Cross-border alliances and strategic games

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Abstract

Purpose – This empirical research examined the factors and conditions that contribute to the success of international strategic learning alliances. The study aimed to provide organisations with evidence-based insights and recommendations that can help them to create more effective and sustainable partnerships and to leverage collaborative learning to drive innovation and growth. The examination is performed using game theory as a mathematical framework to analyse the interaction of the decision-makers, where one alliance's decision is contingent on the decision made by others in the partnership. There are 20 possible games out of 120 outcomes that can be grouped into four different types; each type has been divided into several categories.

Design/methodology/approach – The research methodology included secondary and primary data collection using empirical data, the Delphi technique for obtaining qualitative data, a research questionnaire for collecting quantitative data and computer simulation (1,000 cases, network resources and cooperative game theory). The key variables collected and measured when analysing a strategic alliance were identified, grouped and mapped into the developed model.

Findings – Most respondents ranked reputation and mutual benefits in Type 1 games relatively high, averaging 4.1 and 3.85 of a possible 5. That is significantly higher than net transfer benefits, ranked at 0.61. The a priori model demonstrate that Type 1 games are the most used in cooperative games and in-game distribution, 40% of all four types of games. This is also confirmed by the random landscape model, approximately 50%. The results of the empirical data in a combination of payoff characteristics for Type 1 games show that joint and reputation benefits are critical for the success of cooperation.

Practical implications – Research on cross-border learning alliances has several implications. Managerial implications can help managers to understand the challenges and benefits of engaging in these activities. They can use this knowledge to develop strategies to improve the effectiveness of their cross-border learning alliances. Practical implications, the development of game theory and cross-border models can be applied in effective decision-making in a variety of complex contexts. Learning alliances have important policy implications, particularly in trade, investment and innovation. Policymakers must consider the potential benefits and risks of these collaborations and develop policies that encourage and support them while mitigating potential negative impacts.

Originality/value – International learning alliances have become a popular strategy for firms seeking to gain access to new knowledge, capabilities and markets in foreign countries. The originality of this research lies in its ability to contribute to the understanding of the dynamics and outcomes of these complex relationships in a novel and meaningful way.

Keywords Learning alliances, Game theory, Cooperative games, Payoffs, Strategic partnership, Simulation, Strategic alliances

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1. Introduction

This research examines the conditions for a successful strategic learning alliance (SLA) in international organisation alliances. The examination is performed using game theory as a mathematical framework to analyse the interaction of the decision-makers, where one alliance's decision is contingent on the decision made by others in the partnership. The strategic decisions can be shaped and modelled using game theory (cooperate or defect). Based on the critical success factors of the cross-border alliance models, the partners may decide on terms for future collaborations. Essentially, alliances are all about information transfer and knowledge sharing (Ashmel *et al.*, 2022; Bamel *et al.*, 2021; Ravichandran and Giura, 2019; Aslam *et al.*, 2022), and absorption is the key element in the essence of alliances. The objectives are (1) to examine the motivation and the determinants of alliance success, (2) to determine each partner's perception of the net payoffs from their strategic relationship (costs and benefits analysis) and (3) to define an optimum strategy of behaviour in learning alliances.

Game theory is most beneficial in obtaining insights into how players in the market interact in specific circumstances (Dixit and Nalebuff, 1991; Tlemsani and Matthews, 2021; Nash, 1951, 1953). Such an approach does not help participants learn the right way to play but provides a means of understanding competitor and partner behaviour and what is likely to happen if they alter the rules. Game theory has greatly expanded the business strategy analysis scope, sharpening corporate competitiveness and advancing policy (Tlemsani, 2020).

Game theory applicability is considered a mathematical/simulation approach to aggregate the functionality of players in international strategic alliances (SAs). This paper can trigger economic potential among the players depending on their chosen game. Von Neumann and Morgenstern's (1944) book dealt with zero-sum non-cooperative games (as well as a variety of cooperative games). These are games where one player's gain/loss is always the other player's loss/gain as the returns are the sum of zero (poker/card games can be the classic example). This shows that playing the maximum strategy is the rational thing to do in these games (you look at the worst outcome that your strategies may bring and then choose the strategy with the best "worst" outcome).

This paper is structured as follows. Section 2 contains the literature review on SAs, including motives for alliance formation, perceived benefits and costs, research gap and insight into game theory. Section 3 describes the developed model. Section 4 explains the research methodology and the different models used, such as a priori model with ergodic search, logical constraints, a computer simulation and random landscape model. Section 5 exhibits the findings. Section 6 discusses the empirical results; one is the new taxonomy of games based on the traditional approach, exploring the choice between cooperation and the defection of two coalition members. Section 7 provides the conclusion and the research implications.

2. Literature review

An SA is a cooperative agreement or partnership between two or more organisations to achieve mutual benefits by combining their resources, expertise and market presence. It involves a formal or informal arrangement in which the partnering entities work together to pursue common goals, enhance their competitive positions and create value for both parties involved (Tjemkes *et al.*, 2023; Hashim *et al.*, 2022; Kohtamäki *et al.*, 2023; Gulati and Singh, 1998; Gulati *et al.*, 2012; Mockler, 2000; Parkhe, 1991).

SAs may occur in many industries and between firms of different sizes. They have numerous purposes and may involve vertical or horizontal links between the firms involved (Cacciolatti *et al.*, 2020; Su *et al.*, 2023; Ferreira *et al.*, 2021; Tlemsani, 2010; Lorange *et al.*, 1992).

The latter argues that SAs can vary along a broad continuum and provides the following typology for collaborative relationships and SAs.

Hamel (1991) viewed a firm as a portfolio of core competencies and encompassing disciplines (interfirm abilities supporting core competencies) rather than as a portfolio of product–market entities. He explored the extent to which the collaborative process might lead to the reappointment of skills between alliance partners. He stressed the distinction between gaining *access* to new skills – by taking out a licence and internalising a partner's skills, saying that distinction is crucial. As long as a partner's skills are embodied only in the specific outputs of the venture, they have no value outside the narrow terms of the agreement. Once internalised, however, they can be applied to new geographic markets, products and businesses.

Numerous authors stress the importance of learning in alliances (Aharonson *et al.*, 2020; Wang *et al.*, 2021; Majdalawieh *et al.*, 2017; Varadarajan and Cunningham, 1995) and consider them as a means of getting access to the benefits of other companies' assets (technology and market access). Kogut (1988) explored the motivation for joint venture formation and argued that they give organisational learning opportunities. This motive can be the main reason for establishing cooperation. By definition, tacit knowledge cannot be transferred by contractual codified means and is communicated only by working teams. A cooperative structure (joint ventures or alliances) may be sought in order to achieve this.

Several authors explored the motives underlying alliance formation. There is a common view among researchers (Geleilate *et al.*, 2021; Al-Tabbaa *et al.*, 2019; Segil, 1996; Tlemsani *et al.*, 2020) that firms seek competitive advantages as global competition intensifies and that is why they form SAs since SAs bring value to the organisations entering into them and help to gain or retain a competitive advantage as the global environment changes and competition intensifies.

Harbison and Pekar (1998) summarised the distinct features of SAs opposing them to transactional alliances (shared distribution, collaborative advertising and marketing), often limited in duration and scope. In addition, they argued that the percentage of revenue that the top 1,000 U.S. largest companies have earned from alliances has more than doubled, to 21% in 1997 as compared to the early 1990s; return on investment (ROI) is higher among alliance-oriented firms: 1,000 largest U.S. firms had an average ROI of 10.8%, SAs produced an ROI of nearly 17%; 25 firms most active in alliances achieve 17.2% of return on equity, whereas 25 firms least active in alliances produced a return on equity of only 10.1%.

Several authors (Coughlan *et al.*, 2021; Dzhengiz, 2020; Buhagiar, 2021) consider the benefits of SAs as realised motives for alliance formation and are usually opposed to perceived cooperation costs. Arguments provided by many researchers illustrate the benefits and financial implications of SAs. Segil (1996) describes research conducted by Coopers and Lybrand and points out that firms involved in alliances had 11% higher revenue and a 20% higher growth rate than companies not engaged in alliance activity. Jarillo (1993) argued that the main motivation for forming SAs is to reduce the risk of entering an unknown business territory. Inkpen (1998) also emphasised gaining access to the skills and knowledge of a partner that can be used to enhance the firm's strategy and operations.

In addition, Mockler (2000) discussed the Booz Allen Hamilton survey and reported that the number of alliances between U.S. firms and partners in Europe, Asia and Latin America is growing 25% annually and that 60% of U.S. CEOs viewed alliances as successful as opposed to 20% in 1990 (Mediavilla *et al.*, 2020). Interestingly, previous research which examines the oil market price dynamics using hypothesises also demonstrates a similar notion of ROI and oil market liquidity using conditional equations (Batten *et al.*, 2019).

Haberberg and Rieple (2001) explored "co-specialisation", i.e. learning from other organisations with complementary skills, and argue that alliances, which allow partners to bring together complementary skills, are possible between companies the same or in different countries and industries. Authors (Cui *et al.*, 2018; Inkpen, 2000; Tlemsani, 2022) have stressed the importance of the concept of the learning ability of firms. They argue that it should be a central concept in the theory of alliance learning dynamics.

Over the last 2 decades, the application of game theory has become progressively relevant in various fields, such as economics, business, politics and information technology. The theory is primarily used to understand the partners' strategic move–behavioural decisions in complex situations. Thus, SAs must apply the game theory to a wide range of real-world scenarios and project the potential payoff.

Game theory is also used to advise the policymakers and decision-makers of partners on market outcomes, negotiations, conflicts and competition regulation. This is achieved by developing new techniques, procedures and algorithms using game theory, which leads to new competitive insights discussed in detail in this paper using over 1,000 cases. Following are some illustrations of game theory.

1. **The prisoner's dilemma:** Since the payoff is imprisonment, higher numbers are worse. Prisoner 1 is uncertain what his collaborator in crime will do but notes that if she confesses, he will get seven years for confessing and ten for remaining silent; if she does not confess, he will go free with a confession and otherwise serve a year in jail. So, whatever his conjecture about her actions, he does better to confess, and so does she. Both go to jail for seven years. Both players decided to protect themselves by confessing and got the maximum imprisonment in this situation. However, they had an opportunity to achieve another preferable result. This type of game is referred to as Type 2 game.
2. **Chicken game:** The "chicken game" term was suggested by an analogy of a sadistic sport popular with some drivers in the 1950s in which two vehicles drive towards each other, waiting for one to swerve. The winner is the player who sticks, while the other swerves (the latter is considered Chicken). If both swerve, they are poor players of Chicken. If neither does, they may not be able to play the Chicken again, a Type 3 game.
3. **Dominant cooperative strategy games:** The structure of payoffs for this type determines the cooperative strategy as the most likely outcome for both players, the Type 1 game.
4. **The Battle of the Sexes:** The Battle of the Sexes is an example of a coordination game, a Type 4 game. In this game, players want to coordinate their actions but have different preferences. The example illustrates how a husband and a wife want to coordinate their choice for an evening out. The husband prefers to go to a football game, and the wife prefers to go to the theatre, but both prefer to go together to any of two activities than to do their preferred one alone (Meng *et al.*, 2019; Tang and Dong, 2019). Kay (1993) argues that commitment and hierarchy are two ways of escaping from the Battle of the Sexes. What is needed is simply something to break the symmetry – to distinguish one Nash equilibrium from others. If we already have two tickets to the theatre, that settles it. If we always go to football, that settles it too.

Although the literature on cross-border alliances and game theory combination is widely used, some gaps are evident and remain underdeveloped/grey areas. First, there is a lack of literature which lays a set of conditions/principles that lead to the success of forming complex sustainable partnerships. It requires practical models, approaches and insights. Second, there is also a paucity of empirical research on the effect of distinct differences in alliances' behaviour on cross-border alliances learnings, i.e. the effect of learnings leads to innovation and potential growth among the partners. Third, the role of network connections between alliances can significantly affect resource sharing and the ability to take risks but is limitedly emphasised in contemporary literature.

In this research, we have filled the existing gap by (1) empirically analysing various scenarios, techniques and procedures to form cross-border alliances, (2) offering meta-models to recognise strategic games, (3) developing insights into the distribution of games in the short and long run using *a priori* and (4) framing a reliable set of conditions to form sustainable cross-border alliances. In addition, we analyse the costs and benefits of inter-organisation cooperation, which have received growing attention in recent research grounded in game theory.

3. The model

Matthews (1999) developed this research model with ideas from complexity, network resources and cooperative game theories. The model has the following essential elements.

(1) Matthews (1999) argues that any two alliance partners (stakeholders) are identified as **i** and **j.** There are two kinds of cooperation payoffs: potential and realised. The potential payoffs are denoted by $\mathbf{a_{ij}}$. The sum of the potential payoffs for all stakeholders in an alliance is therefore

$$S_{potential} = \Sigma\, a_{ij} \tag{3.1}$$

(2) Potential payoffs from an alliance are made up of the difference between benefits x_{ij} and costs y_{ij}, so the result is

$$a_{ij} = \left(x_{ij} - y_{ij}\right) \tag{3.2}$$

(3) Payoffs remain potential payoffs unless activated by agents. The realisation of payoffs depends on the extent of cooperation between the partners **i** and **j** defined by agents or stakeholders of **i** and **j.** The cooperative variables are called $\mathbf{\Theta_i}$ and $\mathbf{\Theta_j}$; $\mathbf{\Theta_i\Theta_j}$ denotes the extent of cooperation between the stakeholders **i** and **j.** Decisions are constrained to all or nothing (zero/one, $\Theta \in 0,1)$ choices [1]. Realising payoffs involves recognising potential payoffs $\mathbf{a_{ij}}$ and activating them.

(4) Therefore, the Model can be summarised by the following expression:

$$\left\{\begin{matrix}\text{Realised payoffs}\\ \text{from an alliance}\end{matrix}\right\}\ \begin{matrix}\text{depend}\\ \text{upon}\end{matrix}\ \left\{\begin{matrix}\text{The difference}\\ \text{between potential}\\ \text{benefits and costs}\end{matrix}\right\}\ \text{and}\ \left\{\begin{matrix}\text{The extent of}\\ \text{co-operation}\\ \text{between partners}\end{matrix}\right\}$$

Or, briefly,

$$a_{ij} \sim \Theta_i\Theta_j \tag{3.3}$$

$$S_{actual} = \Sigma_i\Sigma_j\, a_{ij}.\,\Theta_i\Theta_j \tag{3.4}$$

(5) Matthews explores coalitions as cooperative games, develops a cooperation model and describes the following variables: benefits and costs emerging in coalitions.

- *Transfer benefits and costs* (**r** and **c**) are benefits transferred from agent i in the coalition to agent, and j and c are costs of transfer (borne by agent i) [2].

- *Joint benefits* (**b**) are net payoffs received by agents from joint cooperation [3].
- *Reputation benefits* are net benefits (**d**) that accrue to partners merely from being part of the coalition [4].
- *Exit costs* (**h**) are costs of leaving the coalition [5].

(6) The actual payoff can be therefore summarised as follows:

$$S_{\mathrm{actual}} = \Sigma_i \Sigma_j \left(r_{ij}. + b_{ij} + d_{ij} - c_{ij} + h_{ij}\right) \Theta_i \Theta_j \qquad (3.5)$$

(7) Some assumptions have been made to achieve the purposes of this research: the symmetry of payoffs for coalition members. A coalition, therefore, can be represented as a binary set; the payoff matrix is presented in Figure 1.

Assuming symmetry, we can write payoffs for any player as S (player):

$$\left.\begin{array}{ll} S_{(\mathrm{player})i} = r + b + d - c & \text{if } \Theta_i = \Theta_j = 1 \\ S_{(\mathrm{player})i} = d - c & \text{if } \Theta_i = 1 \text{ and } \Theta_j = 0 \\ S_{(\mathrm{player})i} = r + d & \text{if } \Theta_j = 1 \text{ and } \Theta_j = 0 \\ S_{(\mathrm{player})i} = h & \text{otherwise} \end{array}\right\} \qquad (3.6)$$

(1) Benefits and costs emerging in coalitions are randomly determined and distributed between zero and one, except exit costs are determined between minus one and one (Figure 2).

(2) Alliances are seen as searching for different combinations of payoffs depending on the perceived value of alliance benefits and costs. Equations 3.1–3.6 represent the research model.

3.1 Logical possibilities I (model I)

Three possibilities emerge on the first iteration using equations (1) – (6).

(1) Type 1 game

If A > C and B > D, joint benefits exceed transfer costs – game where cooperation is clearly dominant, and Nash equilibrium is (1 1).

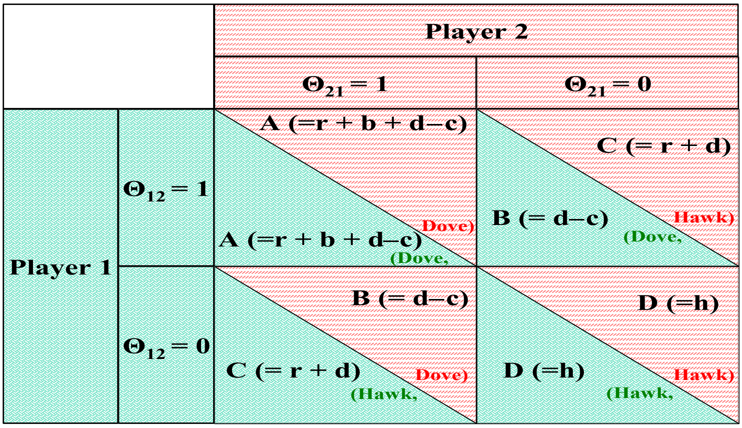

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Figure 1.
Payoff matrix for a binary coalition

(2) Type 2 game

If $A < C$ and $B < D$ and $D \geq 0$, joint benefits are less than transfer costs and reputation benefits are outweighed by transfer costs. Two games can be distinguished:

- a one-shot (prisoners dilemma) game – here, Nash equilibrium is (0 0).
- a repeated game (tit for tat) – Nash equilibrium is (1 1).

(3) Type 3 game

If $A < C$ and $B < D$ and $D < 0$, the game is a chicken game that has three Nash equilibria: (0 1), (1 0) and mixed strategy Nash equilibrium.

3.2 Logical possibilities II (model II)

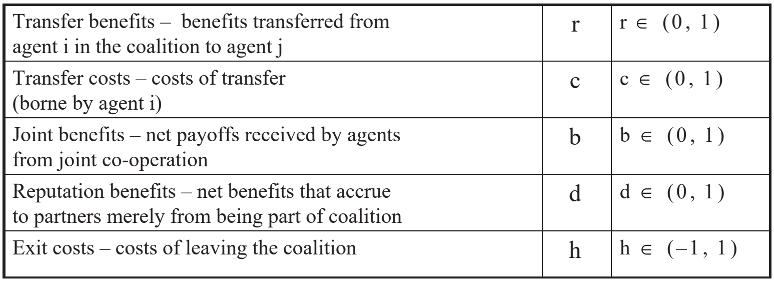
A second iteration using equations (1) – (6) gives a finer classification of games. The models described above are used as the basis for the research methodology.

4. Research methodology

The justification of this research is that it is common knowledge that SAs are formed to bring value to the organisations entering them and help them gain a competitive advantage. Properly managing an SA is becoming one of the best ways for firms to survive and succeed as global competition intensifies. Learning alliances, i.e. associations in which the primary objective of the partners is to learn from each other, constitute an important class of SAs. Therefore, an SLA has become a powerful tool for developing mutual benefits and strengthening partners' competitive positions.

The research methodology includes secondary data collection and primary research. The former consists of two parts: primary data collection using empirical data; the Delphi technique for obtaining qualitative data and the questionnaire research for collecting quantitative data and computer simulation. Secondary data collection was performed to obtain information on SAs, possible benefits and costs of cooperation and strategies for cooperative behaviour. Various literature sources on this subject were critically reviewed. The key variables that should be collected and measured when analysing an SA were identified, grouped and mapped into our model.

The qualitative research included 26 in-depth interviews with top managers of European international organisations in the UK, Germany and Russia that have entered SAs or intend to do so (10 of the interviewees hold chief executive officer positions). The selected



Transfer benefits – benefits transferred from agent i in the coalition to agent j	r	$r \in (0, 1)$
Transfer costs – costs of transfer (borne by agent i)	c	$c \in (0, 1)$
Joint benefits – net payoffs received by agents from joint co-operation	b	$b \in (0, 1)$
Reputation benefits – net benefits that accrue to partners merely from being part of coalition	d	$d \in (0, 1)$
Exit costs – costs of leaving the coalition	h	$h \in (-1, 1)$

Source(s): Authors' own work

Figure 2.
Intervals for benefit and cost variables

organisations have a budget of over £200 million and 2,000 employees and significantly contribute to their national economy (above £1 billion annually). The objectives of the interviews were to find out the top managers' experiences and perceptions of SAs and the joint benefits and challenges of entering SLAs.

The quantitative research element included a questionnaire which was designed and sent to a sample of 330 individuals from the same organisations as the interviewees to identify the importance of benefits and costs of cooperation in SAs. It contained the following sections: about the respondent's company, perceived benefits of SAs, the companies SAs and the possible costs of SAs. All questions about the benefits and costs of cooperation were mapped into our model.

This research adopts innovative approaches to investigate and understand social equality. We ensured that this research was conducted in accordance with ethical review and approval principles. This research adhered to the institutional procedures and was driven by an ethic of respect for cultures, communities, the individual/person and independent knowledge.

4.1 Simulation

Several models originating from the Matthews Model were used for simulation.

(1) Model 1 – a priori model (ergodic search)

This model represents an ergodic search for all possible combinations of payoff perception from the point of view of Player 1, one of the coalition partners. First, it resulted in 24 possible payoff combinations. Then, all possible combinations of positive and negative payoffs were considered. It turned into a total number of 120 possible outcomes. Then, an ergodic search of all games that can meet the game definition provided by the model was performed.

Assuming a different ranking of perception of game payoffs by coalition members [6] (Figure 3), there are 24 possible variants of payoff perception.

Each payoff may be either positive or negative, giving the combinations. For example, if the first choice, say A in Variant 1, is negative, then other choices, B, C and D, are also negative. However, the total number of combinations is significantly less than positive and negative if payoffs were distributed randomly.

If A is negative, then B, C and D are also negative. If A is positive, then B can be either negative or positive. Therefore, the total number of combinations for 24 variants is $24 \times 5 = 120$. Our simulation contains all possible 120 combinations. There are six Type 1, Type 2 and Type 3 games in 24 variants and 30 Type 1, 20 Type 2 and 10 Type 3 games in 120 possible payoff outcomes.

(2) Model 2 – a priori model (restricted search)

This model implies putting logical constraints based on a priori model 1. Its main purpose is to limit the search field and rule out all a priori model combinations that are logically impossible. However, some of the outcomes may be logically impossible. To check it, it is necessary to compare various payoffs and put logical constraints on the outcomes.

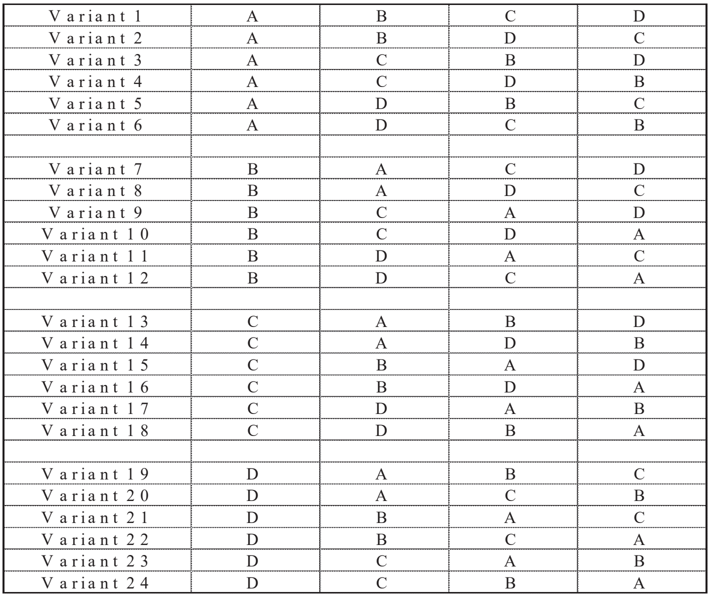
4.1.1 Logical constraints: Step 1. Taking the point of view of one of the players (say Player 1), it is possible to compare payoffs by comparing cost and benefit structure (Figure 4).

Step 1 resulted in two logical constraints:

(1) A cannot be less than B ($A < B$ – impossible)

(2) B cannot be greater than C ($C < B$ – impossible)

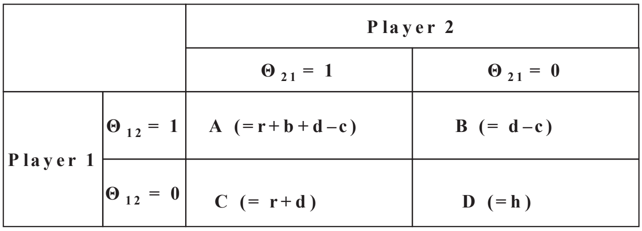
4.1.2 Logical constraints: Step 2. Suppose that D cannot be the first choice of any coalition because it presumes non-cooperative behaviour (Zhang, 2021) of both sides and leaves the coalition [7], therefore



Variant 1	A	B	C	D
Variant 2	A	B	D	C
Variant 3	A	C	B	D
Variant 4	A	C	D	B
Variant 5	A	D	B	C
Variant 6	A	D	C	B
Variant 7	B	A	C	D
Variant 8	B	A	D	C
Variant 9	B	C	A	D
Variant 10	B	C	D	A
Variant 11	B	D	A	C
Variant 12	B	D	C	A
Variant 13	C	A	B	D
Variant 14	C	A	D	B
Variant 15	C	B	A	D
Variant 16	C	B	D	A
Variant 17	C	D	A	B
Variant 18	C	D	B	A
Variant 19	D	A	B	C
Variant 20	D	A	C	B
Variant 21	D	B	A	C
Variant 22	D	B	C	A
Variant 23	D	C	A	B
Variant 24	D	C	B	A

Source(s): Authors' own work

Figure 3.
Possible variants of payoff perception



		Player 2	
		$\Theta_{21} = 1$	$\Theta_{21} = 0$
Player 1	$\Theta_{12} = 1$	A (= r + b + d − c)	B (= d − c)
	$\Theta_{12} = 0$	C (= r + d)	D (= h)

Source(s): Authors' own work

Figure 4.
Payoffs, costs and benefits structure of alliances

(3) D cannot be greater than A, B, C (D > A, B, C – impossible).

4.1.3 Logical constraints: Step 3. Turning back to payoffs A, B, C and D and their cost and benefit structure, one can note that C equals r + d. It cannot be negative [8]. Furthermore, the fourth logical constraint arises (Figure 5).

(4) C cannot be less than zero (C < 0 – impossible).

Putting logical constraints (1) - (4) on the set of all possible outcomes rules out 100 games out of 120 (Appendix 2) *a priori* game distribution restricted search. The rest 20 games can be grouped into the new, enhanced/comprehensive game taxonomy that describes all possible types of games.

(1) Model 3 – random landscape

The computer simulation model, random landscape, was used for the following reasons: (1) the limited accessible set of empirical data, (2) the necessity to explore a large dataset and

(3) the possibility to research a random combination of coalition benefit and cost variables, payoffs, compare them with the a priori model and test the former.

Random values were attached to benefit and cost variables (Figure 2). Then, different payoffs, A, B, C and D, for the payoff matrix were calculated. It was done for 1,000 cases. Then, different types of games were counted, and the distribution of games was analysed.

The random landscape model shows that columns B – F contain random values for cooperation benefit and cost variables r, c, b, d and h in the intervals defined. According to the model, columns H – K calculate payoffs A, B, C and D. Cell A9 contains the counter of cases; cells M9 – AD10 count the number of different games and compute game distribution (Appendix 2).

Every run gives random combinations of coalition benefit and cost variables, completely different results of payoff ordering and a new combination of game distribution (though the game distribution tends to have the same results: the number of games and proportions).

4.2 New taxonomy games

There are 20 logically possible games out of 120 outcomes. They can be grouped into four different types; each type has been divided into several categories. Figure 6 illustrates the new taxonomy.

	Logical constraints		Justification
i	A can not be less than B	($A < B$ – impossible)	$A-B=(r+b+d-c)-(d-c)=r+b>0$
ii	B can not be greater than C	($C < B$ – impossible)	$B-C=(d-c)-(r+d)=-r-c=-(r+c)<0$,therefore $B<C$
iii	D can not be greater than A,B,C	($D > A,B,C$ – impossible)	D presumes non-cooperative behaviour of both sides and leaving the coalition ($\Theta_{12}=\Theta_{21}=0$)
iv	C can not be less than zero	($C < 0$ – impossible)	$C=r+d>0$

Source(s): Authors' own work

Figure 5. Summary of all four logical constraints

Types of games	Payoff ordering	Number of variants	Number of games in category
Type 1			**8**
Type 1.1	$A > C > B > D$	3.1, 3.2, 3.3	3
Type 1.2	$A > C > D > B$	4.1, 4.2, 4.3	3
Type 1.3	$A > D > C > B$	6.1, 6.2	2
Type 2			**5**
Type 2.1	$C > A > D > B, D >= 0$	14.1, 14.2	2
Type 2.2	$C > D > A > B, D >= 0$	17.1, 17.2, 17.3	3
Type 3			**3**
Type 3.1	$C > A > D > B, D < 0$	14.3, 14.4	2
Type 3.2	$C > D > A > B, D < 0$	17.4	1
Type 4			**4**
Type 4.1	$C > A > B > D, D < 0$	13.2, 13.3, 13.4	3
Type 4.2	$C > A > B > D, D >= 0$	13.1	1

Source(s): Authors' own work

Figure 6. New taxonomy of the game

5. Findings

All interviewees stressed the importance of joint and reputation benefits typical for Type 1 games. Most respondents rank reputation and mutual benefits relatively high, averaging 4.1 and 3.85 of a possible five. That is significantly higher than net transfer benefits $r - c$, ranked 0.61 of a possible 5.

The a priori model (restricted search) is the model of possible games that illustrate the importance of joint and reputation benefits for Type 1 games which are the most used in cooperative games and demonstrate that this type of game is the most frequent in-game distribution: 8 of 20 possible games or 40% of all four types of games (Appendix 1).

The random landscape model that simulates possible cooperation outcomes in coalitions also proves that Type 1 games are the most common in-game distribution. They have an even higher probability than in the a priori model, approximately 50%.

The result of the empirical data (Figure 7) in a combination of payoffs characteristic for Type 1 games shows that joint and reputation benefits determine cooperation as the dominant strategy in coalitions. Therefore, this research demonstrates that joint and reputation benefits are critical for the success of cooperation. It will define the behaviour of the companies in SAs: respondents prefer cooperation and mutual gains (joint and reputation benefits) to competitive strategies that are particularly important for learning alliances where partners face incentives to learn from each other (aka "learning race"). No wonder that the average for questionnaire answers resulted in cooperation benefit and cost variables, which give payoffs typical for Type 1 games $A > C > B > D$ (Figure 7).

This fact shows that actual and prospective alliance members perceive the benefits and costs of cooperation to define the cooperative behaviour of companies in coalitions. The cooperative behaviour of partners will determine the success of learning in alliances (e.g. Russian company RGC in alliance with Mars (Rajavel *et al.*, 2021)). In a way, it justifies that in a complex situation, the strategic movement of one player is dependent on the other. Firms can stimulate their strategic behaviours, such as collusion and price setting to maintain and gain market power.

The new taxonomy illustrates possible cooperative strategies for members of SAs, illustrates whether the coalition is the best choice for a prospective partner or whether it could be better to find another coalition with a more attractive payoff combination and explains when cooperation becomes the dominant strategy and when additional measures are required to ensure the success of coalitions.

Particularly it results in a conclusion about the importance of *communication* for the success of cooperative strategies. Type 1 games are the most desirable situations for cooperation in coalitions; joint and reputation benefits are critical for this type of game. Games 3 of 8 have cooperation as a dominant strategy. For the other five games, A is still the Pareto optimum; communication is required to ensure that partners will start to play A, not D, as the other possible Nash equilibrium. These findings are important for successful learning and knowledge transfer in SAs.

$A = r + b + d - c$	8.5656566
$B = d - c$	0.9
$C = r + d$	7.9111111
$D = -h$	−3.2

		Player 2	
		$\Theta_{21} = 1$	$\Theta_{21} = 0$
Player 1	$\Theta_{12} = 1$	$A = 8.57$	$B = 0.9$
	$\Theta_{12} = 0$	$C = 7.91$	$D = -3.2$

Figure 7.
Payoffs distribution and cooperation payoffs

Source(s): Authors' own work

Simulation demonstrates a relatively high distribution of Type 1 games in both a priori and random landscape models, 40% of all possible games and approximately 50% of the total cases. Primary research also shows the perception of benefit and cost variables with high ranking for joint and reputation benefits in interviews and questionnaire answers typical for cooperative Type 1 games.

6. Analysis and discussion

In the context of this research, the continued development and extensive technical application of game theory to SAs enabled a new research scope. It has allowed us to model complex situations with many alliances and strategies in different games. This approach has developed a unique insight into strategic interactions, as technically explained in the next sections.

From an equity perspective, the insights of the game theory have important strategic implications for promoting fairness and cooperation, i.e. distribution of incentives based on investments.

6.1 New taxonomy of games and strategic alliances

Grouping games into different types is based on different payoff ordering and is defined by each game's cost and benefit structure (Figure 8).

(1) Type 1 game

Type 1.1 is a purely cooperative game. Hence, a is the Pareto optimum, Nash equilibrium for this type of game, and cooperation is the dominant strategy.

Type 1.2 and 1.3 games also have A as the Pareto optimum, but they have two Nash equilibria for each type of game.

Though A is still the best choice for both players, they have another option, D as Nash equilibrium, and they will be afraid that if they play Dove, their contra partner will play Hawk, and they get B's "sucker's payoff". Therefore, a temptation to play Hawk for both partners exists. Communication is required to resolve this problem and start to play A for Type 1.2 and 1.3 games. Type 1 games have the following cost and benefit structure (Figure 9).

Types of games	Payoff ordering	Number of variants	Cost and benefit structure	Number of games in category
Type 1				**8**
Type 1.1	A > C > B > D	3.1, 3.2, 3.3	r + b + d–c > r + d > d–c > h	3
Type 1.2	A > C > D > B	4.1, 4.2, 4.3	r + b + d–c > r + d > h > d–c	3
Type 1.3	A > D > C > B	6.1, 6.2	r + b + d–c > h > r + d > d–c	2
Type 2				**5**
Type 2.1	C > A > D > B, D > = 0	14.1, 14.2	r + d > r + b + d–c > h > d–c, h >= 0	2
Type 2.2	C > D > A > B, D > = 0	17.1, 17.2, 17.3	r + d > h > r + b + d–c > d–c, h >= 0	3
Type 3				**3**
Type 3.1	C > A > D > B, D < 0	14.3, 14.4	r + d > r + b + d–c > h > d–c, h < 0	2
Type 3.2	C > D > A > B, D < 0	17.4	r + d > h > r + b + d–c > d–c, h < 0	1
Type 4				**4**
Type 4.1	C > A > B > D, D < 0	13.2, 13.3, 13.4	r + d > r + b + d–c > d–c > h, h < 0	3
Type 4.2	C > A > B > D, D > = 0	13.1	r + d > r + b + d–c > d–c > h, h >= 0	1

Source(s): Authors' own work

Figure 8.
Payoff ordering and the cost and benefit structure of games

Joint and reputation benefits and differences between A and D (A, D) are critical for cooperation in Type 1 games.

(2) Type 2 game

Type 2 game is the prisoner’s dilemma game. Games of this type have C as the Pareto optimum and D as the Nash equilibrium for a one-shot game. However, repetition moves Nash equilibrium to A (Figure 10).

The difference between b and c, i.e. small b and high c, is characteristic of this type of game.

(3) Type 3 game

Type 3 game is the chicken game. It has C as the Pareto optimum, as in Type 2 games.

However, negative D has several Nash equilibria: (0, 1), (1, 0) and mixed strategy Nash equilibrium where each player plays Hawk with a related probability to the structure of payoffs: reward of winning the game to the cost of conflict (Figure 11).

(4) Type 4 game

Type 4 is a new game for the new taxonomy of games. It also has C as the Pareto optimum. Type 4.1 games are known as classical “Hawk-Dove” games. This is because they have negative D. It defines their multiple equilibria similar to the chicken game where each player plays Hawk with a related probability to the structure of payoffs: reward of winning the game to the cost of conflict.

Type 4.2 games have positive D, and because of it, they turn out to be a game like the Battle of the Sexes. In this game, each of the players prefers to go *together* with the partner to the place that the player likes (say football for Player 1) play (0, 1) and then to the partner’s favourite place (say, the theatre) but again *together* with the partner, play (1, 0). If it is impossible, each partner would prefer to go to his/her favourite place and play (0, 0) (Figure 12).

Figure 9.
Cost and benefits structure of Type 1 games

Types of games	Payoff ordering	Cost and benefit structure
Type 1.1	A > C > B > D	r + b + d–c > r + d > d–c > h
Type 1.2	A > C > D > B	r + b + d–c > r + d > h > d–c
Type 1.3	A > D > C > B	r + b + d–c > h > r + d > d–c

Source(s): Authors’ own work

Figure 10.
Cost and benefits structure of Type 2 games

Types of games	Payoff ordering	Cost and benefit structure
Type 2.1	C > A > D > B, D >= 0	r + d > r + b + d–c > h > d–c, h >= 0
Type 2.2	C > D > A > B, D >= 0	r + d > h > r + b + d–c > d–c, h >= 0

Source(s): Authors’ own work

Figure 11.
Cost and benefits structure of Type 3 games

Types of games	Payoff ordering	Cost and benefit structure
Type 3.1	C > A > D > B, D < 0	r + d > r + b + d–c > h > d–c, h < 0
Type 3.2	C > D > A > B, D < 0	r + d > h > r + b + d–c > d–c, h < 0

Source(s): Authors’ own work

6.2 Explanation: random landscape vs a priori model

The distribution of games in the random landscape model gives different results compared to the a priori model. This happens due to the following.

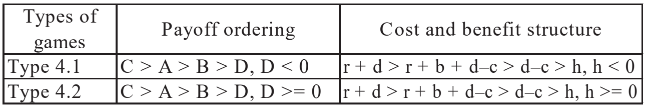
(1) Difference between the number of cases and the classified games

The difference between the total number of cases (1,000) from Model 3 (random landscape, Table 1) and the total number of classified games is explained by the fact that situations where D is the first choice (D > A, B, C) are ruled out by the logical constraint (3) and accrue in the random landscape model, where r, d, d, c and h are distributed randomly. D can be greater than A, B and C (Appendix 1).

Column X contains a counter of outcomes with D greater than A (D-order), and cell X9 gives the total number of such outcomes that, if added to the total number of Type 1–4 games (cell V9 or cell AD9), gives the total number of cases (cell A9).

(2) Disproportion in the game's distribution in a priori and random landscape models

The disproportion between the distribution of games in the two models (Type 1 40% in a priori vs 52.3% in random landscape, or 15% vs 6.7 for Type 3 games) is explained by the fact that the a priori model describes the number and proportion of *possible types* of games. The probability of game distribution depends on the *expected values* of payoffs based on the expected values of cooperation variables. The random landscape model operates with randomly expected values and reflects the game distribution's real situation. Figure 13 illustrates the expected values of cooperation benefit, cost variables and different cooperation outcomes in the a priori model (Appendix 1).



Types of games	Payoff ordering	Cost and benefit structure
Type 4.1	C > A > B > D, D < 0	r + d > r + b + d–c > d–c > h, h < 0
Type 4.2	C > A > B > D, D >= 0	r + d > r + b + d–c > d–c > h, h >= 0

Source(s): Authors' own work

Figure 12. Cost and benefits structure of Type 4 games

Testing a priori (restricted)

	Type 1.1	Type 1.2	Type 1.3	Type 2.1	Type 2.2	Type 3.1	Type 3.2	Type 4.1	Type 4.2	Total
Number of games	3	3	2	2	3	2	1	3	1	20
% to the number of games	15	15	10	10	15	10	5	15	5	100

Random landscape/types of games 1,000 cases D-order 55

		Type 1.2	Type 1.3	Type 2.1	Type 2.2	Type 3.1	Type 3.2	Type 4.1	Type 4.2	
Number of games	308	166	20	129	49	53	3	201	16	945
% to the number of cases	30.8	16.6	2	12.9	4.9	5.3	0.3	20.1	1.6	94.5

For Type 1	For Type 2	For Type 3	For Type 4	For 1–4
8	5	3	4	20
40	25	15	20	100
For Type 1	For Type 2	For Type 3	For Type 4	For 1–4
494	178	56	217	945
52.275132	18.835979	5.9259259	22.96296	100

Source(s): Authors' own work

Table 1. Distribution of games random landscape vs a priori model

Figure 13.
Expected values of cooperation benefit and cost variables for different corporation outcomes

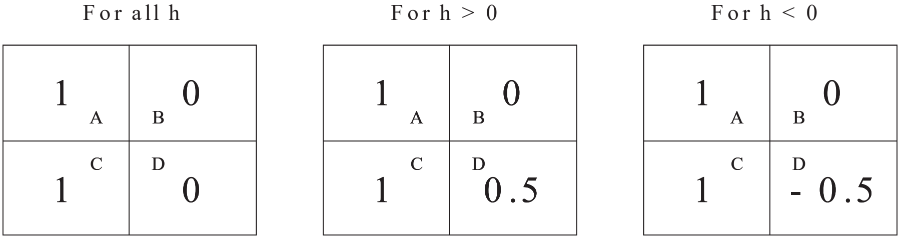
Cooperation benefit and cost variables and cooperation outcomes	Intervals (for cooperation benefit and cost variables) and formulas for cooperation outcomes	Expected values
Transfer benefits (r)	(0 , 1)	0.5
Transfer costs (c)	(0 , 1)	0.5
Joint benefits (b)	(0 , 1)	0.5
Reputation benefits (j)	(0 , 1)	0.5
Exit costs (h)-for all h	(–1 , 1)	0
Exit costs (h)-for positive h	(0 , 1)	0.5
Exit costs (h)-for negative h	(–1 , 0)	–0.5
A	A = r + b + d – c	1
B	B = d – c	0
C	C = r + d	1
D-for all h	D = h	0
D-for positive h	D = h	0.5
D-for negative h	D = h	–0.5

Source(s): Authors’ own work

These values are also calculated in the random landscape model as an average of all cases line . . . cells . . . provide expected values for positive and negative values of h, respectively. Therefore, these values from the random landscape model can be compared with expected values in the a priori model as they are very close. Figure 14 demonstrates how expected values influence payoff structure and, therefore, the distribution of games.

That is why Type 1.1 and Type 1.2 games (payoff ordering A > C > B > D and A > C > D> B, respectively) have higher probability and a proportion in-game distribution, and Type 1.3 game (payoff ordering A > D> C > B) has lower probability and proportion in the game distribution in the random landscape than in the a priori model (Figure 15).

Another possible reason for the difference between logical and simulation distributions of games is the limited number of 1,000 cases. Although this number is relatively high, it can still be insufficient for making the logical model’s simulation distribution.



Games with A and C as the first and the second choice* will happen more likely and will have higher probability

(for all games)

Games with A and C as the first and the second choice*, and D as the third choice will happen more likely and will have higher probability.

(for Type 2 and Type 4.2 games)

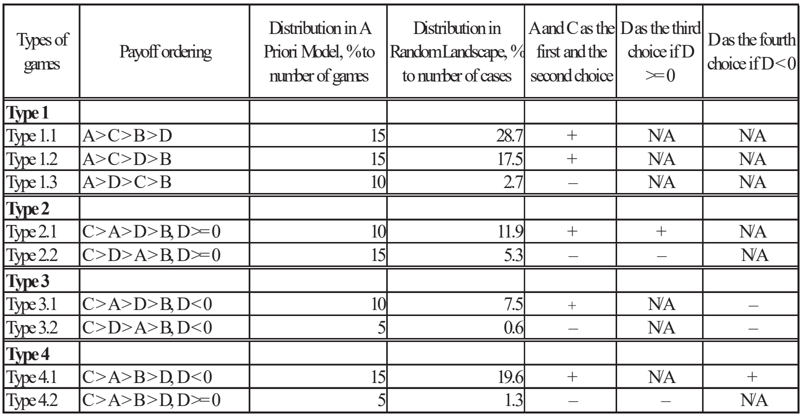
Games with A and C as the first and the second choice*, and D as the fourth choice will happen more likely and will have higher probability.

(for Type 3 and Type 4.1 games)

* - A can be the first choice, C – the second choice and vice versa.

Source(s): Authors’ own work

Figure 14.
Expected values and payoff structure



Types of games	Payoff ordering	Distribution in A Priori Model, % to number of games	Distribution in Random Landscape, % to number of cases	A and C as the first and the second choice	D as the third choice if D >=0	D as the fourth choice if D<0
Type 1						
Type 1.1	A>C>B>D	15	28.7	+	N/A	N/A
Type 1.2	A>C>D>B	15	17.5	+	N/A	N/A
Type 1.3	A>D>C>B	10	2.7	–	N/A	N/A
Type 2						
Type 2.1	C>A>D>B, D>=0	10	11.9	+	+	N/A
Type 2.2	C>D>A>B, D>=0	15	5.3	–	–	N/A
Type 3						
Type 3.1	C>A>D>B, D<0	10	7.5	+	N/A	–
Type 3.2	C>D>A>B, D<0	5	0.6	–	N/A	–
Type 4						
Type 4.1	C>A>B>D, D<0	15	19.6	+	N/A	+
Type 4.2	C>A>B>D, D>=0	5	1.3	–	–	N/A

Source(s): Authors' own work

Figure 15.
Influence payoff structure on the distribution of games

7. Conclusions

Cross-border alliances provide vital insights into the complexities of international business operations and competition. Specifically, game theory has progressed as a widely used and powerful tool for understanding alliances' strategic decisions. Research on cross-border learning alliances and strategic games has become increasingly important in today's globalised economy as firms seek to collaborate and learn from one another across international borders.

This research specifically emphasised the role of game theory in understanding the vital forces influencing the success and sustainability of forming and executing cross-border alliances. These factors include resource sharing, building networks, risk-taking, the alliance's structure and regulatory protocols. It also developed maps/meta-models and a set of principles to shape the progressive elaboration of cross-border alliances.

While learning alliances aim to transfer knowledge between partners, coalition members can prevent cheating by acquiring each other's skills and solidifying their knowledge through cooperative gameplay. Specifically, when engaging in Type 1 games that result in substantial mutual benefits, cooperation emerges as the most advantageous strategy for coalitions seeking to foster mutual gains. The findings of this primary research and simulation affirm the prevalence of cooperation in such scenarios.

Much is still to be learned about the dynamics of cross-border learning alliances and strategic games. Researchers must continue to innovate and develop new methods for studying these complex relationships. By doing so, they can help firms navigate the challenges and opportunities of the globalised economy and develop more effective strategies for collaboration and knowledge sharing across national borders.

Research on cross-border learning alliances has several implications for both managerial and practice. Following are some of the implications:

1. Managerial implications: This research can help managers to understand the challenges and benefits of engaging in these activities. They can use this knowledge to develop strategies to improve the effectiveness of their cross-border learning alliances.
2. Practical implications: The development of game theory and cross-border models (conceptual/meta-models) can be applied in effective decision-making in a variety of complex contexts.

(3) Importance of internationalisation: This research highlights the importance of internationalisation for organisations looking to enhance their competitiveness and capabilities. This can involve developing partnerships with organisations in other countries and engaging in strategic thinking and decision-making in global markets.

(4) Policy implications: Learning alliances have important policy implications, particularly in trade, investment and innovation. Policymakers must consider the potential benefits and risks of these collaborations and develop policies that encourage and support them while mitigating potential negative impacts.

Notes

1. We say that agent i cooperates, or plays Dove, if $\Theta i = 1$, and not cooperates, or plays Hawk if $\Theta i = 0$.
2. Thus, if $\Theta_i = 1$ then $r_{ij} \geq 0$ and $c_{ij} \leq 0$.
3. Thus, $b_{ij} \geq 0$ if and only if both $\Theta_i \geq 0$ and $\Theta_j \geq 0$.
4. Thus, $d_{ij} \geq 0$ if $\Theta_i \geq 0$ or $\Theta_j \geq 0$ or both.
5. Thus, $h_i \leq 0$ and $h_j \leq 0$ if $\Theta_i = 0$ or $\Theta_j = 0$
6. Each of them may perceive A as the most desirable choice, then B, then C, then D . . . etc. in different combinations.
7. $\Theta_{12} = \Theta_{21} = 0$
8. From the point of view of formal logic: $r \in (0,1)$, $d \in (0,1)$ therefore $r + d \in (0,2)$; from the point of view of common-sense transfer and reputation *benefits* cannot be negative.

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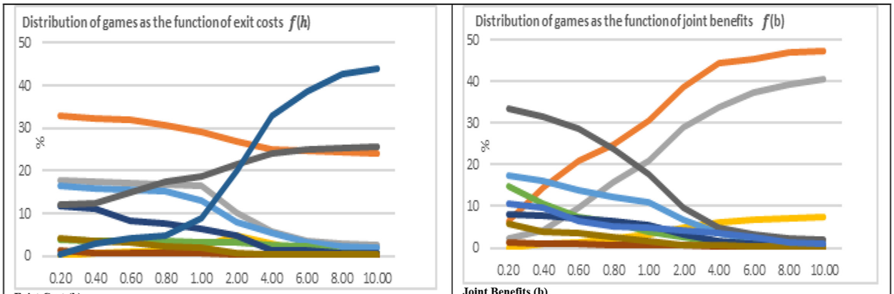
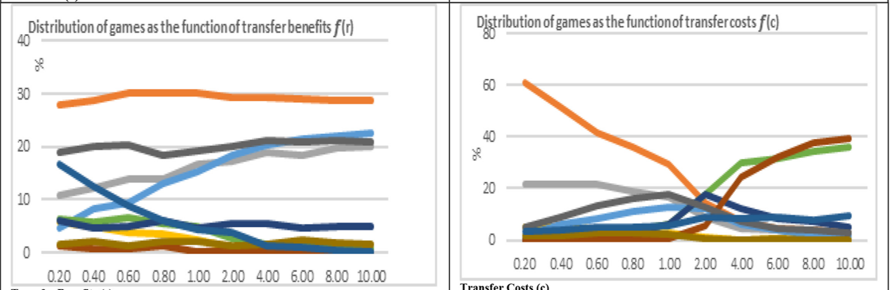
Appendix 1:



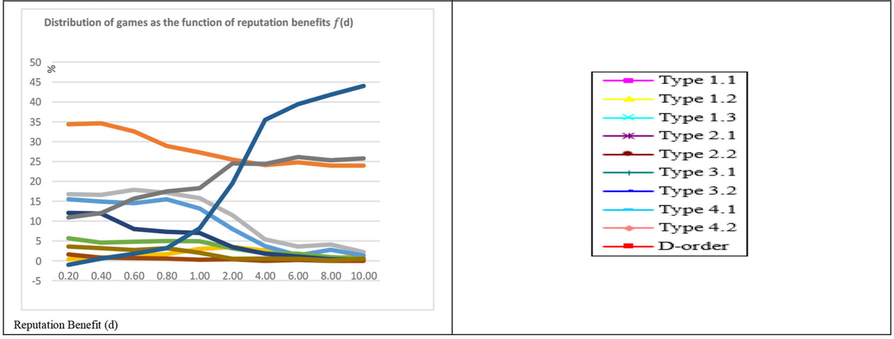
Exist Cost (h)

Joint Benefits (b)



Transfer Benefits (r)

Transfer Costs (c)



Reputation Benefit (d)

Source(s): Authors' own work

Figure A1.
A priori game distribution

Appendix 2:

													Logical constraints			
													i	ii	iii	iv
1	Variant 1	1	A+	B+	C+	D+		Type 1						C < B		
2	Variant 1	2	A+	B+	C+	D –		Type 1						C < B		
3	Variant 1	3	A+	B+	C –	D –		Type 1						C < B		C < 0
4	Variant 1	4	A+	B –	C –	D –		Type 1						C < B		C < 0
5	Variant 1	5	A –	B –	C –	D –		Type 1						C < B		C < 0
6	Variant 2	1	A+	B+	D+	C+		Type 1						C < B		
7	Variant 2	2	A+	B+	D+	C –		Type 1						C < B		C < 0
8	Variant 2	3	A+	B+	D –	C –		Type 1						C < B		C < 0
9	Variant 2	4	A+	B –	D –	C –		Type 1						C < B		C < 0
10	Variant 2	5	A –	B –	D –	C –		Type 1						C < B		C < 0
11	Variant 3	1	A+	C+	B+	D+		Type 1								
12	Variant 3	2	A+	C+	B+	D –		Type 1								
13	Variant 3	3	A+	C+	B –	D –		Type 1								
14	Variant 3	4	A+	C –	B –	D –		Type 1								C < 0
15	Variant 3	5	A –	C –	B –	D –		Type 1								C < 0
16	Variant 4	1	A+	C+	D+	B+										
17	Variant 4	2	A+	C+	D+	B –										
18	Variant 4	3	A+	C+	D –	B –										
19	Variant 4	4	A+	C –	D –	B –										C < 0
20	Variant 4	5	A –	C –	D –	B –										C < 0
21	Variant 5	1	A+	D+	B+	C+								C < B		
22	Variant 5	2	A+	D+	B+	C –								C < B		C < 0
23	Variant 5	3	A+	D+	B –	C –								C < B		C < 0
24	Variant 5	4	A+	D –	B –	C –								C < B		C < 0
25	Variant 5	5	A –	D –	B –	C –								C < B		C < 0
26	Variant 6	1	A+	D+	C+	B+										
27	Variant 6	2	A+	D+	C+	B –										
28	Variant 6	3	A+	D+	C –	B –										C < 0
29	Variant 6	4	A+	D –	C –	B –										C < 0
30	Variant 6	5	A –	D –	C –	B –										C < 0
31	Variant 7	1	B+	A+	C+	D+		Type 1					A < B	C < B		
32	Variant 7	2	B+	A+	C+	D –		Type 1					A < B	C < B		
33	Variant 7	3	B+	A+	C –	D –		Type 1					A < B	C < B		C < 0
34	Variant 7	4	B+	A –	C –	D –		Type 1					A < B	C < B		C < 0
35	Variant 7	5	B –	A –	C –	D –		Type 1					A < B	C < B		C < 0
36	Variant 8	1	B+	A+	D+	C+		Type 1					A < B	C < B		
37	Variant 8	2	B+	A+	D+	C –		Type 1					A < B	C < B		C < 0
38	Variant 8	3	B+	A+	D –	C –		Type 1					A < B	C < B		C < 0
39	Variant 8	4	B+	A –	D –	C –		Type 1					A < B	C < B		C < 0
40	Variant 8	5	B –	A –	D –	C –		Type 1					A < B	C < B		C < 0
41	Variant 9	1	B+	C+	A+	D+							A < B	C < B		
42	Variant 9	2	B+	C+	A+	D –							A < B	C < B		
43	Variant 9	3	B+	C+	A –	D –							A < B	C < B		
44	Variant 9	4	B+	C –	A –	D –							A < B	C < B		C < 0
45	Variant 9	5	B –	C –	A –	D –							A < B	C < B		C < 0
46	Variant 10	1	B+	C+	D+	A+							A < B	C < B		
47	Variant 10	2	B+	C+	D+	A –							A < B	C < B		
48	Variant 10	3	B+	C+	D –	A –							A < B	C < B		
49	Variant 10	4	B+	C –	D –	A –							A < B	C < B		C < 0
50	Variant 10	5	B –	C –	D –	A –							A < B	C < B		C < 0
51	Variant 11	1	B+	D+	A+	C+		Type 1					A < B	C < B		
52	Variant 11	2	B+	D+	A+	C –		Type 1					A < B	C < B		C < 0
53	Variant 11	3	B+	D+	A –	C –		Type 1					A < B	C < B		C < 0
54	Variant 11	4	B+	D –	A –	C –		Type 1					A < B	C < B		C < 0
55	Variant 11	5	B –	D –	A –	C –		Type 1					A < B	C < B		C < 0
56	Variant 12	1	B+	D+	C+	A+							A < B	C < B		
57	Variant 12	2	B+	D+	C+	A –							A < B	C < B		
58	Variant 12	3	B+	D+	C –	A –							A < B	C < B		C < 0
59	Variant 12	4	B+	D –	C –	A –							A < B	C < B		C < 0
60	Variant 12	5	B –	D –	C –	A –							A < B	C < B		C < 0

Figure A2.
A priori game distribution – restricted search

(*continued*)

61	Variant 13	1	C+	A+	B+	D+										
62	Variant 13	2	C+	A+	B+	D –										
63	Variant 13	3	C+	A+	B –	D –										
64	Variant 13	4	C+	A –	B –	D –										
65	Variant 13	5	C –	A –	B –	D –										C < 0
66	Variant 14	1	C+	A+	**D+**	B+			Type 2							
67	Variant 14	2	C+	A+	**D+**	B –			Type 2							
68	Variant 14	3	C+	A+	**D –**	B –				Type 3						
69	Variant 14	4	C+	A –	**D –**	B –				Type 3						
70	Variant 14	5	C –	A –	**D –**	B –				Type 3						C < 0
71	Variant 15	1	C+	B+	A+	D+							A < B			
72	Variant 15	2	C+	B+	A+	D –							A < B			
73	Variant 15	3	C+	B+	A –	D –							A < B			
74	Variant 15	4	C+	B –	A –	D –							A < B			
75	Variant 15	5	C –	B –	A –	D –							A < B			C < 0
76	Variant 16	1	C+	B+	D+	A+							A < B			
77	Variant 16	2	C+	B+	D+	A –							A < B			
78	Variant 16	3	C+	B+	D –	A –							A < B			
79	Variant 16	4	C+	B –	D –	A –							A < B			
80	Variant 16	5	C –	B –	D –	A –							A < B			C < 0
81	Variant 17	1	C+	**D+**	A+	B+			Type 2							
82	Variant 17	2	C+	**D+**	A+	B –			Type 2							
83	Variant 17	3	C+	**D+**	A –	B –			Type 2							
84	Variant 17	4	C+	**D –**	A –	B –				Type 3						
85	Variant 17	5	C –	**D –**	A –	B –				Type 3						C < 0
86	Variant 18	1	C+	**D+**	B+	A+			Type 2				A < B			
87	Variant 18	2	C+	**D+**	B+	A –			Type 2				A < B			
88	Variant 18	3	C+	**D+**	B –	A –			Type 2				A < B			
89	Variant 18	4	C+	**D –**	B –	A –				Type 3			A < B			
90	Variant 18	5	C –	**D –**	B –	A –				Type 3			A < B			C < 0
91	Variant 19	1	D+	A+	B+	C+								C < B	D > A,B,C	
92	Variant 19	2	D+	A+	B+	C –								C < B	D > A,B,C	C < 0
93	Variant 19	3	D+	A+	B –	C –								C < B	D > A,B,C	C < 0
94	Variant 19	4	D+	A –	B –	C –								C < B	D > A,B,C	C < 0
95	Variant 19	5	D –	A –	B –	C –								C < B	D > A,B,C	C < 0
96	Variant 20	1	D+	A+	C+	B+									D > A,B,C	
97	Variant 20	2	D+	A+	C+	B –									D > A,B,C	
98	Variant 20	3	D+	A+	C –	B –									D > A,B,C	C < 0
99	Variant 20	4	D+	A –	C –	B –									D > A,B,C	C < 0
100	Variant 20	5	D –	A –	C –	B –									D > A,B,C	C < 0
101	Variant 21	1	D+	B+	A+	C+							A < B	C < B	D > A,B,C	
102	Variant 21	2	D+	B+	A+	C –							A < B	C < B	D > A,B,C	C < 0
103	Variant 21	3	D+	B+	A –	C –							A < B	C < B	D > A,B,C	C < 0
104	Variant 21	4	D+	B –	A –	C –							A < B	C < B	D > A,B,C	C < 0
105	Variant 21	5	D –	B –	A –	C –							A < B	C < B	D > A,B,C	C < 0
106	Variant 22	1	**D+**	B+	C+	A+			Type 2				A < B	C < B	D > A,B,C	
107	Variant 22	2	**D+**	B+	C+	A –			Type 2				A < B	C < B	D > A,B,C	
108	Variant 22	3	**D+**	B+	C –	A –			Type 2				A < B	C < B	D > A,B,C	C < 0
109	Variant 22	4	**D+**	B –	C –	A –			Type 2				A < B	C < B	D > A,B,C	C < 0
110	Variant 22	5	**D –**	B –	C –	A –				Type 3			A < B	C < B	D > A,B,C	C < 0
111	Variant 23	1	**D+**	C+	A+	B+			Type 2						D > A,B,C	
112	Variant 23	2	**D+**	C+	A+	B –			Type 2						D > A,B,C	
113	Variant 23	3	**D+**	C+	A –	B –			Type 2						D > A,B,C	
114	Variant 23	4	**D+**	C –	A –	B –			Type 2						D > A,B,C	C < 0
115	Variant 23	5	**D –**	C –	A –	B –				Type 3					D > A,B,C	C < 0
116	Variant 24	1	**D+**	C+	B+	A+			Type 2				A < B		D > A,B,C	
117	Variant 24	2	**D+**	C+	B+	A –			Type 2				A < B		D > A,B,C	
118	Variant 24	3	**D+**	C+	B –	A –			Type 2				A < B		D > A,B,C	
119	Variant 24	4	**D+**	C –	B –	A –			Type 2				A < B		D > A,B,C	C < 0
120	Variant 24	5	**D –**	C –	B –	A –				Type 3			A < B		D > A,B,C	C < 0

Source(s): Authors' own work

Figure A2.