

# Myopic or Farsighted ? An Experiment on Network Formation <sup>†</sup>

Marco Mantovani<sup>a,b</sup>, Georg Kirchsteiger<sup>b</sup>, Ana Mauleon<sup>c,d</sup>,

Vincent Vannetelbosch<sup>d</sup>

<sup>a</sup>Università degli studi di Milano, Conservatorio 7, I-20122 Milan, Italy.

<sup>b</sup>ECARES, Université Libre de Bruxelles, 44 Avenue Jeanne, B-1050 Brussels  
Belgium. ECORE, CEPR, and CESifo.

<sup>c</sup>FNRS and CEREC, Facultés universitaires Saint-Louis, Boulevard du Jardin  
Botanique 43, B-1000 Brussels, Belgium.

<sup>d</sup>FNRS and CORE, Université catholique de Louvain, 34 voie du Roman Pays,  
B-1348 Louvain-la-Neuve, Belgium.

## Abstract

Pairwise stability (Jackson and Wolinsky, 1996) is the standard stability concept in network formation. It assumes myopic behavior of the agents in the sense that they do not forecast how others might react to their actions. Assuming that agents are farsighted, related stability concepts have been proposed. We design a simple network formation experiment to test these theories. Our results provide support for farsighted stability and strongly reject the idea of myopic behavior.

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<sup>†</sup>E-mail addresses: marco.mantovani@unimi.it (Marco Mantovani), gkirchst@ulb.ac.be (Georg Kirchsteiger), mauleon@fusl.ac.be (Ana Mauleon), vincent.vannetelbosch@uclouvain.be (Vincent Vannetelbosch).

# 1 Introduction

The network structure of social interactions influences a variety of behaviors and economic outcomes, including the formation of opinions, decisions on which products to buy, investment in education, access to jobs, and informal borrowing and lending. A simple way to analyze the networks that one might expect to emerge in the long run is to examine the requirement that individuals do not benefit from altering the structure of the network. An example of such a condition is the pairwise stability notion defined by Jackson and Wolinsky (1996). A network is pairwise stable if no individual benefits from severing one of her links and no two individuals benefit from adding a link between them, with one benefiting strictly and the other at least weakly. Pairwise stability is a myopic definition. Individuals are not farsighted in the sense that they do not forecast how others might react to their actions. Indeed, the adding or severing of one link might lead to subsequent addition or severing of another link. If individuals foresee how others react to changes in the network, then one wants to allow for this in the definition of the stability concept. For instance, individuals might not add a link that appears valuable to them given the current network, as that might induce the formation of other links, ultimately leading to lower payoffs for the original individuals.

Herings, Mauleon and Vannetelbosch (2009) have proposed the notion of pairwise farsightedly stable sets of networks that predicts which networks one might expect to emerge in the long run when individuals are farsighted.<sup>1</sup> A set of networks  $G$  is pairwise farsightedly stable (i) if all possible pairwise deviations from any network  $g \in G$  to a network outside  $G$  are deterred by the threat of ending worse off or equally well off, (ii) if there exists a farsighted improving path from any network outside the set leading to some network in the set,<sup>2</sup> and (iii) if there is no proper

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<sup>1</sup>Other approaches to farsightedness in network formation are suggested by the work of Chwe (1994), Xue (1998), Herings, Mauleon, and Vannetelbosch (2004), Mauleon and Vannetelbosch (2004), Page, Wooders and Kamat (2005), Dutta, Ghosal, and Ray (2005), and Page and Wooders (2009).

<sup>2</sup>A farsighted improving path is a sequence of networks that can emerge when players form or sever links based on the improvement the end network offers relative to the current network. Each network in the sequence differs by one link from the previous one. If a link is added, then the two players involved must both prefer the end network to the current network, with at least one of the two strictly preferring the end network. If a link is deleted, then it must be that at least one of the two players involved in the link strictly prefers the end network.

subset of  $G$  satisfying Conditions (i) and (ii). A non-empty pairwise farsightedly stable set always exists. Herings, Mauleon and Vannetelbosch (2009) have provided a full characterization of unique pairwise farsightedly stable sets of networks. They have shown that farsightedness can refine pairwise stability by selecting the Pareto efficient network among the pairwise stable ones. For instance, they have found that in the criminal network model of Calvó-Armengol and Zenou (2004), the set consisting of the complete network (where all criminals are linked to each other) is a pairwise farsightedly stable set that selects the Pareto efficient network. Grandjean, Mauleon and Vannetelbosch (2011) have shown that in the Kranton and Minehart (2001) model of buyer-seller networks, pairwise farsighted stability may even sustain the strongly efficient network while pairwise stability sustains networks that are strongly inefficient or even Pareto dominated.

Based on the characterization of unique pairwise farsightedly stable sets of networks of Herings, Mauleon and Vannetelbosch (2009), we define a network  $g$  to be pairwise farsightedly stable (i) if there is no farsighted improving path leaving  $g$  and (ii) if there exists a farsighted improving path from any other network leading to  $g$ . This second condition implies that a pairwise farsightedly stable network is robust to perturbations.<sup>3</sup> When a pairwise farsightedly stable network  $g$  exists, it is the unique one, it is pairwise stable, it belongs to the largest pairwise consistent set (see Chwe, 1994), and the set  $\{g\}$  coincides with the unique pairwise farsightedly stable set and the unique von Neumann-Morgenstern pairwise farsightedly stable set (see Chwe, 1994). Note that the notion of farsightedness has the flavor of a focal point notion. Compared to other stable networks, players realize that all of them could be better off by establishing a farsighted stable network (if it exists), although creating it might require the formation of links that do not immediately benefit the two agents connected by it. So farsighted stability could be viewed as a coordination device. This focal point property is of course reinforced by the uniqueness of the pairwise farsighted stable network.

There is a subtle connection between notions of pairwise stability (PWS) and farsighted stability (FS). In particular, a FS network is always PWS, but not the other way round. Hence, FS can be viewed as a refinement of PWS. But the un-

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<sup>3</sup>There are some random dynamic models of network formation that are based on incentives to form links such as Watts (2002), Jackson and Watts (2002), and Tercieux and Vannetelbosch (2006). These models aim to use the random process to select from the set of pairwise stable networks.

derlying behavioral assumptions of both notions - myopia versus farsightedness - are at odds with each other. In our paper we test these types of behaviors in the context of network formation. Network formation is hard to study in the field, as many potentially conflicting factors are at work. Consequently, we run laboratory experiments. To the best of our knowledge, this constitutes the first experimental test of farsightedness versus myopia in network formation.

In the experiment, groups of four subjects had to form a network. More specifically, they were allowed sequentially to add or sever one link at a time: a link was chosen at random and the agents involved in the link had to decide if they wanted to form it (if it had not been formed yet) or to sever it (if it had been already formed). The process was repeated until all group members declared they were satisfied with the existing network. The payoffs were designed such that a group consisting of myopic agents would never form any link, while a group composed of farsighted agents would form the complete network which was of course FS. The results supported FS and strongly rejected the hypothesis of myopic behavior both at the group and at the individual level. More than 70% of the subjects were farsighted and a similar percentage of the experienced groups reached the FS network, while only 8% of the sample displayed behaviors consistent with myopia.

The number of experiments addressing networks and network formation is rapidly increasing.<sup>4</sup> Relatively few of them, however, deal with pure network formation, intended as a setting where no strategic interactions take place on the network once it has been formed. Among the notable exceptions stand the experiments of Goeree, Riedl and Ule (2009) and Falk and Kosfeld (2003). They investigate the predictive power of a strict Nash network in the framework of Bala and Goyal (2000). They find low support for this concept when the Nash network is asymmetric and the agents homogeneous. The main difference with our design is that they consider a model with unilateral link formation and apply non-cooperative solution concepts, while in our context of bilateral link formation those concepts provide implausible predictions (see Bloch and Jackson, 2006).

Closer to our approach is the work of Pantz and Ziegelmeyer (2008), where R&D networks in a Cournot oligopoly are investigated. Their results generally support pairwise stability. In their design pairwise stable networks are also farsightedly

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<sup>4</sup>See Kosfeld (2004) for a partial survey.

stable and thus there is no tension between myopia and farsightedness.<sup>5</sup>

The only experiment on network formation that addresses in some way farsightedness, to the best of our knowledge, is the one by Berninghaus, Ehrhart and Ott (2008). The authors argue they find evidence of a kind of limited farsightedness, which they use to build the concept of one-step-ahead stability. Relevant features distinguish our work from their model: (i) they assume unilateral link formation; (ii) players play a coordination game on the endogenously formed network and thus the assumption on the beliefs about this latter game affects the predictions; (iii) the farsightedness notion they consider relates specifically to the interaction between the linking strategies and the strategies in the coordination game. So their experiment combines a test of network formation and strategic behavior in the coordination game, while our paper is the first to directly investigate farsightedness and myopia in a network formation context unaffected by any other considerations.

The paper is organized as follows. In Section 2 we introduce the necessary notation and definitions. Section 3 presents the experimental design and procedures. Section 4 reports the experimental results. Section 5 concludes.

## 2 Networks: notation and definitions

Let  $N = \{1, \dots, n\}$  be the finite set of players who are connected in some network relationship. The network relationships are reciprocal and the network is thus modeled as a non-directed graph. Individuals are the nodes in the graph and links indicate bilateral relationships between individuals. Thus, a network  $g$  is simply a list of which pairs of individuals are linked to each other. We write  $ij \in g$  to indicate that  $i$  and  $j$  are linked under the network  $g$ . Let  $g^N$  be the collection of all subsets of  $N$  with cardinality 2, so  $g^N$  is the complete network. The set of all possible networks or graphs on  $N$  is denoted by  $\mathbb{G}$  and consists of all subsets of  $g^N$ . The network obtained by adding link  $ij$  to an existing network  $g$  is denoted  $g + ij$  and the network that results from deleting link  $ij$  from an existing network  $g$  is denoted  $g - ij$ .

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<sup>5</sup>They observe huge differences between the case in which the Cournot profits are considered as exogenously given and identified with the payoffs of the players in the network, and the case in which players play the production stage after forming the network. This supports pure network formation as the cleanest setting to study network formation.

The material payoffs associated to a network are represented by a function  $x : \mathbb{G} \rightarrow \mathbb{R}^n$  where  $x_i(g)$  represents the material payoff that player  $i$  obtains in network  $g$ . The overall benefit net of costs that a player enjoys from a network  $g$  is modeled by means of a utility function  $u_i(g) : \mathbb{R}^n \rightarrow \mathbb{R}$  that associates a value to the vector of material payoffs associated to network  $g$ . This might include all sorts of costs, benefits, and externalities. Given a permutation of players  $\pi$  and any  $g \in \mathbb{G}$ , let  $g^\pi = \{\pi(i)\pi(j) \mid ij \in g\}$ . Thus,  $g^\pi$  is a network that is identical to  $g$  up to a permutation of the players. We say that the function of material payoffs satisfy *anonymity* if, for every  $g \in \mathbb{G}$  and permutation  $\pi$ ,  $x_{\pi(i)}(g^\pi) = x_i(g)$ . Anonymity ensures that the labels of the agents do not matter.

Let  $N_i(g) = \{j \mid ij \in g\}$  be the set of nodes that  $i$  is linked to in network  $g$ . The *degree* of a node is the number of links that involve that node. Thus node  $i$ 's degree in a network  $g$ , denoted  $d_i(g)$ , is  $d_i(g) = \#N_i(g)$ . Let  $S_k(g)$  be the subset of nodes that have degree  $k$  in network  $g$ :  $S_k(g) = \{i \in N \mid d_i(g) = k\}$  with  $k \in \{0, 1, \dots, n-1\}$ . The *degree distribution* of a network  $g$  is a description of the relative frequencies of nodes that have different degrees. That is,  $P(k)$  is the fraction of nodes that have degree  $k$  under a degree distribution  $P$ ; that is  $P(k) = (\#S_k(g)) / n$ . Given a degree distribution,  $\bar{P}$ , we define a *class of networks* as  $C_{\bar{P}} = \{g \in \mathbb{G} \mid P(k) = \bar{P}(k), \forall k\}$ . A class of networks is the subset of  $\mathbb{G}$  with the same degree distribution.

Consider a network formation process under which mutual consent is needed to form a link and link deletion is unilateral. A network is pairwise stable if no player benefits from severing one of their links and no other two players benefit from adding a link between them, with one benefiting strictly and the other at least weakly.

Formally, a network  $g$  is pairwise stable if

- (i) for all  $ij \in g$ ,  $u_i(g) \geq u_i(g - ij)$  and  $u_j(g) \geq u_j(g - ij)$ , and
- (ii) for all  $ij \notin g$ , if  $u_i(g) < u_i(g + ij)$  then  $u_j(g) > u_j(g + ij)$ .

We say that  $g'$  is adjacent to  $g$  if  $g' = g + ij$  or  $g' = g - ij$  for some  $ij$ . A network  $g'$  defeats  $g$  if either  $g' = g - ij$  and  $u_i(g') > u_i(g)$  or  $u_j(g') > u_j(g)$ , or if  $g' = g + ij$  with  $u_i(g') \geq u_i(g)$  and  $u_j(g') \geq u_j(g)$  with at least one inequality holding strictly. Pairwise stability is equivalent to the statement of not being defeated by another (adjacent) network.

Agents are assumed to consider only their own incentives when making their linking choices and not that of the others. In particular, agents do not take into

account the likely chain of reactions that follow an action, but only its immediate profitability. Thus, PWS implicitly assumes myopic behavior on the part of the agents.

We now define myopic behavior. At time  $t$  the link  $ij$  is selected, the action of agent  $i$  is  $a_i^t \in \{0, 1\}$ , where 0 means not to form (to break) the selected link  $ij$ , and 1 means to form (to keep) the link  $ij$ .

**Definition 1.** An action  $a_i^t$  is myopic if:

- (i) whenever  $ij \notin g_{t-1}$ , then  $a_i^t = \begin{cases} 1 & \text{if } u_i(g_{t-1} + ij) \geq u_i(g_{t-1}) \\ 0 & \text{otherwise,} \end{cases}$
- (ii) whenever  $ij \in g_{t-1}$ , then  $a_i^t = \begin{cases} 0 & \text{if } u_i(g_{t-1} - ij) > u_i(g_{t-1}) \\ 1 & \text{otherwise.} \end{cases}$

Myopic behavior only looks at the profitability of adjacent networks.

We now define farsighted behavior. Farsightedness captures the idea that agents will consider the chain of reactions that could follow when deviating from the current network, and evaluate the profitability of such deviation with reference to the final network of the chain of reactions. As a consequence, a farsighted agent will eventually choose against her immediate interest if she believes that the sequence of reactions that will follow her action could make her better off.

A *farsighted improving path* is a sequence of networks that can emerge when players form or sever links based on the improvement the end network offers relative to the current network. Each network in the sequence differs by one link from the previous one. If a link is added, then the two players involved must both prefer the end network to the current network, with at least one of the two strictly preferring the end network. If a link is deleted, then it must be that at least one of the two players involved in the link strictly prefers the end network. We now introduce the formal definition of a farsighted improving path.

**Definition 2.** A farsighted improving path from a network  $g$  to a network  $g' \neq g$  is a finite sequence of graphs  $g_1, \dots, g_K$  with  $g_1 = g$  and  $g_K = g'$  such that for any  $k \in \{1, \dots, K - 1\}$  either:

- (i)  $g_{k+1} = g_k - ij$  for some  $ij$  such that  $u_i(g_K) > u_i(g_k)$  or  $u_j(g_K) > u_j(g_k)$  or
- (ii)  $g_{k+1} = g_k + ij$  for some  $ij$  such that  $u_i(g_K) > u_i(g_k)$  and  $u_j(g_K) \geq u_j(g_k)$ .

If there exists a farsighted improving path from  $g$  to  $g'$ , then we write  $g \rightarrow g'$ . For a given network  $g$ , let  $F(g) = \{g' \in \mathbb{G} \mid g \rightarrow g'\}$ . This is the set of networks that can be reached by a farsighted improving path from  $g$ . Based on this notion of farsighted improving path, we define a network  $g$  to be pairwise farsightedly stable (FS) if there is no farsighted improving path leaving  $g$  and there exists a farsighted improving path from any other network leading to  $g$ . Formally,

**Definition 3.** A network  $g \in \mathbb{G}$  is pairwise farsightedly stable (FS) if:

- (i)  $F(g) = \emptyset$ , and
- (ii)  $\forall g' \in \mathbb{G} \setminus g, g \in F(g')$ .

Although the existence of a FS network is not guaranteed in general, the notion of FS network has very nice properties as a predictive device for our experiment. Indeed, when a FS network exists, it is the unique one (since  $F(g) = \emptyset$  contradicts condition (ii) in order to have another network  $g'' \neq g$  being also FS) and it is pairwise stable (due to the fact that  $F(g) = \emptyset$ ). We are then restricting the analysis to situations where farsightedness refines pairwise stability. Moreover, if a FS network exists, it is consistent with other set-based notions of farsighted stability that have been proposed in the literature. In particular, in case of existence the FS network coincides with the unique pairwise farsightedly stable set<sup>6</sup> (see Herings, Mauleon and Vannetelbosch, 2009) and the unique von Neumann-Morgenstern pairwise farsightedly stable set (see Chwe, 1994).<sup>7</sup> It is also contained by the largest pairwise consistent set (see Chwe, 1994).<sup>8</sup>

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<sup>6</sup>A set of networks  $G \subseteq \mathbb{G}$  is *pairwise farsightedly stable* if (i) all possible pairwise deviations from any network  $g \in G$  to a network outside  $G$  are deterred by a credible threat of ending worse off or equally well off, (ii) there exists a farsighted improving path from any network outside the set leading to some network in the set, and (iii) there is no proper subset of  $G$  satisfying Conditions (i) and (ii).

<sup>7</sup>The set  $G \subseteq \mathbb{G}$  is a von Neumann-Morgenstern pairwise farsightedly stable set if (i) there is no farsighted improving path connecting any two networks in  $G$  and (ii) there is a farsighted improving path from any network outside  $G$  to a network in  $G$ . Corollary 4 in Herings, Mauleon and Vannetelbosch (2009) asserts that the set  $\{g\}$  is a pairwise farsightedly stable set if and only if it is a von Neumann-Morgenstern pairwise farsightedly stable set. Then, when a FS network exists, it coincides with the unique von Neumann-Morgenstern pairwise farsightedly stable set.

<sup>8</sup>A set  $G$  is a pairwise consistent set if both external and internal pairwise deviations are deterred. The largest pairwise consistent set is the set that contains any pairwise consistent set.

Defining farsighted behavior requires that every agent is farsighted and that this is common knowledge. But when a farsighted agent observes a non-farsighted play of another agent, we do not know exactly the kind of action the farsighted agent will choose. Her action will depend, among others, on her beliefs about the others' degree of farsightedness. A complete theoretical analysis of farsighted behavior with heterogeneous agents goes far beyond the purpose of this paper. To define farsighted behavior for the purpose of this paper, note that a general pattern of farsighted behavior can be easily identified. A farsighted agent should move towards the FS network while believing it is reachable, and only change her strategy once convinced that the best feasible stable solution is not the FS network.

Though the details of this *heuristics* must be adapted to the specific case, the features that characterize it as farsighted are invariant. Its structure will consist of the following elements: (i) at the beginning of the game a farsighted agent will act as if everybody else is farsighted; (ii) given her (evolving) beliefs on her group composition she will assess if there is a feasible path that goes to the FS network; (iii) if at some  $t$  the group is not on this path she will target a different stable network. In Section 4 we will specify such a *heuristics* more in detail in order to estimate the portion of farsighted experimental subjects.

### 3 Experimental design and procedures

#### 3.1 The game

We consider a simple dynamic link formation game, almost identical to that proposed by Watts (2001). Time is a countable infinite set:  $T = 0, 1, \dots, t, \dots$ ;  $g_t$  denotes the network that exists at the end of period  $t$ . The process starts at  $t = 0$  with  $n = 4$  unconnected players ( $g_0$  coincides with the empty network,  $g^\emptyset$ ). The players meet over time and have the opportunity to form links with each other.

At every stage  $t > 0$ , a link  $ij_t$  is randomly identified to be updated. At  $t = 1$  each link from the set  $g^N$  is selected with uniform probability. At every  $t > 1$ , a link  $ij$  from the set  $g^N \setminus ij_{t-1}$  is selected with uniform probability. Thus, a link cannot be selected twice in two consecutive stages. If the link  $ij \in g_{t-1}$ , then both  $i$  and  $j$  can decide unilaterally to sever the link; if the link  $ij \notin g_{t-1}$ , then  $i$  and  $j$  can form the link  $ij$  if they both agree.  $g_{t-1}$  is updated accordingly and we move to

$g_t$ . All group members are informed about both the decisions taken by the players involved in the selected link and the consequences on that link. They are informed through a graphical representation of the current network  $g_t$  and the associated payoffs. After every stage all group members are asked whether they are satisfied with the current network or not. If they unanimously declare they are satisfied, the game ends; otherwise, they move to the next stage.<sup>9</sup> To ensure that an end is reached, a random stopping rule is added after stage 25: at every  $t \geq 26$  the game ends anyway with probability 0.2.

The game is repeated three times to allow for learning: groups are kept the same throughout the experiment. Group members are identified through a capital letter (A, B, C or D). The identities are reassigned at every new repetition.

A vector of payoffs is associated to every network: it allocates a number of *points* to each player in the network. The subjects receive *points* depending only on the final network of each repetition. Thus, their total *points* are given by the sum of the points achieved in the final networks of the three repetitions. At the end of the experiment the *points* are converted into Euro at the exchange rate of 1 Euro = 6 *points*.

The subjects are informed about the payoffs associated to every possible network and know the whole structure of the game from the beginning. Before starting the first repetition the participants have the opportunity of practicing the relation between networks and payoffs and the functioning of the stages through a training stage and three trial stages.

## 3.2 Predictions

Since  $n = 4$ , it follows that  $\#g^N = 6$  and  $\#\mathbb{G} = 64$ .

Figure 1 displays the payoffs that were used in the experiment for each class of networks. The function of material payoffs satisfies *anonymity* and then, this representation is sufficient to assign a payoff to each player in each possible network configuration. These numbers were chosen in order to provide the resulting predictions with a set of nice properties that are described below.

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<sup>9</sup>Subjects are informed about the outcome of the satisfaction choices - i.e. end of the repetition or not - but not about individual choices.

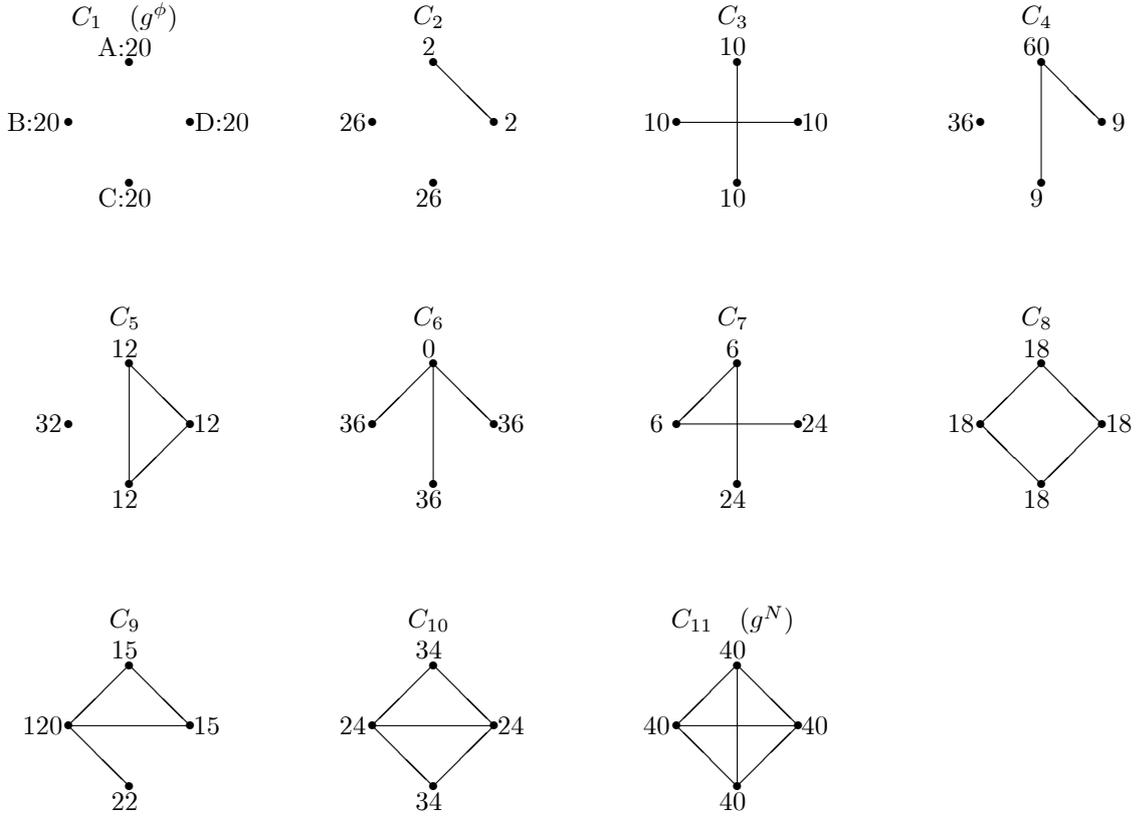


Figure 1: Payoffs

Consider self-regarding agents ( $u_i(g) = f(x_i(g))$ ). There are 6 PWS networks:  $g^\emptyset$ ,  $g^N$  and the four networks in class  $C_5$ . Note that, in every network in  $C_5$ , the connected agents can improve their situation by cutting both of their links. These networks (contrary to  $g^\emptyset$  and  $g^N$ ) are not Nash stable in the terminology of Bloch and Jackson (2006).<sup>10</sup> In our experiment, all groups start at  $g^\emptyset$ , and then groups composed of myopic players are expected not to move from  $g^\emptyset$ . This prediction is robust to errors. Either a sequence of three links added consecutively by error and leading to a network in  $C_5$ , or a sequence of four links added consecutively by error<sup>11</sup> is needed in order to change the prediction for myopic agents. In both cases, these sequences of events are highly unlikely, and our prediction for a myopic group of

<sup>10</sup>Pairwise Nash stability is a refinement of both pairwise stability and Nash stability, where one requires that a network be immune to the formation of a new link by any two agents, and the deletion of any number of links by any individual agent.

<sup>11</sup>In this last case, the players in the group may add the remaining links and end in  $g^N$ .

players is to end up in  $g^0$ .

To identify the FS network, we need to compute  $F(g)$  for every  $g$ . We can prove the following result.

**Proposition 1.** *Consider payoffs as in Figure 1 and a set  $N$  of four self-regarding agents. Then  $F(g^N) = \emptyset$  and  $g^N \in F(g')$  for every  $g' \in \mathbb{G} \setminus g^N$ .*

The proof of this proposition, as well as all other proofs, can be found in Appendix A.

Using the definition of a FS network we derive the following corollary:

**Corollary 1.**  *$g^N$  is the unique farsightedly stable network.*

Hence, a group composed by farsighted agents will end up at  $g^N$ . This prediction is robust to errors in the sense that the farsighted prediction does not depend on the starting point: from any other network  $g \neq g^N$ , there is a farsighted improving path leading to  $g^N$ . Moreover, since  $F(g^N) = \emptyset$ , farsighted agents will stay at  $g^N$  once it is reached. Remember that the FS network is also PWS. Even myopic agents will stay at the FS network once it is reached. Therefore, one cannot find direct experimental evidence against PWS as opposed to FS. But our experiment discriminates between the different behavioral models that lie behind both stability concepts. In this way our experiment can provide evidence in favor or against the farsighted models of network formation in cases where they refine PWS.

The payoffs guarantee that the predicted networks are unique, both for the myopic and the farsighted behavior, and disjoint. Moreover, the predicted networks are not strongly efficient in the sense of Jackson and Wolinsky (1996)<sup>12</sup> nor Pareto dominant. Previous experimental studies have shown that efficiency considerations can drive individual's behavior (see Engelmann and Strobel, 2004). But efficiency arguments could not explain if  $g^N$  or  $g^0$  were observed in the experiment.

Up to now we have considered self-regarding agents. However, many experimental results show that subjects do not only care about their own payoffs, but also about the payoffs of the other agents (for an overview, see Sobel, 2005). Our predictions also hold for social preferences. As an example, take the inequity model of Fehr and Schmidt (1999) and assume that all agents are equally motivated by

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<sup>12</sup>A network  $g \in \mathbb{G}$  is *strongly efficient* if  $\sum_{i \in N} x_i(g) \geq \sum_{i \in N} x_i(g')$  for all  $g' \in \mathbb{G}$ .

inequity aversion. Let  $x = x_1, x_2, \dots, x_n$  be the vector of monetary payoffs. The utility function of player  $i$  is given by

$$u_i(x) = x_i - \alpha \frac{1}{n-1} \sum_{j \neq i} \max\{x_j - x_i, 0\} - \beta \frac{1}{n-1} \sum_{j \neq i} \max\{x_i - x_j, 0\}, \quad (1)$$

with  $\beta \leq \alpha$  and  $0 \leq \beta \leq 1$ .

**Proposition 2.** *For the network formation game with inequity averse agents, it holds that (i) myopic agents will remain in the empty network,  $g^0$ , and (ii) farsighted agents will build the complete network,  $g^N$ , for every  $\beta \leq \alpha$  and  $0 \leq \beta \leq 1$ .*

### 3.3 Experimental procedures

The experiment took place at the EELAB of the University of Milan-Bicocca on June 10th and 11th, 2010. The computerized program was developed using *Z-tree* (Fischbacher, 2007). We run 6 sessions with 24 subjects per session, for a total of 144 participants and 36 groups. Participants were undergraduate students from various disciplines,<sup>13</sup> recruited through an announcement on the EELAB website.

Subjects were randomly assigned to individual terminals and were not allowed to communicate during the experiment. Instructions were read aloud (see Appendix C for an English translation of the instructions). Participants were asked to fill in a control questionnaire; the experiment started only when all the subjects had correctly completed the task.

Sessions took on average 90 minutes, including instructions, control and final questionnaire phases. Average payment was 16.10 Euro (no show up fee was paid) with a minimum of 4.70 and a maximum of 22.70 Euro.

## 4 Results

We start by considering groups' final networks. Table 1 classifies groups with respect to their final network in each repetition (period). In the first period around 40% of the groups reached  $g^N$ . This percentage increased to 70% in the second and third period. Less than 20% of the groups were consistent with the myopic prediction in

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<sup>13</sup>Sociology, economics, business, psychology, statistics, computer science, law, biology, medicine, mathematics, pedagogy and engineering.

the last two periods.<sup>14</sup> So a huge majority of the groups formed the FS network. We also find evidence of learning: the portion of groups that displayed out-of-equilibrium behavior (category "None") decreased to around 10% of the sample in the last period. This result is rather striking since the categories "Myopic" and "Farsighted" consisted of one specific network each, while the residual category "None" covered 62 networks.

Period	1	2	3
Obs.	36	36	36
Myopic	0.28	0.14	0.19
Farsighted	0.42	0.70	0.70
None	0.30	0.16	0.11
Pearson's $\chi^2$	1	13.33**	10.12**
LR test	1.01	14.55**	11.46**

\*\* Significant at the 0.01 level.

Table 1: Final networks: relative frequencies matching predictions (whole sample)

We use the Pearson's chi-square and the Likelihood Ratio test to determine whether the relative frequencies of myopic and farsighted differ or not in the different periods. While in period 1 there is no significant difference between numbers of myopic and farsighted groups, in period 2 and 3 the differences are significant at the 0.01 level (see Table 1).

Table 2 replicates 1 without taking into account those groups that played for more than 25 stages in one period. This is done in order to exclude groups that played when the random stopping rule was in place, as it is difficult to assess the stability of the final network in those cases. Typically, the excluded groups either did not end up in a stable network when they were stopped by the random stopping rule (Category "None" in Table 1). Or they were stopped while being in the empty network ("Myopic" in Table 1). In the last kind of groups, there is somebody refusing to declare himself "satisfied", though the group has been in  $g^0$  for many stages without moving.

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<sup>14</sup>Except for one group in one single period, every other group moves from the empty network. As a consequence we gather indirect evidence about the behavior of groups that do not start from a PWS network.

The results are qualitatively similar when comparing Table 2 and Table 1. The two main findings - widespread and increasing consistency with predictions and huge support for the farsighted one - are indeed strengthened. As shown in Table 2, differences between the myopic and the farsighted relative frequency are now significant in all periods.

Period	1	2	3
Obs.	24	29	29
Myopic	0.21	0.07	0.17
Farsighted	0.62	0.86	0.83
None	0.17	0.07	0.00
Pearson's $\chi^2$	5*	19.59**	12.45**
LR test	5.23*	23.17**	13.53**

\* Significant at the 0.05 level; \*\* Significant at the 0.01 level.

Table 2: Final networks: relative frequencies matching predictions (observations above stage 25 dropped)

Tables 3 and 4 report the change in the outcome of individual groups from Period 1 to 2 and from Period 2 to 3, respectively. For example, take the row "Farsighted" of Table 3. It shows that among the groups who reached the FS network in period 1, only 7 % switched to the empty, myopic network in period 2, whereas 93 % of the groups also reached the FS network in period 2. But among those groups who ended up in the empty network in period 1, only 20% stayed at the empty network in period 2, whereas 50 % switched to the FS network, and 30% to an unstable network. Similarly, among the groups who ended up in some other network in period 1, 55% of them switched to the FS network in period 2, while only 18% of them switched to the empty network.

Tables 3 and 4 show that groups that reached  $g^N$  in a previous period are (almost) always able to replicate the result: the Farsighted-Farsighted cell shows a fraction above 90% in both tables. The other categories display greater mobility across time. Some of them reach the complete network, others fluctuate among the empty network and the None category. On aggregate our results are unambiguous.

**Result 1.** *Group behavior supports farsighted stability. Groups consistent with myopic behavior are less than 20% of the total. On aggregate, pairwise stability accounts*

		Period 2		
		Myopic	Farsighted	None
Period 1	Myopic	0.20	0.50	0.30
	Farsighted	0.07	0.93	0.00
	None	0.18	0.55	0.27
	Total	0.45	1.98	0.57

Table 3: Group flows: from Period 1 to Period 2

		Period 3		
		Myopic	Farsighted	None
Period 2	Myopic	0.60	0.00	0.40
	Farsighted	0.00	0.92	0.08
	None	0.67	0.34	0.00
	Total	1.27	1.26	0.48

Table 4: Group flows: from Period 2 to Period 3

for up to 90% of the observations.<sup>15</sup>

We now turn to individual behavior. While myopic behavior is well defined and provides a clear-cut prediction at every decision node, farsighted behavior depends on the agents beliefs about others which in turns depend on the past play. We will use as a proxy a decision rule of the kind discussed in Section 2. We have tested for many different alternative definitions and the results have proved to be highly stable among all of them. The results of these robustness checks are shown in Appendix B.

An agent is attributed to be farsighted if she uses the following decision rule: (i) start by adding all possible links; (ii) if at *stage 20* the current network has *less than four links*,<sup>16</sup> revert to *myopic behavior*. Phrases in italics represent the parameters manipulated in the robustness check (see Appendix B). This decision rule provides a clear-cut prescription at every decision node.

Thus we can compare actual decisions to the benchmark of myopic and farsighted behavior. Four cases arises from this comparison, distinguishing whether the actual

<sup>15</sup>Notice that both the empty network and the FS network are pairwise stable networks.

<sup>16</sup>When a four link network is reached, myopic and farsighted agents are all willing to add the remaining links. This explains the choice of this threshold.

choice is consistent (i) only with myopia, (ii) only with farsightedness, (iii) with none of them or (iv) with both of them (ambiguous). We classify all single choices according to those cases. The relative majority of the decisions is unambiguously farsighted, and 74% of the decisions are not contradicting farsightedness.

To see whether a subject is myopic or farsighted (or none of the two) we have to aggregate all the choices made by this individual. To do so, we use the following criterion: (i) individual choices are categorized as above, (ii) choices consistent with both myopia and farsightedness are disregarded, (iii) individuals are assigned to category  $x$  if the absolute majority of their remaining choices falls in category  $x$ , (iv) if an absolute majority is not present, the individual is *Not classified*. Step (ii) is necessary if one wants to consider only the choices that can be clearly identified: the Ambiguous class is not a proper category as it collects choices that cannot be classified.<sup>17</sup>

Obs: 144	1	2	3	Overall
Myopic	0.13	0.04	0.10	0.08
Farsighted	0.58	0.76	0.79	0.74
None	0.08	0.06	0.03	0.01
Not Classified	0.21	0.13	0.08	0.17

Table 5: Individuals: relative frequencies of subjects consistent with each category, per period and on aggregate

We implement this procedure for each single period and on the whole vector of individual choices. The corresponding results are shown in Table 5. We are able to classify from around 71% of the participants in the first period to around 89% in the third. Aggregate results show that only 1% of the subjects behave systematically against both myopia and farsighted prescriptions. Only 8% of the individuals behave myopically, whereas three quarters of them are consistent with farsightedness. The difference is huge and it holds across all the three periods. We find evidence of individual learning: the fraction of farsighted agents increases steadily, while the fraction of myopic agents decreases from the first to the second period and increases in the last.

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<sup>17</sup>An alternative way would be to retain those choices and classify individuals according to relative majority. The results of this procedure are qualitatively identical to the ones reported.

	Group final outcome		
N of subjects of type:	Myopic	Farsighted	Other
Myopic	1.32	0.06	0.29
Farsighted	1.36	3.51	2.33
None	0.41	0.09	0.52
Not classified	0.91	0.34	0.86

Table 6: Average group compositions

Table 6 shows how the composition of groups influences the observed outcome. Take as an example the column “Myopic”. On average groups reaching the Myopic network consist of 1.32 myopic individuals, 1.36 farsighted ones, 0.41 individuals whose behavior is not consistent with either myopic or farsighted behavior, and 0.91 subjects that cannot be classified. Groups that reached the FS network consist on average of 3.51 farsighted individuals, and of a negligible number (0.06) of myopic ones. These patterns of group composition indicate that: *(i)* more than three players are needed to reach the complete network for sure; *(ii)* slightly more than one myopic agent is sufficient to make the group consistent with the myopic prediction; *(iii)* more mixed groups have a higher chance of being stuck somewhere in between.

The presence of a small number of myopic agents was able to drive the results of a significant fraction of groups. Moreover, the presence of farsighted agents in myopic groups accounts for the fact that only one group remained in the empty network from the beginning. Summing up:

**Result 2.** *Individual behavior strongly rejects myopia for a vast majority of the subjects; 3 out of 4 participants are found consistent with farsightedness. One myopic participant can be sufficient to enforce a myopic outcome for the entire group.*

## 5 Conclusion

This paper reports an experimental test of the behavioral assumptions underlying the most used stability notions for network formation. In particular we test whether subjects behave myopically or farsightedly when forming a network. As far as we know this is the first experimental investigation into this issue.

Our results strongly reject the hypothesis of myopic behavior both at the group

and at the individual level. Behaviors consistent with farsightedness account for 75% of the individual observations. Consequently, about 60% of the groups reach the farsighted stable network in the first repetition. This share increases to 70% as the game is repeated, and of those groups that stopped before stage 25 even 83% reached the farsighted stable network in the last period.

A conservative account of our results suggests that farsighted stability is a valuable refinement concept when among the pairwise stable networks there are farsightedly stable ones. However, the behavioral model underlying pairwise stability is strongly rejected. This opens the way to new interesting research questions, in particular related to those cases where farsighted stability provides predictions that are not pairwise stable.

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# Appendix

## A Proofs

**Proof of Proposition 1.** To avoid reporting the farsighted improving path for each single network, let  $g^i$  be a generic network in class  $C_i$  and  $c_i \subset C_i$  a generic proper subset of the corresponding class. We will write  $g^i \rightarrow g$ ;  $g \in C_j$  and  $g^i \rightarrow g$ ;  $g \in c_j$ , when the generic network  $g^i$  in class  $C_i$  reaches with a farsighted improving path all the networks in class  $C_j$  or only a proper subset  $c_j$  of  $C_j$ , respectively. The list of farsighted improving paths among the networks in  $\mathbb{G}$  is the following:

$$F(g^0) = \{g \mid g \in C_{10} \cup C_{11}\}$$

$$F(g^2) = \{g \mid g \in C_1 \cup C_{10} \cup C_{11}\}$$

$$F(g^3) = \{g \mid g \in C_1 \cup c_2 \cup c_5 \cup C_{10} \cup C_{11}\}$$

$$F(g^4) = \{g \mid g \in C_1 \cup c_2 \cup c_5 \cup C_{10} \cup C_{11}\}$$

$$F(g^5) = \{g \mid g \in C_1 \cup c_2 \cup C_{10} \cup C_{11}\}$$

$$F(g^6) = \{g \mid g \in C_1 \cup c_2 \cup c_4 \cup c_5 \cup C_{10} \cup C_{11}\}$$

$$F(g^7) = \{g \mid g \in C_1 \cup c_2 \cup c_3 \cup c_4 \cup C_5 \cup C_{10} \cup C_{11}\}$$

$$F(g^8) = \{g \mid g \in C_1 \cup c_2 \cup c_4 \cup C_5 \cup c_7 \cup C_{10} \cup C_{11}\}$$

$$F(g^9) = \{g \mid g \in C_1 \cup c_2 \cup c_4 \cup c_5 \cup c_6 \cup c_7 \cup C_{10} \cup C_{11}\}$$

$$F(g^{10}) = \{g \mid g \in c_2 \cup c_4 \cup c_5 \cup c_6 \cup C_{11}\}$$

$$F(g^N) = \emptyset.$$

It follows that  $g^N \in F(g)$ , for all  $g$  in  $\mathbb{G} \setminus g^N$  and  $F(g^N) = \emptyset$ , which corresponds to our definition of FS network. We know that this network is the unique FS network. ■

### Proof of Proposition 2.

- (i) Result (i) derives from the notion of pairwise stability.

We know that  $g^0$  is pairwise stable if  $\alpha = 0$  and  $\beta = 0$ . To simplify notation, let  $x_{ik}$  be the monetary payoff of player  $i$  in network  $g^k$  and  $u_{ik}$  the corresponding utility.

It is immediate to note that  $u_{ik} \leq x_{ik}$  for any  $g^k$ . Now,  $u_{ik} = x_{ik}, \forall i$ , for every  $\beta \leq \alpha$  and  $0 \leq \beta \leq 1$  if  $g^k = g^0$ . Thus, it follows from the definition that  $g^0$  is pairwise stable for every  $\beta \leq \alpha$  and  $0 \leq \beta \leq 1$ . Since the experiment starts at  $g^0$ , myopic agents will not move.

- (ii) For result (ii), recall the definition of farsighted improving paths and of far-

sightedly stable network.

We know that  $g^N$  is the unique farsightedly stable network if  $\alpha = 0$  and  $\beta = 0$  (i.e., when  $u_{ik} = x_{ik}, \forall i, \forall g^k$ ). Now, for every  $\beta \leq \alpha$  and  $0 \leq \beta \leq 1$ , we have that  $u_{ik} \leq x_{ik}, \forall i, \forall g^k$ , and  $u_{ik} = x_{ik}, \forall i$ , if  $g^k = g^N$ .

Thus, if  $g \rightarrow g^N$  for some  $\alpha$  and  $\beta$ , then  $g \rightarrow g^N$  for every  $\alpha' \geq \alpha$  and  $\beta' \geq \beta$ . Hence, since  $g^N \in F(g)$  for any  $g \in \mathbb{G} \setminus g^N$  for  $\alpha = \beta = 0$ , we also have that  $g^N \in F(g)$  for any  $g \in \mathbb{G} \setminus g^N$  for every  $\beta \leq \alpha$  and  $0 \leq \beta \leq 1$ .

There is no immediate way to show analytically that  $F(g^N) = \emptyset$  for every  $\beta \leq \alpha$  and  $0 \leq \beta \leq 1$ , whenever  $F(g^N) = \emptyset$  for  $\alpha = \beta = 0$ . However we can prove it numerically for our payoffs, simulating the resulting utilities and corresponding farsighted improving paths for the set of admissible parameters. ■

## B Other definitions of farsighted behavior

We present here the robustness check for different proxies of farsighted behavior. The general decision rule prescribes to form all possible links at the beginning and to revert to a different behavior if, at a certain stage, some specific class of networks is not reached.

Name	When	Why	What
Basis	20	Less than four links	Myopic behavior
Why	20	<b>No connected star network or less than four links</b>	Myopic behavior
When 1	<b>15</b>	Less than four links	Myopic behavior
When 2	<b>p1:20, p2,p3:15</b>	Less than four links	Myopic behavior
What	20	Less than four links	<b>Break all links</b>

Table 7: Summary of the parameters used to identify farsighted behavior (in bold the differences with respect to the first row)

As discussed in Section 3, there are three parameters in the farsighted decision rule that can be manipulated: (i) *when* the turning point may occur (up to which stage one tries to build links); (ii) *why* it may occur: which is the reference class of networks; (iii) *what* behavior to take: try to get back to the ‘safe’ empty network or behave myopically.

Table 7 reports on the different parametrizations used. Table 8 report the corresponding results. The results are not sensible to the specific decision rule. Any rule consistent with the general prescription leads to the same conclusions.

Obs: 144	Basis	Why	When 1	When 2	What
Myopic	0.08	0.13	0.09	0.09	0.06
Farsighted	0.74	0.70	0.76	0.76	0.78
None	0.01	0.00	0.00	0.00	0.01
Ambiguous	0.17	0.17	0.15	0.15	0.15

Table 8: Individuals: relative frequencies of subjects consistent with each category

## C Instructions

Welcome to this experiment in decision-making. In this experiment you can earn money. The amount of money you earn depends on the decisions you and other participants make. Please read these instructions carefully. In the experiment you will earn points. At the end of the experiment we will convert the points you have earned into euros according to the rate: 6 points equal 1 Euro. You will be paid your earnings privately and confidentially after the experiment. **Throughout the experiment you are not allowed to communicate with other participants in any way. If you have a question please raise your hand. One of us will come to your desk to answer it.**

### Groups

- At the beginning of the experiment the computer will randomly assign you - and all other participants - to a group of 4 participants. Group compositions do not change during the experiment. Hence, you will be in the same group with the same people throughout the experiment.
- The composition of your group is anonymous. You will not get to know the identities of the other people in your group, neither during the experiment nor after the experiment. The other people in your group will also not get to know your identity.

- Each participant in the group will be assigned a letter, A, B, C, or D, that will identify him. On your computer screen, you will be marked 'YOU' as well as with your identifying letter (A, B, C or D). You will be marked with your identifying letter (A, B, C or D) on the computer screens of the other people in your group.
- Those identifying letters will be kept fixed within the same round, but will be randomly reassigned at the beginning of every new round.

### **Length and articulation of the experiment**

- The experiment consists of 3 rounds, each divided into stages.
- The number of stages in each round will depend on the decisions you and the other people in your group make.
- After a round ends, the following will start, with the same rules as the previous: actions taken in one round do not affect the subsequent rounds.

### **General rules: rounds, stages, formation and break of links**

- In each round the task is to form and break links with other members of the group.
- You will have the possibility to link with any other participant in your group. That is, you can end up with any number of links (0, 1, 2 or 3).
- Thus, the number of links that can be formed in your group will be a number between 0 and 6 (0, 1, 2, 3, 4, 5, 6). The set of links that exist in your group at the same time is called a network.
- Your group starts the first stage of every round with zero links.
- In every stage a network of links is formed, based on your and the other group participants decisions. This network is called the current network.
- Your group will enter a new stage with the links that exist in the network that is formed in the previous stage, according to the following linking rules

## Stage rules

- In each stage the **computer** will select for each group a single link among the six possible at random. A link cannot be selected twice in two consecutive stages.
- The participants involved in that link will be asked to take a decision in that stage, the others will be informed about the selected link and will be asked to wait for others' decisions.
- If this link does not exist at the beginning of the stage, the decision will be whether to form that link or not. If this link exists at the beginning of the stage, the decision will be whether to keep or to break that link.
- Thus, in each stage at most **one** link can be formed or broken.

## Stopping rules

- After every stage you and the other people in your group will be asked if the current network is satisfactory to you. You can answer YES or NO.
- If ALL the people in your group answer YES the round ends and the points associated to the current network are considered to compute your earnings.
- If at least one person in your group answers NO, the group moves to the next stage.
- After stage 25 a random stopping rule is added. In this case, even if you or any of the other people in your group are not satisfied with the current network, the round will end with probability 0.2.

## Earnings

- To every participant in every network is associated a number of points.
- You will receive points according to the network that exists in your group at the end of each round.
- Your total earnings will be the sum of the earnings in each of the 3 rounds.

- Thus, the points associated to the networks you and the other people in your group form at every stage, except for the last of each round, are not considered for the computation of your earnings.
- You are always informed about the points associated to the current network on screen. On the top of your screen, you are always informed of the points you earned in the previous rounds.
- You can learn about the points associated to every other network through the points sheet you find attached to the instructions. It displays the points associated to every class of networks:
  - In every network, the black dots are the participants in the group; the lines are the existing links.
  - Every class of network is characterized by the number of links each participant has.
  - The numbers close to every black dots indicate the number of points a person with that number of links is earning in that specific class of networks.
- An example will clarify the relation between network and points and the developing of the experiment. You will also practice through a training stage.

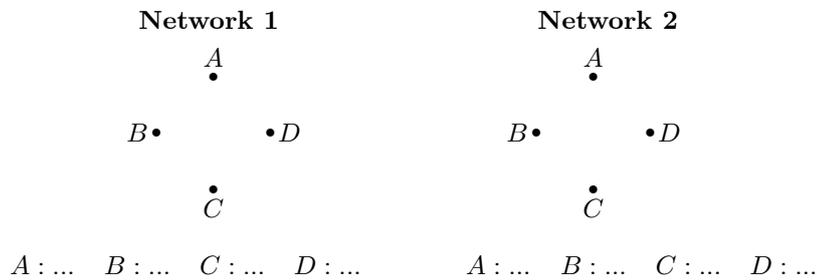
## **Concluding remarks**

You have reached the end of the instructions. It is important that you understand them. If anything is unclear to you or if you have questions, please raise your hand. To ensure that you understood the instructions we ask you to answer a few control questions. After everyone has answered these control questions correctly the experiment will start.

## Control questionnaire

This questionnaire is intended to verify that everybody have understood the instructions. You will not be evaluated according to the answers you give. Once you complete the questionnaire, please, raise your hand and one of the experimenters will come to you to check your answers. In the following we will write  $ab$  to denote the link between participants A and B (and so on).

1. Network 1 includes the links  $ac$  and  $bc$ . Network 2 includes the links  $ac$ ,  $ad$ ,  $bd$ , and  $cd$ . Please draw both networks and fill in with the corresponding points for each participant.



2. The current network consists of the link  $bd$ . The link  $ac$  is selected. A chooses FORM, C chooses NOT FORM.

Is the link formed?

Can you please write down the points for each participant in the resulting network?

A:... B:... C:... D:...

3. The current network consists of the links  $ac$ ,  $bd$  and  $cd$ . The link  $ac$  is selected. A chooses KEEP, C chooses KEEP. Can you please write down the points for each player in the resulting network?

A:... B:... C:... D:...

4. A, B, C, and D all declare that they are satisfied with the current network, after stage 5. This consists of links  $ab$  and  $bd$ . How many stages will the round last?

How much Euro will each participant earn in that round?

A:... B:... C:... D:...

5. If, at the same point as in question 4, A declared she wasn't satisfied, how many stages would at least the round last?