Exploring Performance Assessment Scenarios in Collaborative Business Ecosystems

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Abstract. Sustainability of collaboration in a business ecosystem is a significant concern for organizations to survive in an increasingly competitive marketplace. This study addresses this concern contributing with a performance assessment and influence mechanism to measure the performance and induce more sustainable collaboration behaviours in a Collaborative Business Ecosystem. The level of collaboration can be measured if the ecosystem's manager adopts appropriate performance indicators that, at the same time, can help influencing the behaviour of the organisations as they try to improve their position according to the assessment metrics. A simulation model is designed to evaluate the proposed approach, and a simulation scenario discussed, showing some of the achieved results.

Keywords: Collaborative networks · Business ecosystem · Performance indicators · Sustainable collaboration · Simulation

1 Introduction

The possibilities offered by new information and communication technologies are changing business strategies and innovation capabilities [1]. With increasing competition in the market and the acute need for sustainability, it is crucial for organisations to build long-term relationships with their "*supply-chain*" and other partners through sustainable collaboration [2]. Participation in collaborative processes brings benefits to the involved entities, including the opportunity of "survival capability" in the occurrence of market turbulence and the possibility of better achieving common goals [3]. However, an important challenge is to keep members of the collaborative network engaged, thus ensuring the sustainability of collaboration in the long-term. This study addresses these concerns for Collaborative Business Ecosystems (CBEs), under the assumption that the performance indicators adopted to assess the ecosystem can have an influence on the behaviour of its members and thus affect collaboration sustainability. As such, we present some foundations and propose a set of performance indicators to assess collaboration performance. Furthermore, a model of the influence of these performance indicators in the behaviour

Published by Springer Nature Switzerland AG 2021
L. M. Camarinha-Matos et al. (Eds.): PRO-VE 2021, IFIP AICT 629, pp. 81–91, 2021.
https://doi.org/10.1007/978-3-030-85969-5_7

of the CBE's organisations and the evolution of behaviour towards better performance is described, thus contributing to the sustainability of the ecosystem.

The remaining sections of this paper are organised as follows: section two identifies the benefits of collaboration, highlighting the most important ones for a CBE and presenting the considered research questions; section three briefly explains the structure of a CBE, the profile of organisations, the performance assessment to evaluate the level and status of collaboration and the influence mechanism; section four presents the performance assessment and adjustment model and discusses an example of a simulation scenario; the last section concludes the work, identifying limitations of the study, and ongoing and future work.

2 Collaboration Benefits in a CBE

It is widely accepted that collaboration brings benefits to the involved players, allowing divergent thinking to develop new understandings, which can facilitate the design of new products and services [4], and reduce or remove conflicts [5].

Moreover, multi-stakeholder collaboration optimises financial and human capital, provides organisations with valuable information, access to markets and knowledge, induces creativity due to the diversity of players' backgrounds, helps prevent confrontation, and shortens the time to achieve objectives [6]. Most literature on collaborative networks offers long lists of potential benefits of collaboration. For instance, works on benefits analysis [7] and value systems for sustainable collaboration [3] have highlighted several collaboration advantages: share and reduce costs, share risks, reduce the level of dependence on third parties, increase innovation capacity, defend a position in the market, increase flexibility, increase agility, increase specialisation, establish proper regulations and share social responsibility.

Inspired by Moore's [8] business ecosystem and by Camarinha-Matos and Afsarmanesh's collaborative networks developments [9, 10], the concept of Collaborative Business Ecosystem was introduced in [11], representing a kind of long-term strategic collaborative network that aims to help its members to be prepared to rapidly engage in collaborative business opportunities.

Despite the identified and often mentioned collaboration benefits for collaborative networks in general and CBEs in particular, there is not much concrete work on collaboration assessment and adequate performance indicators to assess these benefits. Therefore, after the literature review, the motivation for the present work is led by the research questions and hypotheses shown in Fig. 1.

3 Performance Indicators for a CBE and Influence Mechanism

As mentioned, a CBE is a business environment of organisations that collaborate, creating relationships. This CBE structure can be modelled as a network of weighted interconnected nodes, whose links refer to the number of collaboration opportunities that the organisations exchange when responding to market opportunities.

According to [12], network structures are described as social capital, for which, in line with the inter-organisational view of [13], ties' weight can mean, for instance, trust

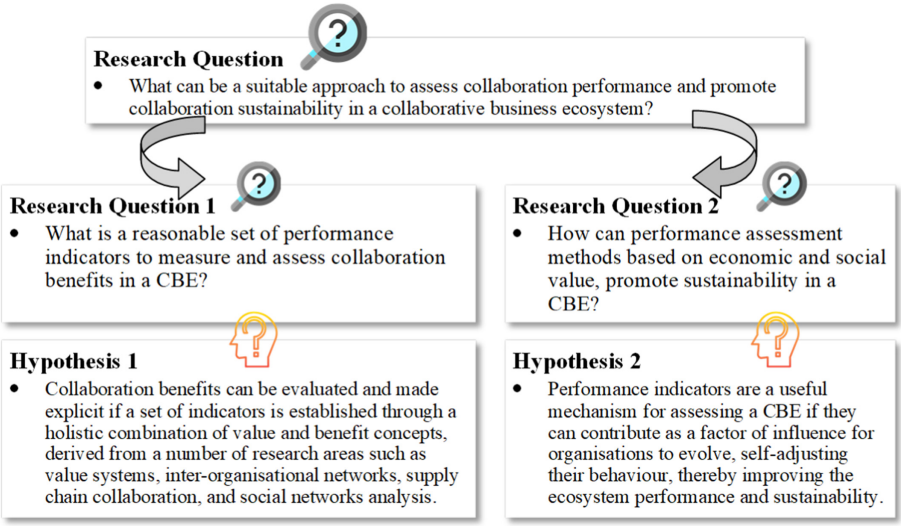


Fig. 1. Research questions and hypotheses to assess and influence a CBE expecting to improve its performance and collaboration sustainability.

and power, and nodes' centrality and network status are associated with their performance. The strength of a tie may also be determined by the frequency of interactions among organisations [14]. According to an inter-organisational network perspective, more measurement efforts can be found in [15] and in complex networks [16]. Taking into account such foundations and inspired by measures and indicators coming from the areas of Social Networks Analysis (SNA) [17, 18] and Collaborative Networks (CNs) [7, 19, 20], we propose a set of performance indicators tailored for CBEs as briefly summarized in Fig. 2.

The choice of the performance indicators is mainly related to the network structure, to assess the benefits that collaboration can bring to the individual organisations and the CBE as a whole.

Considering the measurements at the level of organisations:

- **Contribution Indicator** (CI_i)**:** The number of collaboration links between organisations, taking into account the links' strength, gives a measure of the value created by the organisations, considering as benefits, increased access to markets and knowledge, increased creativity and capacity for innovation, increased flexibility, agility and specialisation, optimised financial and human capital, shared social responsibility, reduction of conflicts, and shorter time to achieve objectives [3–7, 13]. This indicator is calculated by the weighted degree centrality;
- **Prestige Indicator** (PI_i)**:** The topology of the collaboration links, taking into account the links' strength, shows the most prominent/influential organisations signifying power, performance and ability to generate social capital [13]. This indicator is calculated by the weighted betweenness centrality;

CBE Structure

- A **network** of organisations (the **nodes**)
- The **nodes** are connected by relationships (the **connections**) that mean the market opportunities they share by collaborating, called collaboration opportunities (CoOps)
- The **connections** are **weighted** by the number of CoOps (#CoOps) in which they have participated during a period

Performance Assessment

Research Areas / Foundations		Performance Indicators	
- Clarify how to measure centrality considering a node or the network as a whole in Social Network Analysis (SNA) [17] - Define measures of centrality and clustering in SNA [18] - Identify benefits in Collaborative Networks (CNs) combined with metrics of SNA [7] and propose performance indicators for CNs [19] - Propose indicators to measure social capital in CNs inspired by SNA [20]	**- Network** structures are described as social capital [12] "Network level" - measures of density, centrality, clusters of connected organisations [15] and complex networks [16]	$CI_{CBE}in$ $CI_{CBE}out$	Assesses the degree to which the most popular/active organisation in the CBE (max degree centrality in/out) exceeds the contribution of the others
		PI_{CBE}	Assesses the degree to which the most prominent/influent organisation in the CBE (max betweenness centrality) exceeds the contribution of the others
		II_{CBE}	Ratio of innovation of the organisations in the CBE, weighted by the correlation due to collaboration
	- "Ego level" (**node**) - high degree centrality of organisations is positively related to their performance; structural holes and closure generate social capital; and network status explains organisational performance [13] - "Dyadic level" (**connections**) – strong ties among organisations increase trust and generate future ties; high trust lowers transaction costs and increases benefits; and the most requested partner is the one with the most power [13]	$CI_i in$ $CI_i out$	Assesses the contribution of organisation O_i in terms of accepted/created #CoOp (in/out)
		PI_i	Assesses the prominence/influence of organisation O_i in terms of the #CoOp
		II_i	Ratio of the number of new products/services/patentes of the organisation O_i by the total portfolio

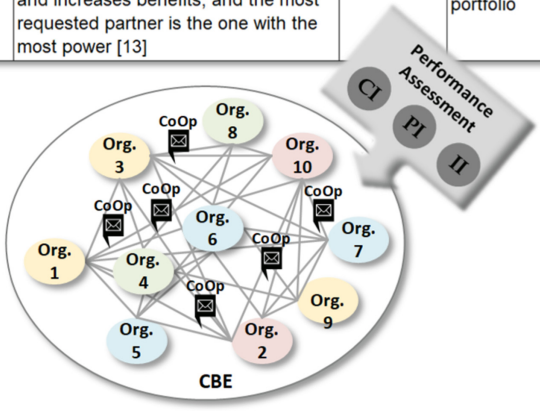


Fig. 2. Foundations and inspiration for a proposal of performance indicators for CBEs.

- **Innovation Indicator** (II_i)**:** The number of collaboration links between organisations that involve innovation when creating products, patents or services, gives a measure of the innovation capacity. This indicator is related to the CI and is calculated by the ratio between the number of new products, patents or services by the organisations' portfolio.

Considering the measurements at the level of the CBE:

- **Contribution Indicator** (CI_{CBE}) and **Prestige Indicator** (PI_{CBE})**:** These indicators assess the equilibrium of collaboration in the CBE, measuring to what extent the organisations with the highest CI_i and PI_i are ahead of the others. The goal is to achieve a more uniform collaboration to assure the sustainability of all the organisations in the CBE;
- **Innovation Indicator** (II_{CBE})**:** This indicator assesses the innovation capacity in the CBE by correlating the II_i with collaboration.

It is expected that the proper measurement of collaboration using performance indicators will motivate organisations to evolve towards better performance, thus contributing to the sustainability of the ecosystem. In other words, the choice of indicators and corresponding weights in an assessment framework can strongly influence the evolution of behaviour of the CBE members.

Some authors have studied how inter-organisational relations influence organisational learning and innovation [14]. These relationships form structures capable of influencing organisations' behaviours, including organisational change, by promoting or constraining their access to information, physical, financial, and social resources [14]. However, organisations manifest different collaborative behaviours in response to market opportunities. As such, in Fig. 3, we propose a composition of classes of collaboration willingness to characterize the organisations' behaviours in terms of willingness to invite others to collaborate (*Contact rate*), the readiness to accept invitations (*Accept rate*), and the tendency to accept opportunities related to innovation (*New products rate*).

The ways social networks influence organisations to change, as found in [14], can help understand the influence on the network structure of a CBE. On the other hand, the micro-foundations and micro-dynamics principles discussed in [21] also help understand network evolution dynamics based on the different profiles of organisations.

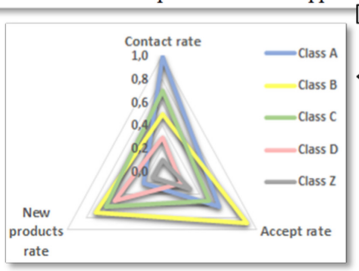
Based on the assumption that the choice of indicators and corresponding weights can influence the behaviour of CBE members, we propose an influence mechanism through which the CBE manager may vary the weights attributed to each performance indicator Fig. 4 in order to analyze behavioural changes. These weights are associated with the attributes of the classes of collaboration willingness, i.e. the *Contact rate* is related to the *CI*, the *Accept rate* to the *PI* and *New products rate* to the *II*. As such, given a factor of influence (*%FI*), the improvement in the organisations' profile is calculated by adding the calculated factor plus an exogenous/random positive or negative influence ($\pm F_e$). This factor can be used in the simulation model, for example, to induce collaboration into organisations that do not accept or invite others, or it can be used to decrease collaboration in cases where it deteriorates and fails.

Organisations Profile

- The CBE organisations have different profiles categorised into classes of collaboration willingness, which characterize their collaborative behaviour in response to market opportunities

Classes of Collaboration Willingness

- **Contact rate:** Willingness to invite others to collaborate
- **Accept rate:** Readiness to accept invitations
- **New products rate:** Tendency to accept opportunities related to innovation



- Identify five ways in which social networks **influence** organisations changes [14]

The Role of Social Networks in Organisational Change	
Ways of Influence	**Description**
Innovation	An organization in a denser organizational network is likely to have more frequent innovations driving organizational change
Imitation	An organization in a denser organizational network is likely to experience change through imitation
Inertia	An organization in a denser network is likely to take a longer period of time to implement and complete change
Structural equivalence	An organization's actions for change are likely to be influenced by those of a structural equivalent
Structural positioning	A more central organization is likely to change more frequently and more successfully

Note. Source: Adapted from Ferreira and Armagan, 2011 [14]

- Identify four primary **micro-foundations** as the fundamental drivers to explain the genesis and **evolution** of networks operating through **micro-dynamics** to form, dissolve or maintain ties [21]

		Micro-foundations			
		Agency	**Opportunity**	**Inertia**	**Exogenous**
Micro-dynamics	Nodal assortativity driven	Homophily, heterophily, prominence attraction	Proximity, common goals, common identity	Habits, networking propensity, collaborative expertise	Network structures may result from exogenous
	Tie pattern driven	Brokerage, closure	Transitivity, repetition, referral	Dense clusters, low connectivity	factors or from simple random processes

Note. Source: Adapted from Ahuja et al. 2012 [21]

Fig. 3. Organisations profile and foundations to explain the network influence and evolution.

As a result of the influence mechanism applying the formulas of Fig. 4, the *Contact rate*, *Accept rate* and *New products rate* are recalculated, causing organisations to self-adjust their behaviour in the direction of the evaluation criteria, the same way as individuals, thus improving their profile and that of the CBE.

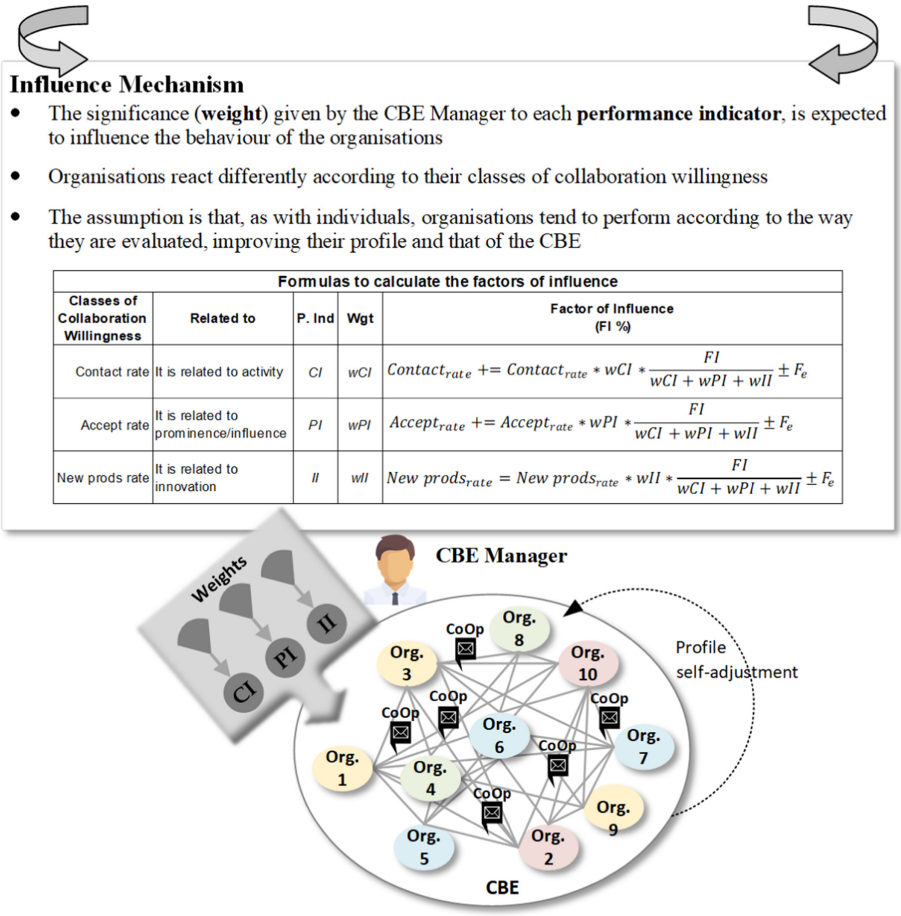


Fig. 4. Proposal of an influence mechanism.

4 Performance Assessment and Adjustment Model

For the experimental evaluation of the proposed CBE model, we designed a Performance Assessment and Adjustment Model (PAAM) using the AnyLogic tool [22], as summarized in Fig. 5. Due to the lack of historical concrete collaboration data from the organisations, PAAM is used for the establishment of several simulation scenarios representing different cases of CBEs (simulation environment), populated with different organisations of different classes (the agents), sending and receiving collaboration opportunities (the links or ties) to accomplish business opportunities.

This study uses a simulation study parameterised using actual data to achieve more realistic scenarios. These data represent one year of activity of IT industry organisations operating in the same CBE, consisting of the number of human resources, number and duration of market opportunities received, and number and duration of collaboration

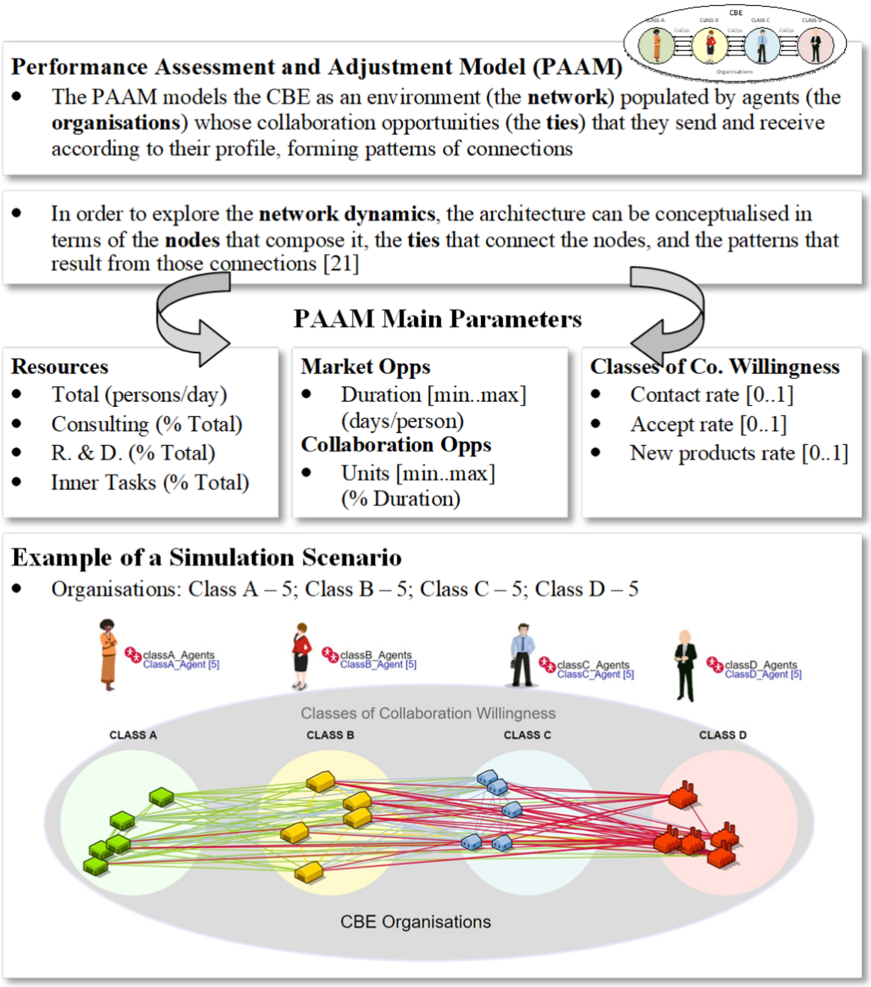


Fig. 5. A scenario of simulation using the performance assessment and adjustment model.

opportunities created and accepted. This latter data also makes it possible to establish different classes of collaboration willingness.

Some results of the simulation scenarios are illustrated in Fig. 6 using a graphical view [23]. The figures represent each organisation's performance measures before and after influencing the CBE by the CBE manager, varying the weights attributed to each performance indicator. The achieved measures correspond to the contribution indicator *CI_in* (accepted collaboration opportunities), *CI_out* (collaboration opportunities created by inviting other organisations), and the prestige indicator *PI* (prominence/influence of organisation in the network).

The variation of the indicators' weights increased the value of *wCI* (related to the collaboration activity of the organisations) and decreased the value of *wPI* (related to

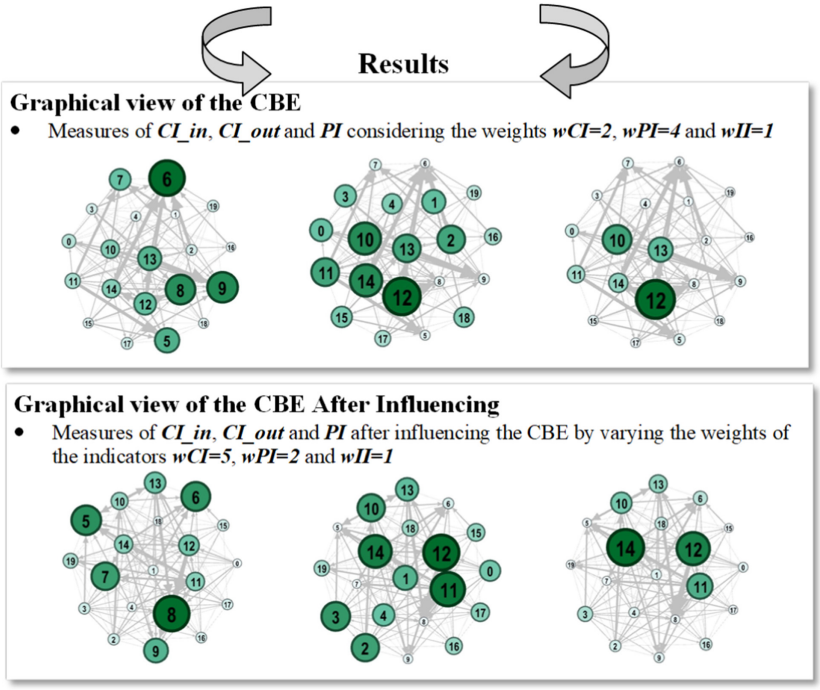


Fig. 6. Results of a scenario of simulation presenting the measures *CI_in*, *CI_out* and *PI*, before and after influencing the CBE by varying the weights of the performance indicators.

the prominence/influence of the organisations). As a result, there was a strengthening (although not very marked) in the CI indicators and a relief in the PI.

The results presented in Fig. 6 illustrate a simulation scenario before and after influencing the CBE by varying the weights of the performance indicators. The nodes' size is correlated with the indicators' measures, and the links' strength is correlated with the number of collaboration opportunities exchanged by the organisations.

The results show that the CBEs' managers might have a set of performance indicators and corresponding weights that can help them measure collaboration and adopt those that can lead to more sustainable ecosystems. Varying the weights, CBEs managers can also analyse several simulation scenarios seeking the best configurations towards the desired behaviour.

5 Conclusions

Sustainable collaboration in a business ecosystem is a significant concern to survive in an increasingly competitive market context. Given the importance of this objective, this study attempts to provide appropriate performance indicators, contributing not only to measure but also to influence organizations towards more effective collaboration.

Due to the lack of actual collaboration data, a simulation model has to be used for the evaluation of the proposed model. Nevertheless, the model can hold any number

of agents whose behaviour can be shaped using actual data from organisations of different collaboration profiles. Furthermore, the links and links' strength created by the collaboration in the simulation environment allow measuring the CBE using the adopted performance indicators by the CBE manager. These measures provide a picture of CBE collaboration, showing the leading organisations in terms of collaboration opportunities created, prominence in accepted invitations to collaborate and propensity for innovation. Moreover, the measures at the CBE level show the homogeneity/heterogeneity of collaboration in the network, which is desirable to be strong in all organisations so that they thus contribute to a more sustainable ecosystem. As such, the CBE Manager can use the PAAM to explore several scenarios and vary the weights of the adopted performance indicators to influence the behaviour of the organisations in the direction of a more sustainable CBE.

On one hand, some limitations can be found in this study. On the other hand, however, a few can be considered for ongoing and future research:

- The PAAM simulation model used in this study was shaped using actual data from the IT services industry. However, this context may not reflect the reality of other business ecosystems. Moreover, the data were collected from three organisations during 2019 and was extrapolated to represent twenty organisations characterised into four classes of collaboration willingness.
- Several other simulation scenarios must be analysed to understand the dynamics of a CBE to improve the influence mechanism towards better collaboration performance and sustainability.
- This study proposes a set of performance indicators for a CBE based on measures of centrality inspired by SNA and measures of innovation correlated with collaboration. For future research, other indicators based on metrics of density and clustering can be considered to assess collaboration sustainability.
- In this study, the CBE model is considered a network of organisations (the nodes) connected by relationships (the ties) that represent collaboration opportunities weighted by the number of times they collaborate. Future research can support different value types (economic, social, and environmental) with different weights.

Acknowledgements. This work was funded in part by Fundação para a Ciência e Tecnologia through the program UIDB/00066/2020, and the European Commission (project DiGiFoF).

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