factor in the cases cited above. In addition, it studies an application field that, for economic, technological and demographic reasons, has developed a lot in recent years, namely, the importance of the cooperation process of corporations with startups as a way to promote innovation.

## 3.1. GENERAL CHARACTERISTICS OF THE MODEL

This model shares some of the characteristics of evolutionary algorithms. The model uses a population of entities, represented by chromosomes, genes and alleles, and a fitness function to indicate the propensity to establish symbiotic relationships. However, there are important differences. In evolutionary algorithms, entities are usually interpreted as belonging to the same species, but in EMSRI, the set of entities represents an ecosystem of species of different nature.

It is considered that complementary characteristics of the actors, i.e., chromosomes and their genes, determine the propensity to establish cooperative relationships in open innovation programs. Thus, the actors will establish symbiotic relationships if they identify attributes in the other party that motivate them to do so. Therefore, an actor will establish a cooperative relationship for innovation due to the characteristics of the other parties that represent a potential for complementarity with their attributes, thus seeking an optimization of their innovative capacity.

The fitness function is a mapping of the combination of a set of resource values that represents the complementarity between ecosystem components. It is assumed that the establishment of symbiotic relationships tends to form combinations more adapted to the context insofar as they meet the interests declared by them. It is also assumed that the relationships between entities are unstable and complementary, i.e., fitness can vary over time.

The EMSRI adopts the representation of an ecosystem, formed by entities that comprise two subsets of different species: 'corporation species' and 'startup species'.

### 3.1.1. CHROMOSOMES AND GENES

To characterize the individual components of the studied ecosystem, the model adopts the concept proposed by Teece (1998, 2004) and proposes the representation of 3 Chromosomes: (1) Knowledge Assets; (2) Complementary Assets; and (3) Dynamic Capabilities.

These Chromosomes are encoded using the Genes that compose them. The following assumptions guide the characterization of Genes:

1.- The actors have **Mastery** of a set of Assets;

2.- The actors show **Willingness** to share their set of Assets;

3.- The actors show **Interest** in obtaining new Assets;

4.- The actors show **Ease** of assimilating new Assets;

5.- The Mastery, the Willingness to share, the Interest in obtaining, and the Ease of assimilation can be measured.

From these assumptions, it is defined, therefore, that each actor is represented by a set of chromosomes and that these are encoded based on the sequence of genes and their alleles. Thus, the coding of chromosomes is given from 4 genes, namely:

1.- **Mastery (MAS)** of the chromosome;

2.- **Willingness (WIL)** to share the chromosome;

3.- **Interest (INT)** in obtaining additional resources related to that chromosome;

4.- **Ease (EAS)** of assimilating additional resources related to that chromosome.

Thus, one has a set of 3 Chromosomes (Knowledge Assets, Complementary Assets and Dynamic Capabilities) coded by 4 Genes (Mastery, Willingness, Interest and Ease), as explained in Figure 1.

### 3.1.2. CHROMOSOME ALLELES

Attributes that characterize individuals and that influence the propensity to establish symbiotic relationships are established. The alleles, therefore, are the specific variations of these Genes that determine how the trait is expressed in an individual.

For the specification of the Chromosome alleles, a set of possible attributes is adopted for the implementation of the model, but the number of attributes and their specification can be flexible in alternative implementations.

In this study, attributes that can be measured and expressed in relation to Genes (Mastery, Interest, Willingness and Ease) were chosen, as described in Table 1.

The alleles of the chromosomes are represented by positive real numbers with three decimal places in a range from 1 (one) to 5 (five). The use real numbers rather than integers is because of the choice to obtain the values of Alleles from simple means of the values observed in the Representative Attributes.

**Figure 1**

*Representation of the Proposed Genetic Structure*

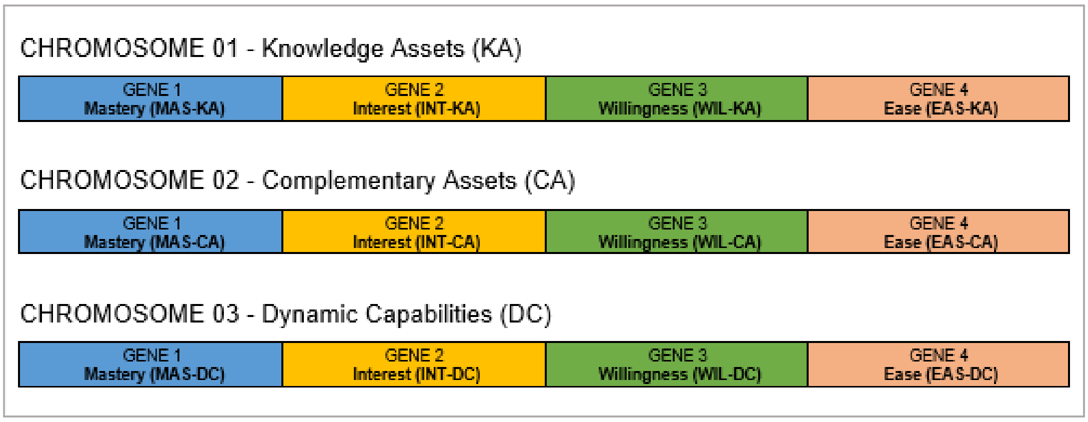



**Table 1**

*Representation of Chromosomes, Genes and Alleles*

| CHROMOSOME | ATRIBUTES | GENES | | | |
|---|---|---|---|---|---|
| | | Mastery | Interest | Willingness | Ease |
| Knowledge Assets (KA) | KA1. Technological knowledge in potential fields of interest | 4,500 | 3,523 | 3,098 | 4,000 |
| | KA2. Market knowledge (customers, suppliers, competition etc.) | 1,287 | 1,743 | 2,176 | 2,798 |
| | KA3. Knowledge of Emerging Business Models | 2,587 | 2,254 | 1,954 | 3,076 |
| Complementary Assets (CA) | CA1. Available productive capacity | 4,008 | 1,565 | 1,023 | 3,054 |
| | CA2. Market Reputation | 3,176 | 4,276 | 1,212 | 2,576 |
| | CA3. Access to distribution channels | 2,565 | 3,287 | 2,212 | 3,577 |
| | CA4. Bargaining power (with suppliers, distributors or retailers) | 3,554 | 4,090 | 2,034 | 3,021 |
| | CA5. Management Domain (tools, process maturity, governance) | 3,537 | 4,078 | 4,523 | 4,712 |
| Dynamic Capabilities (DC) | DC1. Creativity | 3,583 | 4,021 | 4,534 | 4,798 |
| | DC2. Agility, Flexibility and Dynamism on Organizational Action | 3,578 | 4,033 | 4,556 | 4,776 |
| | DC3. Networking | 3,098 | 2,754 | 1,578 | 2,046 |
| | DC4. External Sensing | 1,501 | 4,250 | 4,340 | 3,120 |

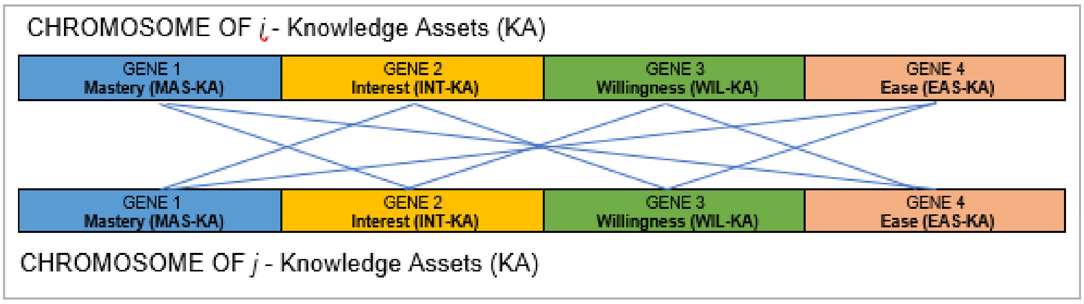
## 3.2. PROPENSITY TO ESTABLISH THE SYMBIOTIC RELATIONSHIP (PESIR)

One of the model's premises is the understanding that the formation of symbiotic relationships depends on the complementarity of their characteristics. For that, it is proposed that the Propensity to Establish the Symbiotic Relationship (PESIR) will take place considering the following rules:

1.- If the Interest (INT) and Ease (EAS) genes on one individual's chromosome is similar to the Mastery (MAS) and Willingness (WIL) genes on the same chromosome from another individual;

**Figure 2**

*Representation of the genetic complementarity relationships between two different individuals - i and j - according to the EMSRI*




2.- There is reciprocity, i.e., that the Interest (INT) and Ease (EAS) gene on the second party chromosome also have similarity with the Mastery and Willingness gene on the first party on the same chromosome;

3.- These conditions will be analyzed on the 3 chromosomes of the individuals.

Figure 2 illustrates the observable complementarity relationships between the genes on chromosomes from two different individuals - *i* and *j*. In this case, the chromosome "Knowledge assets" is illustrated, as an example.

Thus, considering the existence of two actors ***i*** and ***j***, the Propensity to Establish the Symbiotic Relationship (PESIR) will be evaluated for each chromosome of ***i*** in relation to ***j*** (PESIR ***ij***), represented by Equation 1:

(1)

The PESIR is obtained from each chromosome and, from the calculation of the simple average of the observed values, there is an Overall Propensity.

The "MAX" variable represents the highest value that an attribute can be assigned. The denominator '2 * ' is used to normalize the results, thus obtaining PESIR values ranging from 0.00 to 1.00. The MAX variable is raised to the fourth power, since the factors present in the two terms of the numerator are multiplied and, therefore, the product of the four attributes is equivalent to the maximum value raised to the fourth power.

## 3.3. REPRESENTATIVE ALGORITHM OF THE MODEL

**STEP 1**: Start the ecosystem with all entities, i.e., the corporation and the set of available startups and the context that describes the existing rules;

**STEP 2**: Increase the number of the context (c = n + 1);

**STEP 3**: Establish the sequencing of chromosomes by obtaining the mean value of the observed traits, available in the Data Sheet;

**STEP 4**: Select a pair of corporation and startup and simulate the Propensity to Establish the Symbiotic Relationship (PESIR), using Equation 1 for each chromosome - Knowledge Assets (PESIR *KA*), Complementary Assets (PESIR *CA)* and Dynamic Capabilities (PESIR *DC)*;

**STEP 5:** Obtain the mean of the values of PESIR *KA*, PESIR *CA*, PESIR *DC*;

**STEP 6:** Repeat the operation between all pairs until completing all possible combinations;

**STEP 7**: Select the pairs with higher mean PESIR values, which meet the premises of context (c) and establish the Associations;

**STEP 8:** Remove unselected startups from the ecosystem;

**STEP 9**: Establish the Association between the pairs with the highest mean PESIR values;

**STEP 10**: Go back to STEP 1;

**STEP 11**: If there are no symbiotic relationships between pairs, end the algorithm.

## 4. RESULTS

The EMSRI was used to simulate the propensities to establish symbiotic relationships between a corporation and 10 startup candidates to participate in an open innovation program.

The data were obtained through a descriptive case study (Yin, 2001), whose main unit of analysis is focused on a Corporate Open Innovation Program and incorporates in its scope of analysis, in addition to the corporation that promotes the initiative, the startups that are candidates for the selection and development of innovation projects.

Access to the data was obtained with an authorization from the corporation, the identity of the organizations involved were not disclosed. The case study was conducted between November 2019 and January 2020.

The data analyzed comes from the interactions between the entrepreneurs of the startups, the managers of the corporation and a professional of a business accelerator responsible for coordinating the initiative. The data are contained in disclosure materials, internet, contracts, terms of cooperation, management reports, e-mails, authorized records of the interviews and quantitative and qualitative assessment spreadsheets carried out by the involved managers. Therefore, it is a documentary research.

Those information served as input for the Evaluation of the Strategic Innovation Assets of the analyzed actors. For this purpose, a data spreadsheet was adopted to fill in the values corresponding to the analyzed attributes, which are broken down into Performance Indicators and Descriptors that seek to parameterize evaluated aspects that are essentially qualitative. Additionally, interviews were conducted with the managers involved in the activities using a semi-structured script and aiming to validate the understanding about the information collected in the documentary research.

The corporation and startups identity will be kept confidential, hereinafter called the OG and startup proponents of innovative technological solutions.

The OG demands innovative technological solutions that meet the demands of the oil and gas exploration process. The intended solutions aim not only to meet the demands of the production process of the company itself but also of its supply chain and distributors. Thus, the corporation expects to establish strategic partnerships that allow it to have competitive advantages in the operation of its business as well as financial gains from the commercial exploitation of the solutions derived from these cooperation. Intellectual property and partnership agreements are therefore signed between OG and startups that provide the terms of financial gain for the parties. There are no terms in this relationship stage that provide the Corporation with equity interest in the startups. This, however, is seen as a potential unfolding of the relationship between them, in case there are opportunities that justify these new terms.

It is observed that the methodological design of the Program is similar to what is known as Client Venture or Procurement from startups, i.e., when corporations invest in the development of startups that can become suppliers to have access to cutting-edge technologies and new business models and quickly find new approaches to unresolved problems (Schättgen & Mur, 2016; Mocker et al., 2015).

Solutions involving Artificial Intelligence, Robotics, Computational Modeling or Digitalization are needed to improve operational efficiency and issues related to health, safety and environment, in addition to solutions related to geology, geophysics and engineering.

The program received 57 proposals submitted by Brazilian startups that met the requirements of the public call. From these, based on the description of the proposed solutions, 28 candidate startups were selected and underwent remote interviews. 10 were selected to participate in an in-person process of discussions, deepening of projects and cooperation agreements, aiming to advance with up to 5 of these companies to a later stage that would then involve financial investments, technological development and, therefore, intellectual property and commercial exploitation agreements.

Considering the interviews and documents developed by the startups to detail the proposed partnership, the corporation evaluated the 10 startups, adopting 15 criteria, using a scale from 1 to 4, and obtained a mean score that was used to prioritize the 5 chosen candidates.

## 4.1. PRESENTATION AND INTERPRETATION OF RESULTS

The empirical method adopted by the corporation in the selection of startups and the model systematized by the study, EMSRI, were compared. The 10 startups analyzed in depth by the corporation were also evaluated by the model. The PESIR obtained and the classification order established by the corporation are presented comparatively in Table 2.

The results obtained in the PESIR score are relatively similar to the ranking order obtained by the method employed by the corporation. It is observed that among the 10 startups analyzed, the ranking order of PESIR OVERALL coincides with the classification of the assessment made by the company in 5 startups. ST4 and ST5 have a difference of 0.001, inverting their positions. Likewise, ST7, ST8 and ST9 have differences in OVERALL PESIR punctuation in the third decimal place, with dispersion less than 0.007.

Among the 10 startups evaluated, those ranked first and last by the corporation are analyzed comparatively, below. Therefore, the corporation (CORP), the first-ranked startup (ST1) and the worst-ranked startup (ST10) were evaluated. The following mean values of the attributes analyzed were obtained for the three entities, CORP, ST1 and ST10, and, therefore, the coding of their chromosomes and genes was performed (Figure 3).

Based on these observed attributes, the PESIR rates between the two sets of organizations, related to Knowledge Assets, Complementary Assets, Dynamic Capabilities and the overall value given by the mean of those three values, are obtained, as shown in Figure 4.

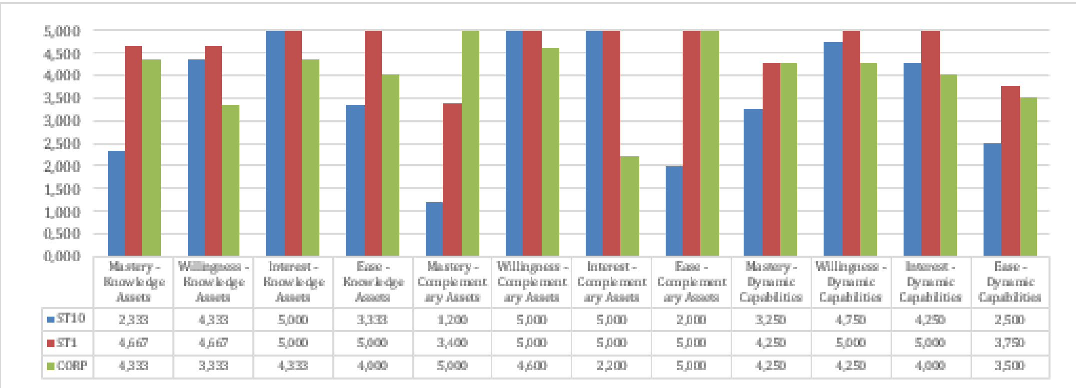
**Table 2**

*Plots of the Values of Propensity to Establish the Symbiotic Relationship between the Corporation and the Startups studied*

| | PESIR-KA Knowledge Assets | PESIR-CA Comple-mentary Assets (CA) | PESIR-DC Dynamic Ca-pabilities | OVERALL PESIR | SORT ORDER BY CORP. |
|---|---|---|---|---|---|
| ST1+CORP | 0.59 | 0.61 | 0.51 | 0.570 | 1 |
| ST2+CORP | 0.57 | 0.56 | 0.56 | 0.566 | 2 |
| ST3+CORP | 0.53 | 0.57 | 0.44 | 0.514 | 3 |
| ST5+CORP | 0.45 | 0.53 | 0.46 | 0.482 | 4 |
| ST4+CORP | 0.42 | 0.48 | 0.54 | 0.483 | 5 |
| ST6+CORP | 0.47 | 0.45 | 0.49 | 0.469 | 6 |
| ST8+CORP | 0.41 | 0.56 | 0.27 | 0.413 | 7 |
| ST9+CORP | 0.35 | 0.55 | 0.35 | 0.412 | 8 |
| ST7+CORP | 0.41 | 0.46 | 0.39 | 0.419 | 9 |
| ST10+CORP | 0.33 | 0.24 | 0.33 | 0.299 | 10 |

**Figure 3**

*Plots of the mean values of the attributes observed*



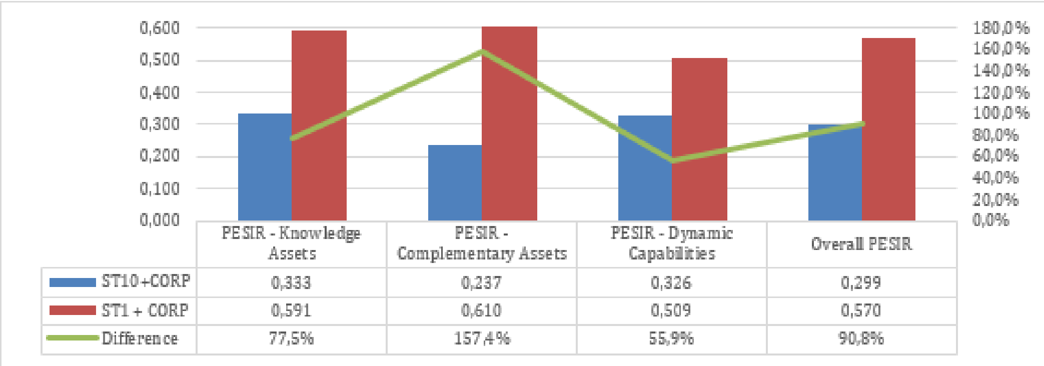

EMSRI, therefore, indicates a propensity of ST1 to establish a symbiotic mutualistic relationship with CORP approximately 90.8% greater than that observed between ST10 and CORP. This difference is present in the 3 chromosomes and is more accentuated, especially when considering the Complementary Assets, where the propensity of the ST1 + CORP pair is 157.4% higher than the ST10 + CORP.

It can therefore be inferred that the main difference is in relation to attributes that are relevant to the creation and capture of value of the intended business. Complementary Assets, for example, are resources related to productive capability, distribution and supply chain, market access, among others.

In this way, it is possible to understand that the group of 10 startups selected from a larger group of 57 candidates in total, already had a bias that portrays more evident aspects regarding the complementarity of the Knowledge Assets (technological domain, field of application etc.) and possess Dynamic Capabilities common to most startups nowadays, such as crea-

**Figure 4**

*Plots of the Values of Propensity to Establish the Symbiotic Relationship between the Corporation and the Startups*




tivity, agility, networking, among other aspects. Therefore, the deviation between the values observed in these attributes was smaller.

## 5. CONCLUSIONS AND FUTURE PROSPECTS

The proposed model intends to be suitable for the simulation of the formation of mutualistic symbiotic relationships between corporation and startup because it seeks to identify pairs with a higher degree of complementarity of strategic assets for innovation. In other words, it seeks to identify the compositions of organizations that complement each other in terms of the attributes necessary for the innovative process.

For this, the model considers not only the Mastery of attributes related to Strategic Assets for Innovation suggested by the bibliography studied but also the Willingness to share its set of Assets, the Interest in obtaining new Assets, and the Ease of assimilating these new Assets. Thus, the Interest and the Ease of one party are complemented by the Mastery and the Willingness of the other, and vice versa.

It is important to stress that the model evaluates the propensity to establish symbiotic relationships between these organizations from a strategic perspective. That is, tactical and operational aspects that may influence decisions for the formation of these relationships are not considered in its conception.

Future studies may consider broader perspectives of open innovation processes and other decision-making aspects, such as the analysis of financial, legal, cultural, technological and marketing issues, as well as other aspects that influence the effectiveness of projects derived from the establishment of these symbiotic relationships.

Another thing to keep in mind is the characterization of the type of symbiotic relationship considered in this model, mutualism. Such type of association assumes that, for the formation of relationships between startups and large corporations, the perspectives of the two parties need to be considered to the same extent.

In the future, it is possible to evaluate, as in nature, the propensity to form commensalism and parasitism relationships, among other symbiotic relationships.

As in symbiogenesis, when the symbiotic relationship results in the creation of new species resulting from the genetic integration of the symbionts, it is possible to envision the expansion of the model to evaluate the propensities of these sets of organizations to become new entities, i.e., of mergers that result in the combination of their characteristics, as observed in joint ventures, acquisitions and corporate mergers.

The simulations performed in this article used data from a specific open innovation program with a restricted set of entities in an oil and gas sector, with startups that operated in specific technological fields. It is not possible, therefore, to conclude that they are applicable to other contexts. It is recommended to analyze in subsequent studies the suitability of the model under other circumstances, company profiles, economic sectors, and designs of open innovation programs, among other possible aspects.

It is important to note that EMSRI is flexible, allowing future studies to adopt other attributes of the analyzed actors, new evaluation scales, and most likely the expansion of its use for other types of organization, in addition to corporations and startups, such as universities and technological centers.

Therefore, the model represents a contribution to studies on the formation of mutualistic symbiotic relationships in open innovation programs, and due to its broad conception, its application can be studied in other contexts.

## REFERENCES


Asima, T., & Rajat Kumar, P. (2018). Symbiotic Interactions, Law of Purposive Association and the +/+ Nature of all Co-evolution. *Indian Journal of Science and Technology, 11*(43), 1–12. https://doi.org/10.17485/ijst/2018/v11i43/132577

Barcellos, J. C. H. de. (2000). *Algoritmos Genéticos Adaptativos: Um estudo comparativo* [Doctoral thesis]. Universidade de São Paulo.

Bennet D., Bennet A. (2004) The Rise of the Knowledge Organization. In: Holsapple C.W. (eds) *Handbook on Knowledge Management 1*. International Handbooks on Information Systems, vol 1. Springer.

Blank, S., & Dorf, B. (2012). *The Startup Owner's Manual.*

Carneiro, T. K. G (2014). *Redes de afinidade como estratégia de gestão pedagógica e difusão do conhecimento em cursos na modalidade a distância* [Doctoral thesis]. Doutorado Multi-institucional e Multidisciplinar em Difusão do Conhecimento. https://repositorio.ufba.br/ ri/bitstream/ri/16842/1

Das, T. K., & Teng, B. S. (2000). A resource-based theory of strategic alliances. *Journal of Management, 26*(1), 31–61. https://doi.org/10.1177/014920630002600105

Embley, T. M., Van der Giezen, M., Horner, D. S., Dyal, P. L., Bell, S., & Foster, P. G. (2003). Hydrogenosomes, Mitochondria and Early Eukaryotic Evolution. *IUBMB Life, 55*(7), 387–395. https://doi.org/10.1080/15216540310001592834

Freeman, J., & Engel, J. S. (2007). Models of innovation: Startups and mature corporations. *California Management Review, 50*(1), 94-+.

Grant, R. M. (1991). The Resource-Based Theory of Competitive Advantage: Implications for Strategy Formulation. *California Management Review, 33*(3), 114–135. https://doi.org/10.2307/41166664

Hillman, R. S. (1970). Bureaucracy and Innovation. *Revista de Administração de Empresas, 10*(3), 226–229. https://doi.org/10.1590/S0034-75901970000300014

Lacerda, R. (2018). *Uma proposta de um modelo evolutivo para redes de difusão do conhecimento organizacional* [Doctoral thesis]. Centro Universitário SENAI CIMATEC.

Leonard-Barton, D. D. (1998). Core Capabilities and Core Rigidities: A Paradox in Managing New Product Development. *Strategic Management Journal, 13,* 111–125.

Martin, B. D., & Schwab, E. (2012). Current Usage of Symbiosis and Associated Terminology. *International Journal of Biology, 5*(1). https://doi.org/10.5539/ijb.v5n1p32

Mills, R., & Watson, R. A. (2007). *Symbiosis, synergy and modularity: Introducing the reciprocal synergy symbiosis algorithm. Lecture Notes in Computer Science* (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), 4648 LNAI, 1192–1201. https://doi.org/10.1007/978-3-540-74913-4_119

Mocker, V., Bielli, S., & Haley, C. 2015. *Winning Together: A Guide to Successful Corporate-Startup Collaborations.* Startup Europe Partnership.

Monteiro, R., Fontoura, J., Carneiro, T., Moret, M., & Pereira, H. (2014). Evolution based on chromosome affinity from a network perspective. *Physica A, 403,* 276–283. https://doi.org/10.1016/j.physa.2014.02.019

Monteiro, R. L. S. (2012). *Um Modelo Evolutivo para Simulação de Redes de Afinidade,* 1–150.

Monteiro, R. L. S., Carneiro, T. K. G., Andrade, L. P. C. da S., Fadigas, I. de S., & Pereira, H. B. de B. (2015). An affinity-based evolutionary model of the diffusion of knowledge. *Obra Digital,* (9), 44–57.

Ries, E. (2011). *The lean startup: how today's entrepreneurs use continuous innovation to create radically successful businesses* (1st ed.). Crown Publishing.

Sampaio, R. R., Monteiro, R. L. S., Lacerda, R., Nolasco, A. X. de S., & Nakame, M. T. (2018). Uma proposta de um modelo evolutivo para redes de difusão do conhecimento organizacional. *Obra Digital,* (14), 83-101. https://doi.org/10.25029/od.2017.144.14

Schättgen, N., Mur, S. (2016). *The age of collaboration*. Retrieved from http://www.adlittle.co m/downloads/tx_adlreports/ADLMatchMaker_ The_Age_of_Collaboration.pdf.

Spender, J.-C., Corvello, V., Grimaldi, M., & Rippa, P. (2017). Startups and open innovation: a review of the literature. *European Journal of Innovation Management, 20*(1), 4–30. https://doi.org/10.1108/EJIM-12-2015-0131

Teece, D. J. (1998). Capturing Value from Knowledge Assets: The New Economy, Markets for Know-How, and Intangible Assets. *California Management Review, 40*(3), 55–79. https://doi.org/10.2307/41165943

Teece, D. J. (2004). *Knowledge and Competence as Strategic Assets. In Handbook on Knowledge Management* 1 (pp. 129–152). Springer. https://doi.org/10.1007/978-3-540-24746-3_7

Thieme, K. (2017). *The Strategic Use of Corporate-Startup Engagement.*

Tidd, J. (2006). *A review of innovation models,* Discussion paper, Imperial College London. Retrieved from http://www.emotools.com/static/upload/files/innovation_models.pdf.

Watson, R. A., & Pollack, J. B. (1999). *How Symbiosis Can Guide Evolution.* In D. Floreano, J.-D. Nicoud, & F. Mondada (Eds.), Advances in Artificial Life (pp. 29–38). Springer.

Weiblen, T., & Chesbrough, H. W. (2015). Engaging with Startups to Enhance Corporate Innovation. *California Management Review, 57*(2). https://doi.org/10.1525/cmr.2015.57.2.66

Yin, R. (2001). *Estudo de Caso: Planejamento e Métodos* (2nd ed.). Bookman.