Membership Rule and Strategic Alliances: An Experimental Approach

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Abstract

Recently, new game theoretic approaches have been suggested that address the emergence of inter-firm collaborative agreements (strategic alliances) that are situated between standard market transactions of unrelated companies and their integration by means of mergers and acquisitions. This paper experimentally investigates the interdependence between two membership rules and the endogenously emerging inter-firm collaborative structures. In the implemented frameworks, the formation of coalitions between competing firms is modelled as a two-stage non-cooperative game. On a first stage firms form collaborative coalitions in order to decrease their marginal costs of production. Consecutively, firms compete on the market. More precisely, we look at the coalition formation models of Bloch [RAND Journal of Economics, 26, 1995; Games and Economic Behavior, 14, 1996] who applies an exclusive membership rule and contrast it with a setting in which an open membership rule such as suggested in Yi [RAND Journal of Economics, 29, 1998] prevails. While in the former setting a firm can enter into a coalition only if all existing members of the coalition agree, in the latter setting a firm does not need the consent of anybody to join a coalition. In addition to comparing the behavior under the regimes of the two mentioned membership rules, we compare these baseline settings to others into which we introduce coalition formation costs increasing linearly with coalition size.

JEL Classification: C92; D43.

Keywords: Endogenous formation of coalitions; R&D; Cournot competition; Collusion; Experiments.

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1 Introduction

Inter-firm collaborative agreements that are situated between standard market transactions of unrelated companies and their integration by means of mergers and acquisitions is increasingly common.[1] These collaborative agreements between competing firms take various forms: firms agree on common standards, they launch joint marketing campaigns, they develop new products and processes, they produce common inputs, they jointly use some facilities, etc. The term "strategic alliance" was invented to encompass the multitude of forms inter-firm collaborative agreements have taken, one possible definition for strategic alliance being a web of agreements whereby two or more partners share the commitment to reach a common goal by pooling their resources together and coordinating their activities (Teece, 1992).

Generally, one can distinguish between technological, non-technological and mixed (strategic) alliances. Technological alliances are concerned with R&D, design, licensing, supply arrangements and sourcing, and university-industry collaborations. Non-technological alliances concern marketing, distribution, and advertising. Alliances incorporating e.g. marketing and R&D are mixed. Another critical distinction has to be made between equity-based and contractual, i.e., non equity-based alliances.[2] In line with this distinction, different governance forms can be ranked according to the degree of interdependence between cooperating firms, these different forms of organizational design of collaboration having different effects on market structures and the companies involved (the classification of modes of inter-firm collaborative agreements in terms of the extent of inter-organizational dependence has been first suggested by Hagedoorn, 1990). While there is a large variety of types of strategic alliances, their purpose is always to reduce the cost of production or to increase market demand for alliance members.

Although policy steps were made to accommodate and actively promote strategic alliances,[3] collaboration between competitors raises two sorts of antitrust issues: those related to *operations* and those related to *membership*. The first issue requires a balancing of the benefits of various sorts of cooperation between rivals and the costs of diminished competition resulting from potential collusion in the market. Indeed, there has been some evidence during the past decade pointing at the possibility that strategic alliances, especially those focusing on technological issues, offer additional platforms for firms to make a contact (for example, Vonortas, 2000a shows that anti-competitive behavior increases significantly when repeated R&D collaboration occurs between U.S. firms). The more frequent the contact between firms, the argument goes, the better they can learn each other's strategies, the larger the chances of finding reasons to collude, and the more effective the mechanisms for enforcing collusion. The second issue demands an economic evaluation of the membership rule applied by an alliance. Here potential threats to competition, both from exclusion and inclusion decisions, need to be taken care of. Exclusion of a set of firms from an alliance may reduce competition by either completely excluding these firms from the market, or by turning them into non-serious competitors. On the other hand, the inclusion of a large fraction of actual or potential competitors may reduce or eliminate competition with other alliances as their members crossing the floor rob them of scale economies.[4]

The policy-maker has a grip on the actually imposed membership rules. The first case where this has been played out is almost five generations old and concerned the Associated News Press Organization (AP).[5] AP provides a vehicle for the gathering, transmission, and exchange of news reports created by its members. Collaboration in AP implies significant economies of scale which resulted in the saturation

[1]Though inter-firm cooperation is not a new phenomenon, the number of cooperative agreements has increased dramatically during the past couple of decades. Looking at the worldwide growth pattern of a certain kind of inter-firm collaborative agreement, namely inter-firm R&D partnership, in the last forty years, Hagedoorn (2002) finds strong evidence for a considerable acceleration, starting out with about 10 partnerships per year in the 1960s and rising to about 700 new R&D collaborations in 1995. According to Spekman, Isabella, MacAvoy, and Forbes (1996), more than 20,000 new inter-firm collaborative agreements were formed between 1987 and 1992 in the US alone. Factors like the internalization of markets, the increase in costs of R&D, and the necessity for large companies to monitor a spectrum of technologies could explain this general growth in inter-firm cooperation.

[2]Within technological alliances there has been a gradual shift away from equity based partnering to non-equity forms of agreement. See Caloghirou, Ioannides, and Vonortas (2003) for more details.

[3]The United States and the European Union mobilized in the early 1980s to establish policies that both provided the necessary legal environment and actively promoted R&D cooperation (Vonortas, 2000b).

[4]Obviously, forcing an alliance that has already created tangible or intangible property to admit non-members, itself raises concerns not only because it is not obvious how to determine the price of membership but more importantly because it raises uncertainty. This then may prevent firms from investing in the formation of alliances in the first place.

[5]*Associated Press v. United States* (1945). See Soma, Forkner, and Jumps (1998).

of the news gathering market. Though membership in AP was generally open to all newspapers, the bylaws of AP established oppressive entry-requirements for applicant newspapers in competition with existing local incumbents. Each existing member could block membership by competing newspapers and thereby remain the exclusive outlet for AP news in its locality. Here the Supreme Court ruled that AP's barring of local competitors is illegitimate. Related cases are the ruling on the Florist Telegraph Delivery Association, the Department of Justice investigation of Electronic Payment Services and the antitrust 1998 complaint against Visa and MasterCard. Together these cases underline the importance public authorities have attributed to the regulation of membership rules.[6]

This paper experimentally investigates the interdependence between two membership rules and the endogenously emerging inter-firm collaborative structures. In the implemented frameworks, the structure of alliances emerges from a two-stage non-cooperative game of alliance formation. In the first stage, firms form collaborative agreements in order to decrease their marginal costs of production, and in the second stage they compete on the market. We consider the alliance formation model of Bloch (1995) who applies an *exclusive* membership rule and contrast it with a setting in which an *open* membership rule such as suggested in Yi (1998) prevails. While in the former setting a firm can enter into an alliance only if all existing members of the alliance agree, in the latter setting a firm does not need the consent of anybody to join an alliance. As shown by Yi (1997), under two rather mild monotonicity properties,[7] if membership in an alliance is open, all firms will belong to the alliance whereas, if the membership is exclusive, meaning that firms can prevent other firms from entering the group, the alliance will not cover the entire industry. The intuition for this result is straightforward. Indeed, the formation of an alliance induces negative externalities on outsiders. Members of an alliance enjoy a lower marginal cost, and are thus more aggressive on the market, reducing the profits of their competitors. Hence, if cooperative agreements are open to all firms, a single alliance comprising all the firms will be formed. Additionally, when a firm joins an alliance, cost benefits are asymmetric. The new member immediately benefits form all the synergies created within the group, whereas standing group members only receive the additional benefit of the new member. Hence, if cooperative agreements are restricted to the original signatories, after the alliance has reached a given size, it has no incentive to accept new members. We contribute to this theoretical literature by associating costs to the formation of alliances.[8] Beyond adding realism, these costs have an important influence on the equilibrium alliance structure.

Motivated by the legal, theoretical and empirical discussion outlined above, we intend to shed some light on the actual efficiency performance of the two alternative membership rules under discussion. Concretely, we evaluate whether the equilibrium predictions derived from the models under consideration are behaviorally supported. This immediately implies a test of the conjecture that cooperative agreements on a pre-competitive stage per se induces players to collude on the product market stage. Such a conjecture conflicts with the assumption underlying the theoretical models according to which collusion on the second stage can be prevented effectively. Empirical evidence is required here as the desirability and hence the justifiability of public support for strategic alliances needs to be related to such findings.

Although the influence of economic scholarship on antitrust doctrines and their enforcement is unparalleled in any other area (see Kovacic and Shapiro (1999) and Kovacic (1992)) experiments have surprisingly rarely been used to explicitly evaluate antitrust policies. Davis and Wilson (2002) argues that this may be due to the fact that few situations arise where an experiment can directly provide

[6] The academic debate surrounding these cases is very controversial and extensive. See Baker (1993), Balto (1995), Carlton and Frankel (1995), Carlton and Salop (1996), Evans and Schmalensee (1995) and Balto (1999b) for a discussions of the context and history of litigation involving association membership. See Balto (1999a) for a discussion of the impact of previous court decisions on electronic commerce. This author's home page contains recent discussion of exclusivity issues in generic drug strategic alliances and related areas.

[7] The axiom of monotonicity of small alliances states that whenever a group of alliances merge, members of the smaller alliance benefit from the merger. The axiom of individual monotonicity indicates that an individual firm always has an incentive to leave an alliance in order to join an alliance of equal or larger size.

[8] Abstracting from costs of alliance formation is a remnant simplifying assumptions from cooperative game theory, where alliance agreements were assumed to be external to games, binding, costless and easily arranged. But clearly these assumptions need to be lifted, as realistically we observe impediments to cooperation arising from the fact that the actual establishment of cooperative arrangements or organizations is not costless, and furthermore, costs increase with the size of the group involved in the arrangement. The point is not only that transaction costs (contracting costs) and congestion increase with numbers but moreover that it gets more difficult to secure agreement (free-riding problem) and to solve the internal bargaining problem of dividing costs and benefits of the joint endeavor among its potential members (bargaining impassés). See e.g. Dixit and Olson (2010).

evidence critical to the specifics of a *particular* legal case. Hong and Plott (1982), Grether and Plott (1984), and Apesteguia, Dufwenberg, and Selten (2003) are exceptions to the latter. We believe that, also beyond a particular case, experiments can contribute by discerning the *behavioral* implications of policy measures, which automatically implies testing the relevance of those theoretical models these measures are based on. Experiments then, can help evaluate the drawing power and stability of the equilibrium predictions generated by those theoretical models from which policy measures are derived. They can make this a fair test in which demand and cost structures are pre-specified and sellers interact exactly as the model demands. This knowledge is needed to settle particular law cases,[9] but also more generally to rigorously evaluate concrete antitrust policy measures, in place or under discussion.

The paper is organized as follows: In section 2 we draw attention to the relevant theoretical and experimental literature. Section 3 introduces the seminal games that we use as baselines for our framework, and derives the theoretical results with regard to the introduction of coalition formation costs. Section 4 summarizes our experimental design and section 5 provides the results. The experimental instructions can be found in the Appendices.

2 Related Literature

In this section we provide a brief summary of the relevant theoretical and experimental literature. Henceforth, we interchangeably use the term (strategic) alliance or coalition to refer to an inter-firm collaborative agreement.

2.1 Theoretical Literature

Many important streams of the general literature have been left out as we concentrate on the for us relevant application of coalitions to industrial organization, where we only consider the literature on coalitions with negative externalities, i.e., cost-reducing/efficiency enhancing alliances. For a more comprehensive overview of the theoretical literature, we refer the reader to the surveys of Bloch (2003a) and Yi (1997).

The standard application example of cost-reducing/efficiency-enhancing inter-firm alliances in the theoretical literature are not so much network industries but strategic research alliances. Here Katz (1986) is the seminal paper which for the first time looks at endogenous R&D cooperation decisions, where these decisions have a direct impact on the marginal cost function. D'Aspremont and Jacquemin (1988), going beyond Katz, show that cooperative behavior may play a positive role in duopolies where R&D activities generate spillover effects.[10] D'Aspremont and Jacquemin (1988) is generally considered the seminal two-stage model of market competition with R&D in the presence of spillovers. D'Aspremont and Jacquemin's (1988) model assumes that there is a unique R&D alliance involving all firms in the market (where they look at a duopoly). Firms on stage one decide *how much they want to spend on R&D*, and on stage two compete in quantities. D'Aspremont and Jacquemin identify the spillover size as the variable that determines whether competition or cooperation on stage one is more beneficial for firms. Other authors have extended D'Aspremont and Jacquemin's (1988) approach to more general market conditions (see e.g. Suzumura (1992)), or have allowed for more than one R&D collaboration agreement (see e.g. Kamien and Zang (1993)).

The more recent literature focuses on the *endogenous formation of cost-reducing alliances*, while it does not explicitly model R&D contributions. Consequently, these models take a coarser perspective as the choice of the alliance size (on the first stage) directly translates into cost reductions that become effective on the second (production) stage. Hence there is no separate stage on which R&D efforts would be chosen. These models can therefore not account for the R&D specific feature of spillovers. The seminal papers in this area are Bloch (1995) and Yi (1998), which we will introduce in more detail below as they provide the baseline for our framework.

In terms of models that have tried to account for both, the endogenous formation aspect and an explicit modelling of the R&D environment we are only aware of Greenlee (1999). Greenlee confirms the

[9] See Gavil (1997) for a discussion.

[10] In R&D settings *spillovers* are a concern as firms' R&D efforts are imperfectly appropriable meaning that part of firm i's R&D results leak out to rival firms, resulting in cost reductions for these rivals. We will in the following clearly distinguish 'spillover' and 'externality', where the latter denotes the side effects of a strategy. See also De Bondt (1996).

robustness of Bloch's (1995) results in a setting that incorporates spillovers.

2.2 Experimental Literature

There is of course an extensive body of work on endogenous coalition formation which is dating back to the early days of experimental economics. See Sauermann (1978) or Rapoport (1990) for overviews of some of the seminal studies in this field. Still, these early studies as well as related more recent ones are clearly situated in the cooperative game-theoretical framework. In contrast, we are looking at a non-cooperative coalition formation protocol in the context of its application to industrial organization.

One of the main objectives of the present study is to evaluate the degree of collusion in the market, given that firms collaborate on a pre-competitive stage. Huck, Normann, and Oechssler (forthcoming) provide a recent survey on this topic for Cournot markets. According to the surveyed studies, collusion does occur in the duopoly case, while it is rarely observed in the triopoly case. Once there are 4 or 5 firms, collusion has *never* been observed. Since our experiments involve $n = 4$ firms, these previous findings allow us to directly attribute collusive behavior in our setting to the collaboration decisions on stage one. Furthermore, the possibility of forming asymmetrically sized coalitions on the first stage may give rise to an asymmetric quantity competition on the second stage. The experimental evidence on asymmetric Cournot competition suggests that here competition is even stronger (see Mason, Phillips, and Nowell (1992) and Fonseca, Huck, and Normann (2003) for the duopoly case, and Rassenti, Reynolds, Smith, and Szidarovsky (2000) for an oligopoly).

The following papers are also related to ours: Suetens (2001) and Suetens (2003) has tested the classical model of D'Aspremont and Jacquemin (1988) in the lab and looked at the efficiency of the actually made R&D effort choices. Silipo (2003) has implemented an explorative experimental design to look at the emergence of research joint ventures in a patent race instead of the non-tournament setting we are looking at. The study is preliminary as the implemented design is too complex to allow the author to derive rigorous theoretical benchmarks to compare his data to.

3 Alliance Formation Games

In this section we first introduce the required notation and provide some definitions. We then introduce the seminal models of Bloch (1995) and Yi (1998), discuss their commonalities and differences and justify why we have chosen them as baseline models. We then introduce the models we have actually implemented and provide some theoretical results. We close this section by summarizing the theoretical benchmarks for our experimental implementation of these models.

3.1 Notation

Let $N = \{1, \ldots, n\}$ be the set of n symmetric firms, indexed by i. We denote an alliance structure by $\mathcal{A} = \{A_1, A_2, \ldots, A_R\}$, where $\mathcal{A}$ is a partition of N into disjoint sets A_r, $r = 1, \ldots, R$. $A_r = \{i : j : \ldots : k\}$ denotes the r-th alliance that represents the coalition of players $i, j, \ldots, k$. Hence we will write $\mathcal{A} = \{A_1, \ldots, A_R\} = \{\{i : j : \ldots : k\}, \ldots, \{h : l : \ldots : m\}\}$, or simply $\mathcal{A} = \{i : j : \ldots : k, \ldots, h : l : \ldots : m\}$. Given the symmetric setting, it will often be more convenient to refer to alliance A_r by its cardinality $|A_r| = a_r$, and hence we will denote the alliance structure in terms of the sizes of the different alliances by $\mathcal{A}^a = \{a_1, a_2, \ldots, a_R\}$. Finally, by $a(i)$ we refer to the size of the alliance to which $i \in N$ belongs to.

In our experimental setup, we only consider the quadropoly ($n = 4$) case. Hence, in the experiment there are (in terms of the size representation) only five alliance structures possible. These are: $\{1, 1, 1, 1\}$, $\{2, 1, 1\}$, $\{2, 2\}$, $\{3, 1\}$, and $\{4\}$, where the first denotes the singleton structure and the last the grand coalition comprising all firms in the market.

3.2 Baseline Models: Bloch (1995) and Yi (1998)

The models of Bloch (1995) and Yi (1998) have the following common features. Both consider a symmetric oligopoly setting where the interaction among firms is modelled as a noncooperative game with *two stages*. On the first stage, alliances are formed. Then, given the alliance structure formed, firms compete on the market on a second stage. The coalition structure chosen on stage 1 translates into the production stage only through changes in the unit-cost vector, as these models assume that collusion on the production stage can effectively be avoided.

The core difference between the models of Bloch (1995) and Yi (1998) concerns the rule governing the formation of alliances on the first stage. While Bloch (1995) relies on an unanimous alliance formation process (*unanimity game*), Yi (1998) captures situations where firms can freely enter into any alliance (*open membership game*). Consequently, Bloch (1995) considers a protocol based on *exclusive membership*, according to which incumbent firms can bar outsiders from entering an existing agreement, whereas Yi (1998) does not apply any restrictions of this sort and leaves membership to existing alliances unregulated.

As we will soon see, the nature of the membership rule not only affects individual firms' payoffs but also industry-profits and social welfare. This raises the previously mentioned debates and controversies. In the following we contribute to this discussion not only by providing empirical evidence concerning the relevance of the suggested models but also by introducing what, to our understanding, is an empirically relevant variable that has up to now been assumed away in these models: namely, the costs associated with the formation of coalitions. Concretely, we suggest two games that differ *only* with respect to the membership rule (exclusive versus open). Before introducing these two games we first outline the original models of Bloch (1995) and Yi (1998) which serve as their foundation.

3.2.1 The Sequential-Move Exclusive Membership Game: Bloch (1995)

Bloch's (1995) two-stage game can be specified as follows:

First Stage: Alliance Formation One of the firms is chosen as the initiator and is asked to propose the formation of an alliance A_r. Each prospective member of A_r responds in turn to the offer. If all firms accept the offer, this alliance formation protocol is repeated among the remaining firms. If one of the prospective members of A_r rejects the offer, she becomes the initiator in the next round.

Second Stage: Production Stage On the second stage, firms compete in quantities. Concerning the market specifications, Bloch (1995) assumes a linear inverse demand schedule $p_i = \alpha - q_i - \sum_{j \neq i} q_j$. Firm i's marginal production costs are given by $c_i = \lambda - \mu a(i)$, where $c(\cdot)$ is a decreasing function of the alliance size $a(i)$.

Bloch's (1995) alliance formation protocol is defined by three generic features: Firstly, alliances are only formed by unanimous agreement. Secondly, once firms agree to the formation of a coalition they are bound to remain in it as the protocol does not accommodate renegotiation. Thirdly, alliances are formed sequentially.

Bloch's core proposition concerns the equilibrium coalition structure.

Proposition 1 *(Bloch (1995)) Under Cournot competition with homogeneous products where the cost structure is linear, there exists an unique equilibrium alliance structure given by* $\mathcal{A}^* = \{A_1^*, A_2^*\}$*, where the size of alliance* A_1^**,* a_1^**, is the integer closest to* $\frac{3n+1}{4}$*.*[11]

The intuition driving the result that industry-wide cooperative agreements (which actually are the efficient ones) are not achieved under an exclusive membership rule, is that firms while cooperating to reduce costs remain competitors on the market. The formation of an alliance simultaneously decreases not only a firm's own marginal costs, but also the marginal costs of the other members of its alliance. Against these firms, the firm competes on the market afterwards. While a reduction in the own costs induces the firm to behave more aggressively on the market, the same holds for the alliance partners. Hence there is both a direct effect resulting from the own cost reduction as well as a strategic effect due to the reduction in the costs of the other alliance members. Taken together these two effects provide the reason for why the all-inclusive alliance structure is not an equilibrium outcome.

3.2.2 The Simultaneous-Move Open Membership Game: Yi (1998)

The alliance formation game that Yi (1998) specifies applies an open membership rule, where the two stages can be presented as follows:

[11] Originally this is Bloch's (1995) Proposition 2.

First Stage: Alliance Formation Firms simultaneously announce "addresses". The firms that announce the same address, belong to the same coalition.

Second Stage: Production Stage On the second stage, firms choose a production strategy q_i.

The core feature of Yi's (1998) formation process is that outsiders do not need the consent of the current members of an existing coalition in order to join it. For a more general setting than the one previously outlined for Bloch (1995), Yi (1998) concludes:

Proposition 2 *(Yi (1998)) The industry-wide joint venture is the unique pure-strategy Nash equilibrium outcome of the simultaneous-move open membership game. Both, consumer and total social surplus, are higher under the industry-wide joint venture than under any other joint venture structure.*[12]

From this result it immediately follows that both consumer and total social surplus are higher in Yi's (1998) simultaneous-move open membership game than in Bloch's (1995) sequential-move coalition unanimity game.

3.3 Sequential-Move Alliance Formation Games with Costs of Alliance Formation

We now specify the modifications we applied to the aforementioned seminal alliance formation games. In addition to introducing costs of coalition formation to both baseline models, we will adapt Yi's (1998) game in the following way:

1. We consider a sequential-move instead of the original simultaneous-move version of the game.

2. We introduce the possibility of committing to remain independent.

The first modification is undertaken in order to minimize the differences between the two games. Additionally, the sequential version is easier to implement and understand in the laboratory as we circumvent the coordination problem that would arise in a simultaneous implementation.

In the original open membership game, which has been suggested by Yi and Shin (2000) and then applied by Yi (1998) to the industrial organization context, the strategy space of the players is a message space M with $|M| = n$, meaning that there are at least as many messages as players. All players simultaneously announce a message in M. Coalitions are formed by all players who have announced the same message, $A(m) = \{i \in N, m_i = m\}$, for all $m \in M$. As has first been noted by Bloch (1997) [Bloch (2003b)] this formulation implies that firms cannot commit to remain independent. Clearly, this is not in line with the idea of voluntary participation which characterizes real alliances, which is why we deviate from the original also in this respect. Rundshagen (2002), following Bloch's (1997) suggestion, has proposed what she calls a "*restricted* open membership game". Besides still accommodating the idea of open membership, meaning that it is not possible to bar outsiders from entering an existing coalition, it allows players to remain singletons if they wish to do so. This is done by extending the message space M by including message 0 (a "stay alone" option). Here each player $i \in N$ announces a message $m_i \in \{0, 1, \ldots, N\}$. Players who announce 0 remain singletons. Players who announce the same address, different from 0, form a coalition.

We will now first theoretically and then also experimentally study two alliance games that incorporate the mentioned modifications: the Sequential-Move Coalition *Unanimity Game* with Costs of Coalition Formation, based on Bloch (1995) and the Sequential-Move Restricted *Open Membership Game* with Costs of Coalition Formation based on Yi (1998). In the former, stage one is modelled as presented in section 3.2.1. The first stage in the latter game draws on the protocol presented in section 3.2.2, but "address" choices are made sequentially and a 0-address is introduced.

Both games share the same stage two specifications: We consider an inverse demand function $p = \alpha - \sum_{i=1}^{n} q_i$, with $n \geq 2$, where q_i is firm i's quantity, and $\alpha > 0$. Firm i's marginal cost is given by $c_i = \lambda - \mu a(i)$, and $\lambda, \mu > 0$. Finally, we introduce costs of formation of alliance that linearly increase

[12] Originally these results are presented in Yi's (1998) Propositions 5, 6, 7 and 8.

with the size of the coalition: $f(a(i)-1)$, with $f>0$.[13] Formally, firm i's payoff function can be written down as

$$\Pi_i(\mathcal{A}) = [\alpha - q_i(\mathcal{A}) - \sum_{j\neq i} q_j(\mathcal{A})]q_i(\mathcal{A}) - [\lambda - \mu a(i)]q_i(\mathcal{A}) - f(a(i)-1) \quad (1)$$

The Cournot-Nash output equilibrium is then given by

$$q_i(\mathcal{A}) = \frac{\alpha-\lambda}{n+1} + \mu a(i) - \frac{\mu \sum_{r=1}^{r=R}(a_r)^2}{n+1} \quad (2)$$

In line with previous work, we assume that $\alpha - \lambda \geq \mu[(n-1)^2 - n]$, which ensures that in any alliance structure equilibrium quantities are positive. The i's payoff function at equilibrium is $\Pi_i(\mathcal{A}) = \pi_i(\mathcal{A}) - f(a(i)-1)$, where $\pi_i(\mathcal{A}) = q_i^2(\mathcal{A})$. It will be convenient to denote $\Pi_i(\mathcal{A}) = \Pi_i(\mathcal{A}^a) = \Pi_i(\{a(i), a(-i)\}) = \Pi_i(a(i), a(-i))$, where $a(-i)$ denotes the vector of coalition sizes of all those coalitions except the one to which player i belongs. That is, we will write the alliance structure in terms of alliance sizes, where the first element in the vector of alliance sizes refers to player i.

We next derive the equilibrium alliance structure predictions when there are costs of forming coalitions for $n=4$, which is the case we implemented in the laboratory (proofs are available upon request from the authors).

Proposition 3 *Let $n=4$. The pure-strategy subgame perfect alliance structure equilibria of the Sequential-Move Exclusive Membership Game with costs of coalition formation are given by:*

1. *for any $f \in [0, f^0[$, $\mathcal{A}^* = \{3,1\}$,*
2. *for any $f \in [f^0, f^1[$, $\mathcal{A}^* = \{2,1,1\}$, and*
3. *for any $f \geq f^1$, $\mathcal{A}^* = \{1,1,1,1\}$,*

where $f^0 = \frac{6\mu(\alpha-\lambda)+3\mu^2}{25}$ and $f^1 = \frac{6\mu(\alpha-\lambda)+15\mu^2}{25}$.

Proposition 4 *Let $n=4$. The pure-strategy subgame perfect alliance structure equilibria of the Sequential-Move Restricted* Open Membership Game *with costs of coalition formation are given by:*

1. *for any $f \in [0, f^0[$, $\mathcal{A}^* = \{4\}$,*
2. *for any $f \in [f^0, f^1[$, $\mathcal{A}^* = \{3,1\}$,*
3. *for any $f \in [f^1, f^2[$, $\mathcal{A}^* = \{2,1,1\}$, and*
4. *for any $f \geq f^2$, $\mathcal{A}^* = \{1,1,1,1\}$,*

where $f^0 = \frac{8\mu(\alpha-\lambda)-9\mu^2}{50}$, $f^1 = \frac{26\mu(\alpha-\lambda)+57\mu^2}{125}$, and $f^2 = \frac{6\mu(\alpha-\lambda)+15\mu^2}{25}$.

Note that the introduction of costs of coalition formation has a non-trivial impact on the equilibrium coalition architectures. New equilibrium structures arise, in which a number of firms form an alliance while the remaining firms remain singletons.

Theoretical Benchmarks: Production Stage

We consider three standard benchmarks for the production stage: Besides the Cournot-Nash quantity equilibrium (as specified in equation 2), we will compare our experimental data to the "joint-profit maximizing" or collusive outcome as well as to the competitive equilibrium solution.

By *collusive solution* we refer to a scenario where firms collude within but not across coalitions. We assume that the members of a coalition produce equal outputs (this is not a restrictive assumption as

[13] Of course, other formation-cost specifications are plausible. Still, already the linear function complicates the analysis considerably, while leading to interesting results. Furthermore, the linear specification allows easy comparison with the network formation literature whose environment we herewith match exactly, the only difference being that collaboration agreements are here bilateral rather than multilateral (see e.g. Goyal and Joshi (2003) or Goyal and Moraga-Gonzalez (2001)).

these firms are symmetric). More formally, let $\mathcal{A}^a = \{a_1, \ldots, a_R\}$. Hence, there are R coalitions, indexed by h. Denote by $q(a_h)$ the total output level of coalition h, which has a_h members. The output level of a firm i belonging to coalition h is $q_i = q(a_h)/a_h$. Accordingly, the payoff function of coalition h is

$$\Pi_{a_h}(\mathcal{A}) = \left[\alpha - \sum_{r=1}^{r=R} q(a_r)\right] \; q(a_h) - [\lambda - \mu a_h] \; q(a_h) - [f(a_h - 1)] \; a_h \tag{3}$$

Consequently, the collusive equilibrium quantity amounts to

$$q(a_h) = \frac{\alpha - \lambda}{R+1} + \mu a_h - \frac{\mu n}{R+1} \tag{4}$$

In our environment which features constant marginal costs, the *competitive equilibrium* benchmark is only meaningful in ex-post symmetric alliance structures. That is, where either the industry-wide, all-encompassing alliance, a $(2,2)$ structure or no alliance is formed at all, i.e., when the singleton structure $(1,1,1,1)$ is maintained. By here equalizing inverse demand and marginal costs we obtain the competitive equilibrium output as

$$q_i = \frac{\alpha - \lambda}{n} + \frac{\mu \sum_{r=1}^{r=R} (a_r)^2}{n^2} \tag{5}$$

We implemented the following parametrization: $\alpha = 60$, $\lambda = 30$ and $\mu = 5$. We run both *zero-cost treatments* with $f = 0$ as well as *non-zero cost treatments* where we set $f = 10$.[14] The costs have been set such that they preserve the structural benchmark prediction, i.e., we implement *negligible* costs. The aim here has merely been to test the robustness of Bloch's (1995) and Yi's (1998) baseline models to the introduction of negligible coalition formation costs. The subgame perfect alliance equilibria (in terms of coalition sizes) are $\{3,1\}$ for the exclusive membership games, and respectively $\{4\}$ for the open membership games.

Given our parametrization we induce the following monetary consequences to the formation of coalitions: If a player is not involved in any coalition her unitary production costs equal 25 points. These costs decrease by 20% if the player decides to collaborate with one of her competitors. If she instead becomes a member of a three-player coalition she can reduce her unit costs by 40%, and by 60% if she gets involved in an industry-wide coalition (with the stand-alone cost as standard of comparison).

The following tables summarize the complete set of second-stage best responses to any observable alliance structure in terms of the three previously introduced solution concepts of the game, i.e., Cournot-Nash,[15] intra-alliance joint-profit maximization (collusion) and competitive behavior.

STAGE 2 Alliance Structure $\mathcal{A}$	Cournot-Nash quantities	Equilibrium net profits	Collusive quantities	Collusive net profits	Competitive quantities	Competitive net profits
{4}	10	100	6.25	156.25	12.5	0
{3,1}	11, 1	121, 1	6.11, 8.33	112.04, 69.22	not applicable	not applicable
{2,2}	8, 8	64, 64	6.67, 6.67	88.89, 88.89	10	0
{2,1,1}	10, 5	100, 25	6.25, 7.50	78.13, 56.25	not applicable	not applicable
{1,1,1,1}	7, 7	49, 49	4.375, 4.375	76.56, 76.56	8.75, 8.75	0,0

Key: The values are always quoted in the same order as the alliance sizes. That is, e.g., when the alliance structure is {3,1} then the members of the 3-firm alliance produce a Cournot-Nash equilibrium quantity of 10 units.

Table 1: Benchmarks, Stage 2. **Zero-cost Treatments**.

[14] Our parametrization meets the following requirements: firstly, we ensure a significant difference between the efficient and the individually payoff-maximizing outcome in the Exclusive Membership game. Secondly, we guarantee that for all possible alliance sizes, equilibrium quantities are positive. Furthermore, the Cournot-Nash quantity is in the interior of the action space.

[15] Due to the discretization of the production space new output equilibria arise. For example: For the grand coalition in addition to the symmetric output equilibrium $q = (10,10,10,10)$ the production vectors $q = (9,9,11,11)$ and $q = (9,10,10,11)$ are also stage-two equilibria. However, for all coalition structures the aggregate production level remains unchanged. Furthermore, it is easy to check that the equilibrium coalition structures remain unchanged. Given this, we will in the following concentrate on the symmetric output equilibria.

STAGE 2 Alliance Structure $\mathcal{A}$	Cournot-Nash quantities	Equilibrium net profits	Collusive quantities	Collusive net profits	Competitive quantities	Competitive net profits
{4}	10	70	6.25	126.25	12.5	-30
{3,1}	11, 1	101, 1	6.11, 8.33	92.04, 69.22	not applicable	not applicable
{2,2}	8, 8	54, 54	6.67, 6.67	78.89, 78.89	10	-10
{2,1,1}	10, 5	90, 25	6.25, 7.50	68.13, 56.25	not applicable	not applicable
{1,1,1,1}	7, 7	49, 49	4.375, 4.375	76.56, 76.56	8.75, 8.75	0,0

Table 2: Benchmarks, Stage 2. **Non-zero-cost Treatments**.

4 Experimental Design

We consider a 2×2 design with the membership rule (exclusive versus open membership) and the costs of alliance formation ('zero' and 'non-zero' costs) as treatment variables. Subjects interact for a total of 30 rounds in a partners design in groups of four, according to which any given subject faces the same three other subjects for the duration of the whole experiment.

Each subject is referred to by a label ("person x", where $x \in \{1, 2, 3, 4\}$). Labels are randomly reassigned before the beginning of each round. In this way we make sure that subjects are not able to condition their strategies on particular fellow players' identities.

On stage 1, the order in which decisions are taken is given by the labels, where the person with the lowest label takes the first decision and the others follow in an ascending order of their labels. Note that given the relabelling of subjects, it is ensured that different subjects take the first decision in each round.

Each subject is continuously informed on her screen about any finalized decision and the status of any proposal involving her. By "finalized decision" we refer to decisions that have actually been implemented. In the case of the open membership game subjects are always informed about addresses announced by previously deciding subjects. In the exclusive membership treatments subjects that are not involved in a currently made proposal will only get informed about it if the proposal has been accepted by all involved persons, i.e., when the suggested coalition has been formed. Prospective members on the other hand are continuously updated about the status of a proposal, i.e., they get informed about which persons are involved, and will in the course of the acceptance process get to know who has already accepted the proposal, or who has rejected it.

After all first-stage decisions have been finalized subjects are provided with a summary of the actually formed coalitions and their composition. On stage 2 production decisions are taken simultaneously. Afterwards each individual is informed about the aggregate production level chosen by the others, and the own payoff.

The action space on the second stage has been restricted to 14 actions to remain able to represent the complete payoff information by means of payoff tables. Still, this leaves enough action alternatives to ensure that deviation from one benchmark does not automatically imply meeting an alternative benchmark. Furthermore, we ensure that the Cournot-Nash solution is in the interior of the action space which allows us to clearly identify both collusion and competitive behavior.

Expected payoffs are equal across all treatments (cost conditions and membership rules) as the conversion rate of experimental points into Euro has been adapted accordingly.[16]

Practical procedures

The experiment has been conducted using the computerized network of the Max Planck Research Laboratory at Jena. In total 20 subjects were invited for each session, 16 of which actually took part.[17] All participants were students of Jena University.[18] Overall, one session with four groups à four persons

[16]In the open-membership rule/zero-cost treatment 200 experimental points exchanged for 1 Euro, whereas it was 140 points in the open-membership/non-zero treatment. In the exclusive membership treatments the respective amounts were 180 and 150 points.

[17]We invited additional subjects to ensure that only those that had fully understood the procedures (tested by a pre-experimental questionnaire) participated.

[18]All of them read natural sciences, engineering, computer sciences or economics/business administration. By selecting subjects in this way for this experiment we guaranteed that subjects are used to solve abstract problems.

was run in each treatment, where no subject took part in more than one session. Consequently, we have collected four independent observations per treatment, based on a total of 64 ($4 \times 4 \times 4$) participants.

Subjects interacted via computer terminals, which were visually isolated from each other. Communication other than through the decisions made was not allowed. Subjects were informed about the rules of the game by written instructions which were made common knowledge by also reading them out loudly. The instructions were neutrally formulated and quite exhaustive (see App.). In addition to the written instructions each subject was provided with four payoff tables, each specifying possible individual payoffs given one of the four possible coalition sizes (see App.).[19] Additionally, each subject attained a 'history sheet' prepared in such a way that it was easy to note and keep track of own and others' decisions and outcomes during the experiment if a subject wished to do so.

Subjects had full knowledge of the experimental procedures and knew that they would only be allowed to participate conditional on their performance in the questionnaire. Subjects, whose questionnaire results clearly indicated that they had not understood the game sufficiently, were paid out a minimal payoff and replaced.[20]

After the questionnaire and the replacement of subjects, we took subjects through 5 practice rounds to familiarize them with the software. Subjects were here asked to enter decisions announced by an experimenter. Own decisions were prevented by the software which only accepted the announced entries. This was done in order to disable subjects to gain experience about optimal strategies or about opponents' behavior. In the course of the practice rounds, subjects were taken through all 5 possible coalition structures, starting with the grand coalition and going to the singleton coalition. The production levels to be chosen on stage 2 were always set to 0 for all subjects.

After the practice rounds, the actual experiment was started. The sessions took approximately 2 hours in the open as well as the exclusive membership sessions.

5 Aggregate Results

In line with the logic of backward-induction we first present results concerning the behavior on the production stage before moving on to analyzes of the coalition formation stage. We close this section by looking at the effects of negligible coalition formation costs.

5.1 Stage Two: Production Decisions

The equilibrium *average* output levels for the different coalition structures, denoted by $\bar{q}(\mathcal{A}^a)$, can be ordered in the following way (recall Tables 1 and 2):

$$\bar{q}(4) > \bar{q}(3,1) > \bar{q}(2,2) > \bar{q}(2,1,1) > \bar{q}(1,1,1,1)$$

Table 3 now provides the actually observed average production levels for the different alliance structures, distinguished by treatment. As is immediately obvious, our data in each of the four treatments comply with the predicted ranking. As a matter of fact, contrasting $\bar{q}(\{4\})$ and $\bar{q}(\{3,1\})$, the Wilcoxon Signed Ranks test[21] on the basis of the average output levels for the individual groups shows a significance level of 1% (one-sided, $N = 24$).[22]

This result provides first evidence in favor of the predictive adequacy of the Cournot-Nash equilibrium on the second stage. Effectively, the latter is backed by Figures 2, 3, 4 and 5 which demonstrate that the observed aggregate output time series are very close to the predicted Cournot-Nash equilibrium series. In fact, in a majority of groups the aggregate production levels converge almost perfectly to the predicted

[19] Each payoff table was printed in poster size (A3), and the four tables were cellar-taped next to each other onto the partition screens of each cubicle so that they could comfortably be read by the subjects.

[20] The questionnaire comprised 10 questions, four concerning the calculation of payoffs and six more general questions concerning the coalition formation protocol, the relabelling etc. Except for those questions concerning the formation protocol, the questionnaire was identical in all sessions. Subjects that answered three or more questions incorrectly were replaced. Subjects made between 0 and 4 mistakes, with an average of 1 mistake. Depending on the session, we had to replace between 1 and 3 subjects. Subjects performed better in the exclusive membership sessions but also were much slower in answering the questions.

[21] See Siegel and Castellan (1988) for details concerning the used statistical tests.

[22] The other coalition structures were observed in too few groups (see Figures 2, 3, 4 and 5) to allow for statistical testing.

Observed $\mathcal{A}$	Exclusive-Membership		Open-Membership	
	zero cost	non-zero cost	zero cost	non-zero cost
$\{4\}$	9.49	8.94	9.80	9.38
$\{3,1\}$	8.36	8.74	7.81	8.04
$\{2,2\}$	7.38	8.75	7.75	6.75
$\{2,1,1\}$	–	–	–	6.5
$\{1,1,1,1\}$	–	–	–	–

Table 3: Average Production Levels per Coalition Structure

Cournot-Nash equilibrium. This indicates that subjects were on aggregate well aware of the consequences of choosing one coalition over the other. More generally, this shows that the assumption of *competition* on the production stage, on which the here discussed theoretical models rely, is in fact empirically justified - at least for a majority of groups in the quadropoly case we are looking at.

For the moment we have just looked at the ordering of average output levels *across* coalition structures. Now, we will check the consistency of the average output ordering *within* a given coalition structure. Here the only asymmetric coalition structure observed sufficiently many times to perform statistical analyzes is the $\{3,1\}$-structure. Therefore, we will now check whether it is in fact the case that the average output level produced by those players in the 3-person coalition is significantly higher than that produced by the singleton as predicted by Cournot-Nash (recall Tables 1 and 2). Table 4 shows that the average quantities produced in big coalition are in all treatments higher than those produced by the singleton. The Wilcoxon Singed Ranks test backs this result at any significance level. Note, however, that the average quantity produced by the 3-person coalition (resp. by the singleton) is in all treatments considerably below (above) the predicted equilibrium level. Consequently, the members of the big coalition do actually profit less than predicted in equilibrium. We will return to this point later in the analysis.

Average output level	Exclusive-Membership		Open-Membership	
	zero cost	non-zero cost	zero cost	non-zero cost
Average output level in the coalition of size 3	9.3	8.2	8.6	9.0
Average output level in the coalition of size 1	5.5	6.7	5.5	5.2

Table 4: Average Production Levels in the $\{3,1\}$ coalition structure sorted by coalition size.

We close this section by checking for each coalition structure whether there is a significant difference in the average quantity levels between the exclusive and the open membership treatments. Concretely, we again concentrate on the grand coalition and the $\{3,1\}$-coalition structure and test whether groups that were confronted with the open membership regime behaved significantly different from those that faced the open membership regime. Here the permutation test yields no significance for either coalition structure (two-sided, $N = 16$ for the $\{4\}$ and respectively $N = 12$ for the $\{3,1\}$ coalition structure).

5.2 Stage One: Formation of Alliances

Now moving back to the first stage we first take a look at the frequencies with which we observe the five different possible alliance structures, separately for different groups and treatments (see Table 5). Recall that the equilibrium prediction in the open membership treatments is the industry-wide coalition $\{4\}$ while equilibrium play in the two exclusive membership treatments should lead to the $\{3,1\}$ coalition structure. Irrespective of the membership regime and hence of the treatment, the industry-wide coalition $\{4\}$ is efficient.

According to our data, as summarized in Table 6, the industry-wide alliance $\{4\}$ is formed by far most frequently, independently of both the implemented membership rule and cost structure.

In terms of frequency the grand coalition is followed by the $\{3,1\}$-coalition structure, the $\{2,2\}$ and finally by the $\{2,1,1\}$-structure. The singleton structure $\{1,1,1,1\}$ has never been observed. Besides, Table 6 suggests a similar frequency pattern for both the open and the exclusive membership treatments. Relying on a permutation test performed on the basis of the frequencies per game (this gives 8 independent observations per sample) we can show that there is no significant difference between the frequencies with which the different coalition structures are observed in the two membership regimes.

	Exclusive-Membership							
	zero cost				**non-zero cost**			
Observed $\mathcal{A}$	$\{2,1,1\}$	$\{2,2\}$	$\{3,1\}$	$\{4\}$	$\{2,1,1\}$	$\{2,2\}$	$\{3,1\}$	$\{4\}$
Group 1	0	0	0	30	0	0	0	30
Group 2	0	2	6	22	0	2	0	28
Group 3	0	2	14	14	0	0	3	27
Group 4	0	0	0	30	0	2	11	17
	Open-Membership							
	zero cost				**non-zero cost**			
Observed $\mathcal{A}$	$\{2,1,1\}$	$\{2,2\}$	$\{3,1\}$	$\{4\}$	$\{2,1,1\}$	$\{2,2\}$	$\{3,1\}$	$\{4\}$
Group 1	0	0	2	28	0	0	6	24
Group 2	0	0	3	27	1	0	10	19
Group 3	0	0	6	24	0	0	4	26
Group 4	0	1	4	25	1	2	9	18

Table 5: Frequencies of observed coalition structures per group.

	Exclusive-Membership		**Open-Membership**	
Observed $\mathcal{A}$	zero cost	non-zero cost	zero cost	non-zero cost
$\{4\}$	96	102	104	87
$\{3,1\}$	20	14	15	29
$\{2,2\}$	4	4	1	2
$\{2,1,1\}$	0	0	0	2
$\{1,1,1,1\}$	0	0	0	0

Table 6: Observed Structures, First Stage.

This immediately implies that the predictive success of the coalition equilibrium is comparatively low in the exclusive membership treatments. Noting the actual compliance of the observed structures with the predicted ones for the different treatments we attain the following first-stage success rates:

Exclusive-Membership			**Open-Membership**		
Predicted $\mathcal{A}$	zero cost	non-zero cost	**Predicted $\mathcal{A}$**	zero cost	non-zero cost
$\{3,1\}$	17%	12%	$\{4\}$	87%	73%

Table 7: Success Rates, First Stage.

A reason for the poor performance of the equilibrium prediction $\{3,1\}$ may be that players do not actually realize the advantages of being a member of the 3-person coalition once assuming that there is competition a la Cournot on the second stage (and here we showed that this is actually the case).

In order to evaluate whether this may in fact play a role we now take a look at the coalition *proposals* made in the exclusive membership treatments rather than at the realized coalitions as has been done up to now. Remember that according to the coalition formation protocol applied in the exclusive membership treatments a player that wants to form a coalition with some others has to first make a proposal. This proposal is brought before all prospective coalition members who are asked to accept or reject it. The proposed coalition is only actually realized (and hence only enters the previous analyzes as Table 6 only reports the accepted proposals) if it is accepted by all prospective members. If it is instead rejected by at least one member the member who rejected it is asked to take the next decision which can be to stay alone or suggest a new coalition. Table 8 reports all proposals that have been made in the exclusive membership treatments and hence includes both the accepted and therewith implemented as well as those proposals that have been submitted but were rejected in the course of the first stage.

Table 8 exhibits strong differences between individual groups concerning the types of proposals that have been made. Firstly, in three out of the eight groups nothing but the grand coalition has been proposed. Here it is furthermore the case that the grand coalition has always been the first proposal made that then got accepted right away. But there are also groups in which the alliance equilibrium $\{3,1\}$ has been proposed a number of times, but often got rejected (see Group 3 in the zero-cost treatment, and Groups 2 and 4 in the non-zero cost treatment). Overall the picture concerning the frequencies of

	Exclusive-Membership							
	zero cost				non-zero cost			
Proposal Size	One	Two	Three	Four	One	Two	Three	Four
Group 1	0	0	0	30	0	0	0	30
Group 2	1	5	6	25	0	4	10	33
Group 3	1	4	16	16	0	0	3	27
Group 4	0	0	0	30	1	5	16	25

Table 8: Frequencies of proposals in the exclusive membership experiments sorted by size.

proposals qualitatively matches the picture concerning the frequencies of actually implemented alliance structures with the grand coalition being the most frequently proposed and implemented structure, followed by the 3-person coalition. Still, the gap between the frequencies of the grand compared to the 3-person coalition gets slightly smaller when looking at the proposed rather than the implemented structures, i.e., the 3-person coalition has been proposed more often than it actually got realized.

If we now look at individual proposal behavior we find that in those groups in which 3-person proposals were submitted, 90% (18 out of 20) of the players at least once submitted a 3-person proposal. In the two groups that exhibited the greatest number of 3-person proposals these proposals are not attributable to just one or two of the players but are spread across the players.[23] What this shows is that a number of players were well aware of the desirability of the coalition structure $(3,1)$, leading them to propose it, but at the same time were not successful in joining and coordinating efforts to enforce this outcome and exploit its advantages. Comparing Tables 6 and 8 it becomes clear that 33.3% of the size (3)-proposals were rejected. Figure 1 plots the evolution of proposals aggregated over all groups and shows that there has not been a trend in proposals at the aggregate level.

	Exclusive-Membership		Open-Membership	
Observed $\mathcal{A}$	zero cost	non-zero cost	zero cost	non-zero cost
$\{4\}$	111.1	90.4	103.3	83.2
$\{3,1\}$	(105.4,4.3)	(73.9,-3.7)	(119.9,11)	(89.5,5.1)
$\{2,2\}$	60.9	43.2	69.7	73.7
$\{2,1,1\}$	–	–	–	(89.8,21.5)
$\{1,1,1,1\}$	–	–	–	–

Table 9: Average Payoff per Coalition Structure

As Table 9 establishes, subjects that are in the zero-cost treatment involved in a 3-person coalition do - on average - not only profit less than predicted in equilibrium but in fact attain lower average profits than those persons extract that get involved in the grand coalition. Hence, in this treatment there is little incentive to establish the equilibrium coalition structure.

5.3 Zero Costs versus Non-zero Costs

The costs that have been introduced in the non-zero cost treatments are negligible, meaning that their introduction preserves the equilibrium predictions both on the alliance formation stage as well as on the actual production stage. When we now verify this prediction based on the data provided in Tables 6, 7 and 10 we find that even the negligible costs that we introduced seem to have a slight impact on the aggregate behavior in both stages.

On the first stage, the predictive success of the respective alliance equilibrium seems to decrease with the introduction of costs of coalition formation. The decrease in predictive success is observed in both the open and the exclusive membership experiments meaning that the introduction of costs of coalition formation paradoxically increases the number of grand coalitions formed in the exclusive treatment whereas it works in the opposite direction, i.e., decreases the number of grand coalitions in favor of $(3,1)$-structures in the open membership treatment. On the production stage, the data summarized in Table 10 suggest both for the exclusive and the open membership treatments, that the introduction

[23]The frequencies for Group 3 in the zero costs treatment and Group 4 in the non-zero costs are, respectively: .31, .19, .13, and .38, and .44, .25, .25, and .06.

	Exclusive-Membership		Open-Membership	
Outputs (all periods)	zero cost	non-zero cost	zero cost	non-zero cost
Group 1	9.56	7.36	9.81	9.03
Group 2	9.52	9.07	9.78	9.23
Group 3	8.55	9.46	8.83	9.23
Group 4	9.33	9.23	9.62	8.32
Average	9.24	8.78	9.51	8.95

Table 10: Average Production Levels per Group

of coalition formation costs provokes a slight reduction in aggregate outputs. However, this impression is not confirmed by the results of a permutation test performed on the basis of the individual groups as the latter yields non-significance in either case.

6 Conclusion

It has been our aim in this paper to answer the following questions. How do alliance equilibria look like when the costs of forming coalitions are non negligible? Is there a significant empirical difference in terms of efficiency between open and exclusive membership alliance formation games? Is the assumption of competition on the output stage empirically justified? And, finally, what is the behavioral sensitivity to the introduction of low costs of forming coalitions?

We have found that alliance equilibria change with the costs of coalition formation in a non-trivial way. New equilibria emerge. In particular, we have seen that we obtain coalition architectures where a group of firms form a coalition and the rest remain singletons. We have derived here general results for the open membership games. The corresponding result for the exclusive membership games, however, remain a task for future research.

The theoretical prediction is that open membership games are more efficient than exclusive membership games. This is due to the fact that the industry-wide coalition is predicted at equilibrium in the former, while an asymmetric coalition structure is obtained in the latter. The experimental results, however, are unambiguous in this respect. It is the industry-wide coalition the one is formed most of the time in both types of games. As a matter of fact, we have not only looked to the coalitions formed, but also to the proposals made. It emerges that the $\{3,1\}$ coalition structure is quite often proposed, but it is most of the time rejected. We have conjecture that, in line with the recent literature on social preferences, this may be due because players may be motivated by inequity averse considerations. That is, players show a preference for the symmetric distribution of payoffs involved in the grand coalition versus the asymmetric one implied in the $\{3,1\}$ coalition structure. The consequence of this is that the fundamental difference between open and exclusive membership games is not empirically relevant, at least for the context of our experiment.

We have observed in the data a remarkable correspondence between the coalition structure formed in stage one, and the aggregate output level observed in stage two. Furthermore, it seems that Cournot-Nash quantity levels accurately predict the dynamics of stage two decisions. In a few groups, however, collusive tendencies are observed in the early rounds, but aggregate behavior moves towards the Cournot-Nash benchmark as time proceeds. Consequently, concerns that often arise about the possibility of collusion in the market place after having been cooperating in a pre-competitive stage, are not justified in our data. At the aggregate level subjects play Nash in the second stage.

Finally, we mention that there is a small change in aggregate behavior when introducing negligible costs of coalition formation. It seems that aggregate output levels are reduced by this. However, we do not find statistical significance for this observation.

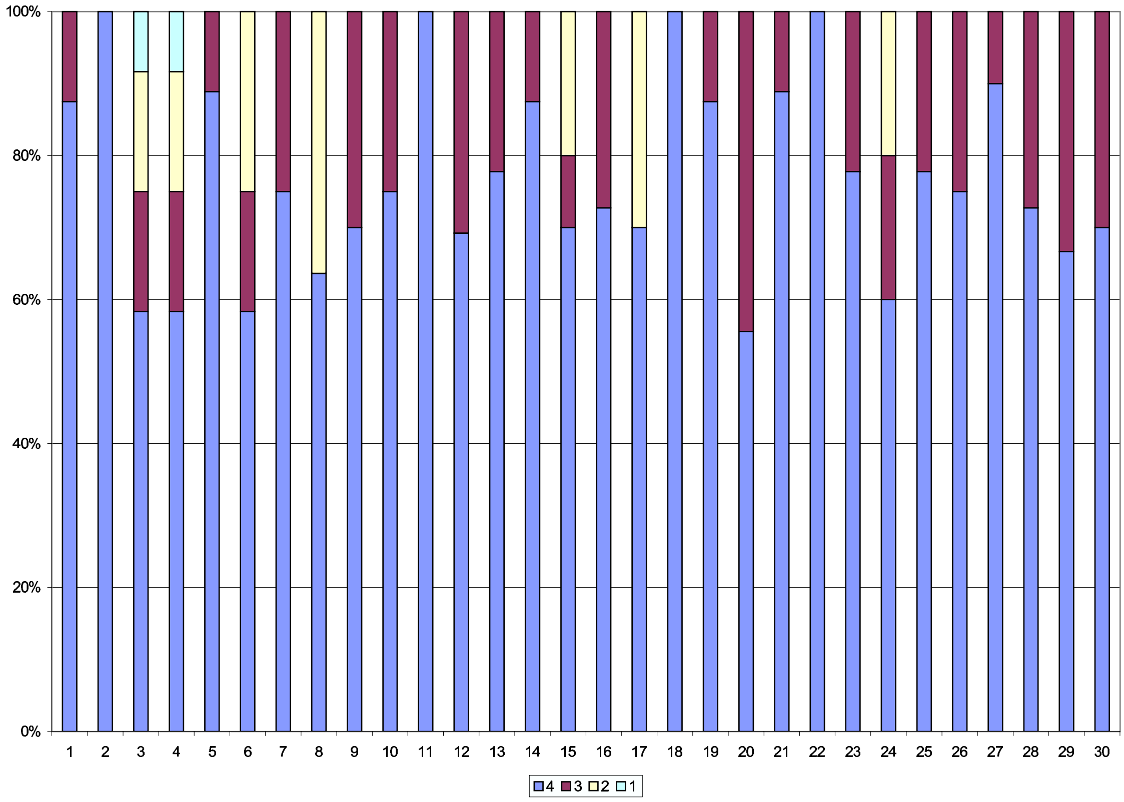

Figure 1: Evolution of All Proposals made in the Exclusive Membership Treatments.

Appendix 1: Data

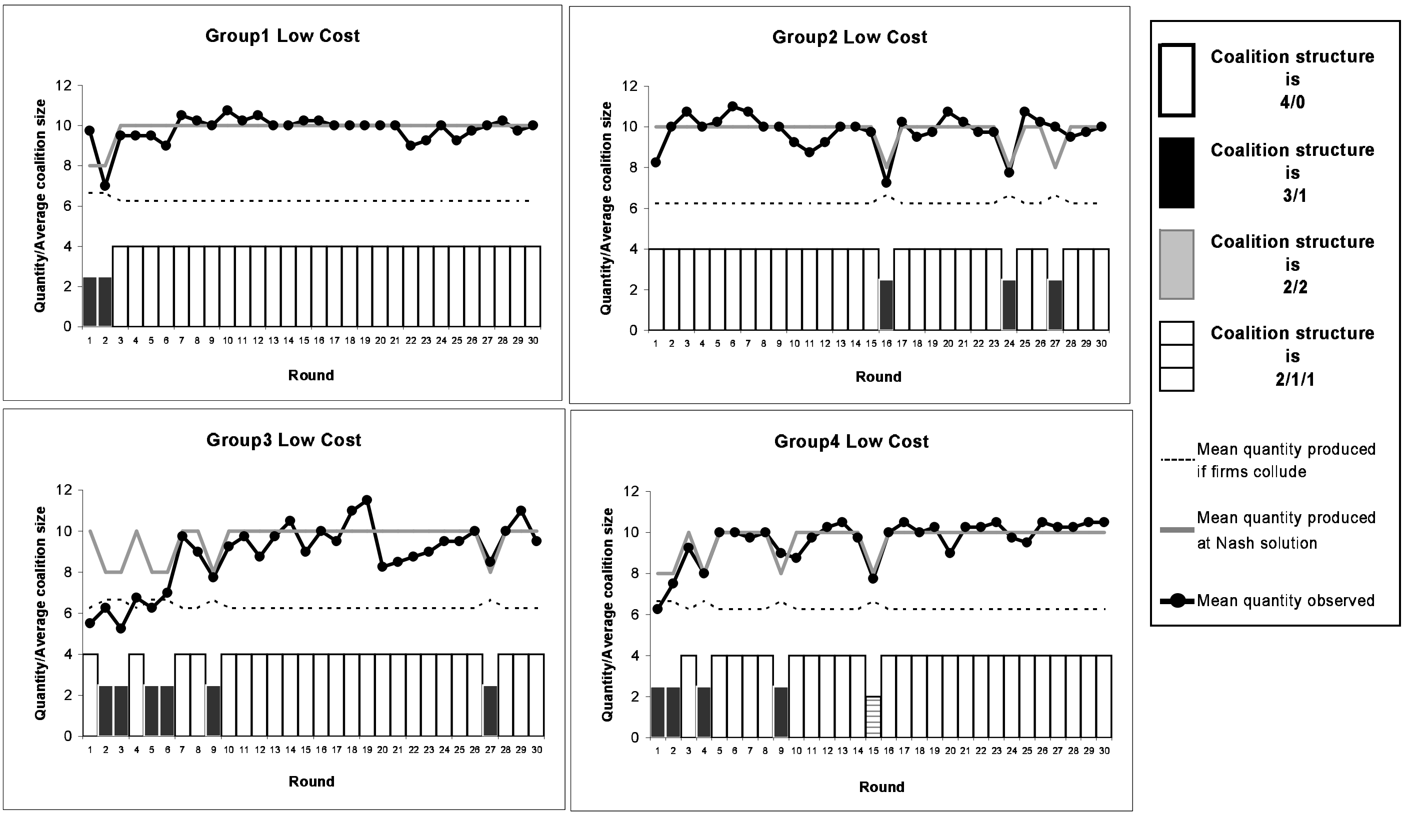

Figure 2: Open-membership Rule with Zero-Cost.

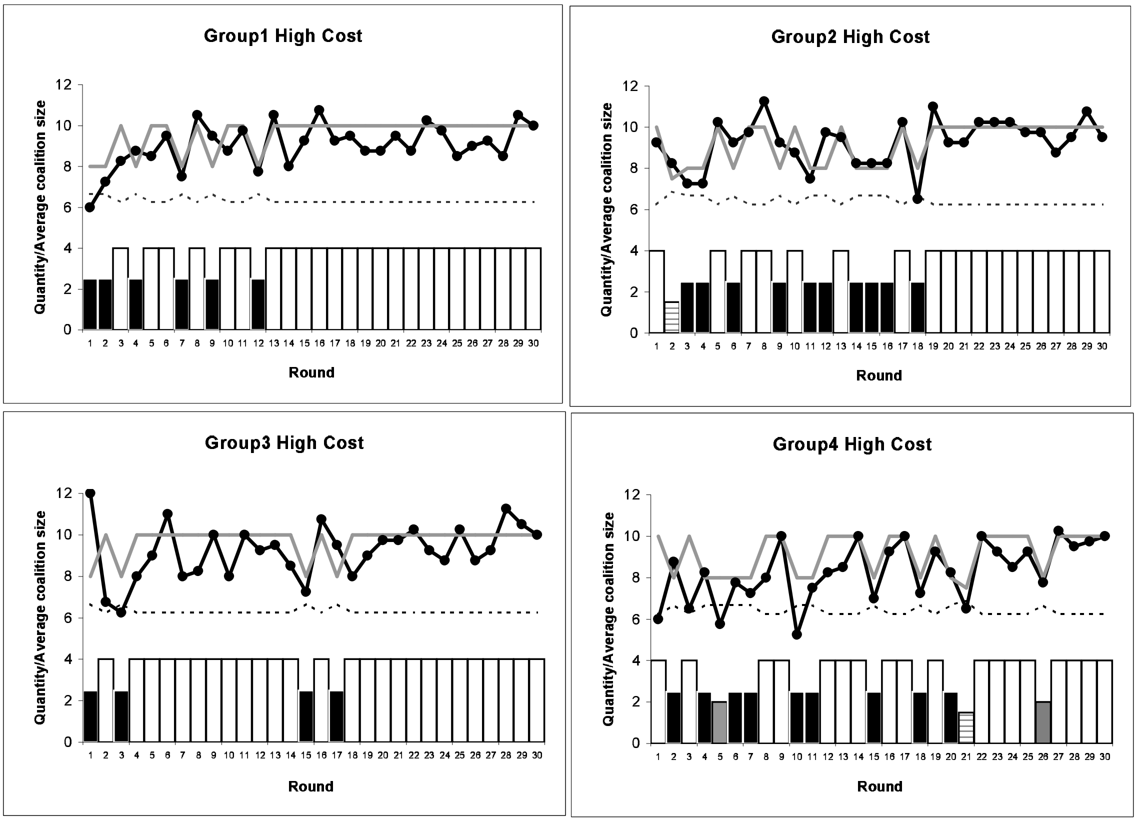

Figure 3: Open-membership Rule with Non-Zero-Cost.

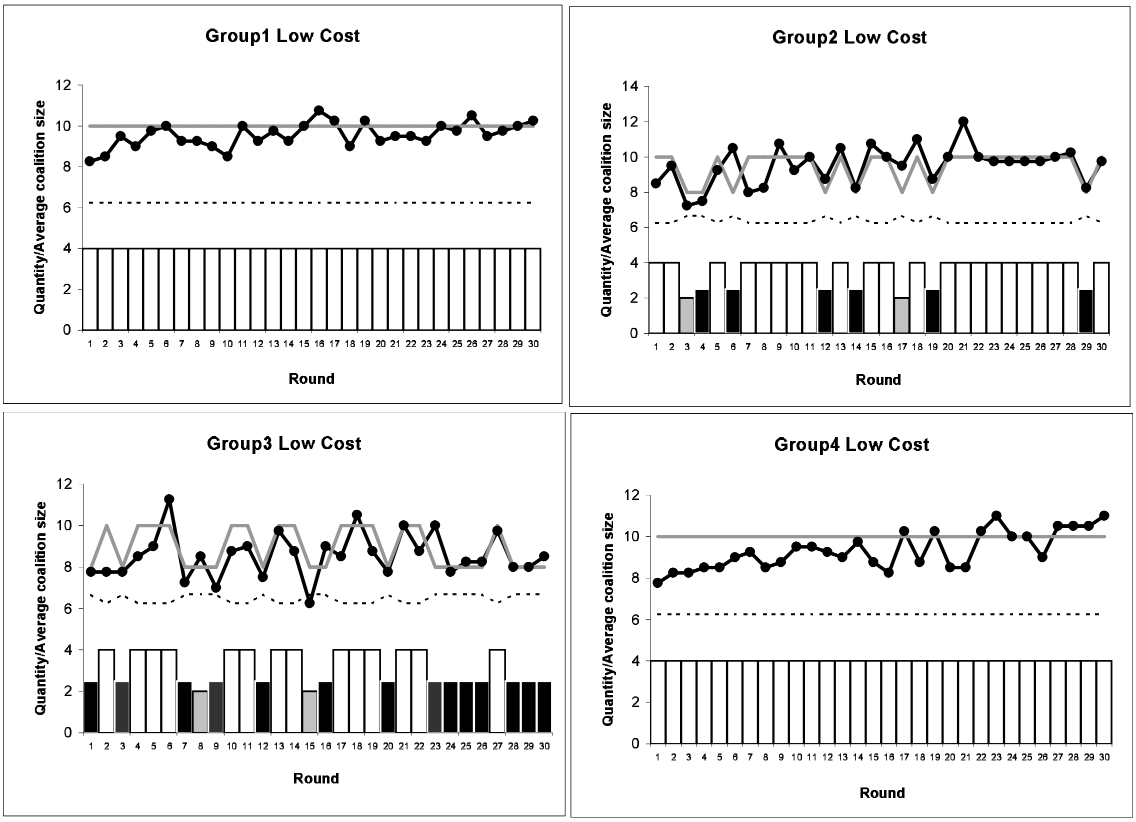

Figure 4: Exclusive-membership Rule with Zero-Cost.

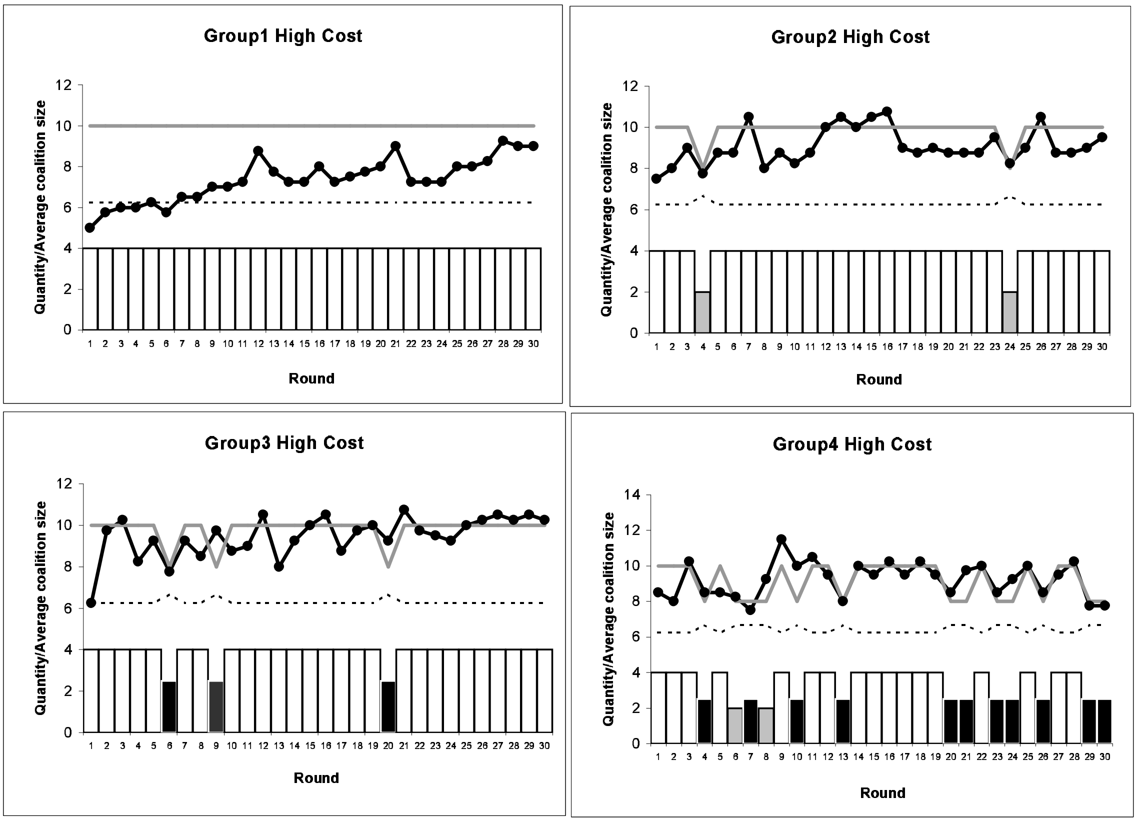

Figure 5: Exclusive-membership Rule with Non-Zero-Cost.

Appendix 2: Instructions (translated)

In the following we provide a translation of our experimental instructions. Where the versions for the open/exclusive membership and respectively the zero/non-zero cost treatments differed in non-trivial ways we have provided the different versions in two different columns. The columns are labelled accordingly.

Instructions

You will take part in a decision-making experiment and will be paid in cash for your participation. Different participants may earn different payoffs. The payoff you earn depends on your own and the decisions taken by other participants. In addition to the payoffs deriving from the decisions you take, you receive a fixed amount of 2.50 Euros for participating in this experiment. The experiment will be conducted on the computer. It is important that you do not speak or communicate in any other way with other participants. Should you not stick to this rule, we will have to exclude you from this experiment and you will not receive any payment.

Once all participants have read the instructions they will be read out loudly by one of the experimenters. After that we will ask you to fill in a questionnaire which tests your understanding of central features of this experiment. **You can only participate in this experiment if you have fully understood the instructions**. Before the start of the experiment we will take you through 5 practice rounds in order to familiarize you with the software. These 5 rounds are not part of the experiment and are therefore not payoff relevant.

We will now give a a description of the decision situation which you will face in this experiment. **The decision situation is identical for all participants**.

DESCRIPTION

In the following you will go through 30 rounds, each consisting of two stages. On each of these stages you interact with three of the other participants. The three other participants you are interacting with will remain the same for the entire experiment. In a given round, one participant will be referred to as person 1, one participant as person 2, one participant as person 3, and one participant as person 4. These labels are randomly drawn and are assigned only for the duration of one round. After each round, each participant gets a new label. You are informed at the beginning of each round which label you have been assigned.

In the course of your interaction with the other participants you will collect experimental points. The conversion rate of experimental points into Euro is provided to you at the end of these instructions. We will now explain the rules of interaction and how you can collect experimental points.
You take the following decisions:

First Stage[1]: You can either choose one out of four possible addresses, which are denoted as "Address A", "Address B", "Address C" and "Address D" or you can choose the option "Stay alone". These decisions are taken sequentially: Person 1 decides first, after that person 2 takes her decision, then person 3, and finally person 4 decides. Any person will know the decisions made by those preceding her, if there is any. All persons that have chosen the same address at the end of the first stage form a group.

First Stage[2]: You decide whether you want to build a group with some or all of the three persons with whom you are interacting or whether you want to stay alone. If you want to build a group you have to make a proposal first. All persons involved in the proposal you made will then be asked whether they want to accept or reject the proposal. A proposed group will only be formed if all persons involved accept the proposal. After a group has been formed its members cannot leave it or accept additional members in the current round. On the first stage decisions are taken sequentially. We will provide you with the details concerning the order according to which decisions are taken on the first stage in a separate section at the end of these instructions.

1 open-membership
2 exclusive membership

Second Stage: You and the three other persons choose a number between 0 and 13. More precisely, you can choose one of the following numbers: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 or 13. All persons take this decision simultaneously. Hence, when you choose your number you do not know which numbers have been chosen by the other three persons.

Together with your decision on the first stage you determine how much you then have to pay for the number you choose on the second stage. This is the case, as your costs depend on the size of your group. If you remain alone, you are treated as a 1-person group.

The costs[1] you have to pay for the number you choose are calculated in the following way:

The costs[2] you incur are composed of two parts: You incur costs for the number you choose in stage two, as

$$\text{Your costs} = (30 - 5 * \textit{Your group size}) * \textit{Your number}$$

well as for the size of the group to which you belong that was formed in stage 2. The costs you have to pay are calculated in the following way:

$$\text{Your costs} = (30 - 5 * \textit{Your group size}) * \textit{Your number} + 10 * (\textit{Your group size} - 1)$$

1 zero-cost

2 non-zero-cost

We have summarized the costs that arise according to this formula for all possible numbers and group sizes in the following table:[24]

	YOUR NUMBER													
If you are member of a	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1-person group (alone)	0	25	50	75	100	125	150	175	200	225	250	275	300	325
2-person group	0	20	40	60	80	100	120	140	160	180	200	220	240	260
3-person group	0	15	30	45	60	75	90	105	120	135	150	165	180	195
4-person group	0	10	20	30	40	50	60	70	80	90	100	110	120	130

You receive credits for the number you choose on the second stage. The number of credits you receive depends on the number you have chosen in stage 2 and the numbers chosen by the other three persons in the following way:

$$\text{Your credits} = (60 - \textit{Your number} - \textit{Sum of the three other numbers}) * \textit{Your number}$$

Note that the number of credits you receive depends on your own and the numbers chosen by **all three other persons you are interacting with** independently of whether you have formed a group with these persons on the first stage or not.

Your payoff in a given round is calculated by subtracting your costs from the credits you received. In addition to the formula given to you above, we provide you with four payoff tables at your place in which we have summarized your payoff (credits minus costs) for all situations you can possibly face.

YOUR PAYOFF TABLE

There are four payoff tables available to you:[25]

For the case[1] in which **you at the end of the first stage stay alone**, either because you have chosen the option "Stay alone" or because no other person has chosen the same address as you, **Table 1** provides your payoff, viz. your credits net of your costs for all numbers you can choose and all possible sums of the three numbers chosen by the other three persons. Example: If you choose number '3' and the sum of the numbers chosen by the three other persons amounts to '19', you receive a payoff of 39 experimental points.

For the case in which **you are member of a 2-person group at the end of the first stage**, i.e., there have been exactly one other person that has chosen the same address as you, **Table 2** provides your payoff, viz. your credits net of your costs for all numbers you can choose and all possible sums of the three numbers chosen by the other three persons. Example: If you choose number '1' and the sum of the numbers chosen by the three other persons amounts to '0', you receive a

For the case[2] in which **you at the end of the first stage stay alone**, **Table 1** provides your payoff, viz. your credits net of your costs for all numbers you can choose and all possible sums of the three numbers chosen by the other three persons. Example: If you choose number '3' and the sum of the numbers chosen by the three other persons amounts to '19', you receive a payoff of 39 experimental points.

For the case in which **you are member of a 2-person group at the end of the first stage**, **Table 2** provides your payoff, viz. your credits net of your costs for all numbers you can choose and all possible sums of the three numbers chosen by the other three persons. Example: If you choose number '1' and the sum of the numbers chosen by the three other persons amounts to '0', you receive a payoff of 39 experimental points.

For the case in which **you are member of a 3-person group at the end of the first stage**, **Table 3** provides your payoff, viz. your credits net of your costs for all numbers you can choose and all possible sums of

[24] Here we provide only the zero-cost version of the table. The respective transformations necessary to attain the non-zero version should be obvious.

[25] Here we provide only the zero-cost examples.

payoff of 39 experimental points.

For the case in which **you are member of a 3-person group at the end of the first stage**, i.e., there have been exactly two other persons that has chosen the same address as you, **Table 3** provides your payoff, viz. your credits net of your costs for all numbers you can choose and all possible sums of the three numbers chosen by the other three persons. Example: If you choose number '1' and the sum of the numbers chosen by the three other persons amounts to '5', you receive a payoff of 39 experimental points.

For the case in which **you are member of a 4-person group at the end of the first stage**, i.e., there have been exactly three other persons that has chosen the same address as you, **Table 3** provides your payoff, viz. your credits net of your costs for all numbers you can choose and all possible sums of the three numbers chosen by the other three persons. Example: If you choose number '13' and the sum of the numbers chosen by the three other persons amounts to '34', you receive a payoff of 39 experimental points.

1 open-membership
2 exclusive membership

the three numbers chosen by the other three persons.

Example: If you choose number '1' and the sum of the numbers chosen by the three other persons amounts to '5', you receive a payoff of 39 experimental points.

For the case in which **you are member of a 4-person group at the end of the first stage**, **Table 3** provides your payoff, viz. your credits net of your costs for all numbers you can choose and all possible sums of the three numbers chosen by the other three persons. Example: If you choose number '13' and the sum of the numbers chosen by the three other persons amounts to

'34', you receive a payoff of 39 experimental points.

DECISION ORDER FIRST STAGE[26]

At the beginning of the first stage, decisions are taken in the following order: Person 1 decides first, after that person 2 takes her decision, followed by person 3 and finally person 4 decides. Person 1 decides whether she wants to stay alone or suggest a group. If person 1 decides to stay alone, it is person 2's turn to take a decision. After a person has decided to stay alone, it is among those remaining always the person with the lowest-numbered label that decides next. If person 1 instead of staying alone decides to suggest a group, all persons involved in this proposal have to decide in ascending order of their labelling whether they accept or reject the proposal. If all involved persons accept the offer, the person with the lowest label among the remaining persons decides next. If a person rejects a proposal, this person is the one to take the next decision. Please note that a proposal is invalid whenever a single person has rejected it. If this is the case, further persons involved in the proposal will not be asked to accept or reject the offer anymore.

GENERAL REMARKS

Your total payoff in this experiment is given by the sum of payoffs received in the 30 rounds. During the experiment credits, costs and payoffs are quoted in experimental points. At the end of the session experimental points will be converted into Euro according to the following exchange rate: 200 experimental points exchange for 1 Euro.[27].

After the instructions have been read out to you we will ask you to fill in a questionnaire. You can only participate in this experiment if your questionnaire shows that you have understood the instructions. After answering the questionnaire we will take you through 5 practice rounds. Immediately after that the experiment starts.

Please raise your hand whenever you have a question. Please do not ask questions loudly.

[26]This section only existed in the exclusive-membership instructions.
[27]See footnote 16 for the adapted conversion rates used in the different treatments

Appendix 3: Payoff Tables[28]

This table summarizes your payoff,
if you have remained alone.

	Sum of the numbers chosen by the other three persons.																																							
Your number	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	34	33	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	-1	-2	-3	-4	-5
2	66	64	62	60	58	56	54	52	50	48	46	44	42	40	38	36	34	32	30	28	26	24	22	20	18	16	14	12	10	8	6	4	2	0	-2	-4	-6	-8	-10	-12
3	96	93	90	87	84	81	78	75	72	69	66	63	60	57	54	51	48	45	42	39	36	33	30	27	24	21	18	15	12	9	6	3	0	-3	-6	-9	-12	-15	-18	-21
4	124	120	116	112	108	104	100	96	92	88	84	80	76	72	68	64	60	56	52	48	44	40	36	32	28	24	20	16	12	8	4	0	-4	-8	-12	-16	-20	-24	-28	-32
5	150	145	140	135	130	125	120	115	110	105	100	95	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
6	174	168	162	156	150	144	138	132	126	120	114	108	102	96	90	84	78	72	66	60	54	48	42	36	30	24	18	12	6	0	-6	-12	-18	-24	-30	-36	-42	-48	-54	-60
7	196	189	182	175	168	161	154	147	140	133	126	119	112	105	98	91	84	77	70	63	56	49	42	35	28	21	14	7	0	-7	-14	-21	-28	-35	-42	-49	-56	-63	-70	-77
8	216	208	200	192	184	176	168	160	152	144	136	128	120	112	104	96	88	80	72	64	56	48	40	32	24	16	8	0	-8	-16	-24	-32	-40	-48	-56	-64	-72	-80	-88	-96
9	234	225	216	207	198	189	180	171	162	153	144	135	126	117	108	99	90	81	72	63	54	45	36	27	18	9	0	-9	-18	-27	-36	-45	-54	-63	-72	-81	-90	-99	-108	-117
10	250	240	230	220	210	200	190	180	170	160	150	140	130	120	110	100	90	80	70	60	50	40	30	20	10	0	-10	-20	-30	-40	-50	-60	-70	-80	-90	-100	-110	-120	-130	-140
11	264	253	242	231	220	209	198	187	176	165	154	143	132	121	110	99	88	77	66	55	44	33	22	11	0	-11	-22	-33	-44	-55	-66	-77	-88	-99	-110	-121	-132	-143	-154	-165
12	276	264	252	240	228	216	204	192	180	168	156	144	132	120	108	96	84	72	60	48	36	24	12	0	-12	-24	-36	-48	-60	-72	-84	-96	-108	-120	-132	-144	-156	-168	-180	-192
13	286	273	260	247	234	221	208	195	182	169	156	143	130	117	104	91	78	65	52	39	26	13	0	-13	-26	-39	-52	-65	-78	-91	-104	-117	-130	-143	-156	-169	-182	-195	-208	-221

Figure 6: Payoff Table 1: zero-cost.

This table summarizes your payoff,
if you have become a member of a two-person group.

	Sum of the numbers chosen by the other three persons.																																							
Your number	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	39	38	37	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
2	76	74	72	70	68	66	64	62	60	58	56	54	52	50	48	46	44	42	40	38	36	34	32	30	28	26	24	22	20	18	16	14	12	10	8	6	4	2	0	-2
3	111	108	105	102	99	96	93	90	87	84	81	78	75	72	69	66	63	60	57	54	51	48	45	42	39	36	33	30	27	24	21	18	15	12	9	6	3	0	-3	-6
4	144	140	136	132	128	124	120	116	112	108	104	100	96	92	88	84	80	76	72	68	64	60	56	52	48	44	40	36	32	28	24	20	16	12	8	4	0	-4	-8	-12
5	175	170	165	160	155	150	145	140	135	130	125	120	115	110	105	100	95	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20
6	204	198	192	186	180	174	168	162	156	150	144	138	132	126	120	114	108	102	96	90	84	78	72	66	60	54	48	42	36	30	24	18	12	6	0	-6	-12	-18	-24	-30
7	231	224	217	210	203	196	189	182	175	168	161	154	147	140	133	126	119	112	105	98	91	84	77	70	63	56	49	42	35	28	21	14	7	0	-7	-14	-21	-28	-35	-42
8	256	248	240	232	224	216	208	200	192	184	176	168	160	152	144	136	128	120	112	104	96	88	80	72	64	56	48	40	32	24	16	8	0	-8	-16	-24	-32	-40	-48	-56
9	279	270	261	252	243	234	225	216	207	198	189	180	171	162	153	144	135	126	117	108	99	90	81	72	63	54	45	36	27	18	9	0	-9	-18	-27	-36	-45	-54	-63	-72
10	300	290	280	270	260	250	240	230	220	210	200	190	180	170	160	150	140	130	120	110	100	90	80	70	60	50	40	30	20	10	0	-10	-20	-30	-40	-50	-60	-70	-80	-90
11	319	308	297	286	275	264	253	242	231	220	209	198	187	176	165	154	143	132	121	110	99	88	77	66	55	44	33	22	11	0	-11	-22	-33	-44	-55	-66	-77	-88	-99	-110
12	336	324	312	300	288	276	264	252	240	228	216	204	192	180	168	156	144	132	120	108	96	84	72	60	48	36	24	12	0	-12	-24	-36	-48	-60	-72	-84	-96	-108	-120	-132
13	351	338	325	312	299	286	273	260	247	234	221	208	195	182	169	156	143	130	117	104	91	78	65	52	39	26	13	0	-13	-26	-39	-52	-65	-78	-91	-104	-117	-130	-143	-156

Figure 7: Payoff Table 2: zero-cost.

[28] We only provide the zero-cost versions here.

This table summarizes your payoff, if you have become a member of a three-person group.

Your number	Sum of the numbers chosen by the other three persons.																																						
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	44	43	42	41	40	39	38	37	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5
2	86	84	82	80	78	76	74	72	70	68	66	64	62	60	58	56	54	52	50	48	46	44	42	40	38	36	34	32	30	28	26	24	22	20	18	16	14	12	10	8
3	126	123	120	117	114	111	108	105	102	99	96	93	90	87	84	81	78	75	72	69	66	63	60	57	54	51	48	45	42	39	36	33	30	27	24	21	18	15	12	9
4	164	160	156	152	148	144	140	136	132	128	124	120	116	112	108	104	100	96	92	88	84	80	76	72	68	64	60	56	52	48	44	40	36	32	28	24	20	16	12	8
5	200	195	190	185	180	175	170	165	160	155	150	145	140	135	130	125	120	115	110	105	100	95	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5
6	234	228	222	216	210	204	198	192	186	180	174	168	162	156	150	144	138	132	126	120	114	108	102	96	90	84	78	72	66	60	54	48	42	36	30	24	18	12	6	0
7	266	259	252	245	238	231	224	217	210	203	196	189	182	175	168	161	154	147	140	133	126	119	112	105	98	91	84	77	70	63	56	49	42	35	28	21	14	7	0	-7
8	296	288	280	272	264	256	248	240	232	224	216	208	200	192	184	176	168	160	152	144	136	128	120	112	104	96	88	80	72	64	56	48	40	32	24	16	8	0	-8	-16
9	324	315	306	297	288	279	270	261	252	243	234	225	216	207	198	189	180	171	162	153	144	135	126	117	108	99	90	81	72	63	54	45	36	27	18	9	0	-9	-18	-27
10	350	340	330	320	310	300	290	280	270	260	250	240	230	220	210	200	190	180	170	160	150	140	130	120	110	100	90	80	70	60	50	40	30	20	10	0	-10	-20	-30	-40
11	374	363	352	341	330	319	308	297	286	275	264	253	242	231	220	209	198	187	176	165	154	143	132	121	110	99	88	77	66	55	44	33	22	11	0	-11	-22	-33	-44	-55
12	396	384	372	360	348	336	324	312	300	288	276	264	252	240	228	216	204	192	180	168	156	144	132	120	108	96	84	72	60	48	36	24	12	0	-12	-24	-36	-48	-60	-72
13	416	403	390	377	364	351	338	325	312	299	286	273	260	247	234	221	208	195	182	169	156	143	130	117	104	91	78	65	52	39	26	13	0	-13	-26	-39	-52	-65	-78	-91

Figure 8: Payoff Table 3: zero-cost.

This table summarizes your payoff, if you have become a member of a four-person group.

Your number	Sum of the numbers chosen by the other three persons.																																						
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	49	48	47	46	45	44	43	42	41	40	39	38	37	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10
2	96	94	92	90	88	86	84	82	80	78	76	74	72	70	68	66	64	62	60	58	56	54	52	50	48	46	44	42	40	38	36	34	32	30	28	26	24	22	20	18
3	141	138	135	132	129	126	123	120	117	114	111	108	105	102	99	96	93	90	87	84	81	78	75	72	69	66	63	60	57	54	51	48	45	42	39	36	33	30	27	24
4	184	180	176	172	168	164	160	156	152	148	144	140	136	132	128	124	120	116	112	108	104	100	96	92	88	84	80	76	72	68	64	60	56	52	48	44	40	36	32	28
5	225	220	215	210	205	200	195	190	185	180	175	170	165	160	155	150	145	140	135	130	125	120	115	110	105	100	95	90	85	80	75	70	65	60	55	50	45	40	35	30
6	264	258	252	246	240	234	228	222	216	210	204	198	192	186	180	174	168	162	156	150	144	138	132	126	120	114	108	102	96	90	84	78	72	66	60	54	48	42	36	30
7	301	294	287	280	273	266	259	252	245	238	231	224	217	210	203	196	189	182	175	168	161	154	147	140	133	126	119	112	105	98	91	84	77	70	63	56	49	42	35	28
8	336	328	320	312	304	296	288	280	272	264	256	248	240	232	224	216	208	200	192	184	176	168	160	152	144	136	128	120	112	104	96	88	80	72	64	56	48	40	32	24
9	369	360	351	342	333	324	315	306	297	288	279	270	261	252	243	234	225	216	207	198	189	180	171	162	153	144	135	126	117	108	99	90	81	72	63	54	45	36	27	18
10	400	390	380	370	360	350	340	330	320	310	300	290	280	270	260	250	240	230	220	210	200	190	180	170	160	150	140	130	120	110	100	90	80	70	60	50	40	30	20	10
11	429	418	407	396	385	374	363	352	341	330	319	308	297	286	275	264	253	242	231	220	209	198	187	176	165	154	143	132	121	110	99	88	77	66	55	44	33	22	11	0
12	456	444	432	420	408	396	384	372	360	348	336	324	312	300	288	276	264	252	240	228	216	204	192	180	168	156	144	132	120	108	96	84	72	60	48	36	24	12	0	-12
13	481	468	455	442	429	416	403	390	377	364	351	338	325	312	299	286	273	260	247	234	221	208	195	182	169	156	143	130	117	104	91	78	65	52	39	26	13	0	-13	-26

Figure 9: Payoff Table 4: zero-cost.

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