Limited Farsightedness in Network Formation

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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 perfectly farsighted, related stability concepts have been proposed. We design a simple network formation experiment to test these extreme theories, but find evidence against both of them: the subjects are consistent with an intermediate rule of behavior, which we interpret as a form of limited farsightedness. On aggregate, the selection among multiple pairwise stable networks (and the performance of farsighted stability) crucially depends on the level of farsightedness needed to sustain them, and not on efficiency or cooperative considerations. Individual behavior analysis corroborates this interpretation, and suggests, in general, a low level of farsightedness (around two steps) on the part of the agents.

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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. Any such requirement must answer the question of how individuals assess those benefits.

An extreme answer to this problem is to assume perfect myopia on the part of the agents, as in 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. Individuals are myopic, and 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, and so on. 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.

The von Neumann - Morgenstern pairwise farsightedly stable set (VNMFS) of networks predicts which networks one might expect to emerge in the long run when individuals are farsighted. As the other approaches to farsighted stability,[1] it incorporates the assumption that agents are perfectly farsighted, meaning they can consider sequences of reactions to their moves of any length. As this constitutes the exact opposite of perfect myopia, there appears to be an unbridged gap between those extreme theories.

The closest attempt in this direction is the work of Dutta et al. [2005], which allows for different degrees of farsightedness. In their equilibrium concept, for a dynamic Markovian process of network formation,[2] farsightedness is captured by a discount factor, that applies to the stream of future payoffs. But as such it entangles patience and farsightedness. Moreover, their dynamic equilibrium model

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[1]See the work of Chwe [1994], Xue [1998], Herings et al. [2004, 2009], Mauleon and Vannetelbosch [2004], Page et al. [2005], and Page and Wooders [2009].

[2]See Konishi and Ray [2003] for a similar approach to the formation of coalitions.

is hardly comparable to the static stability notions,[3] in particular for intermediate values of farsightedness.[4]

In our paper we test the myopic and the (possibly limited) farsighted types of behaviors in the context of network formation and compare the stability notions that are based on them. 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 did not want to modify the existing network. In all of the three treatments, the payoffs were designed such that a group consisting of myopic agents would never form any link. The treatments are characterized by slight manipulations of the payoffs, resulting in networks in VNMFS sets featuring different properties.

In treatment 1, a group composed of farsighted agents would form the complete network. This network provides the players with equal payoffs, is strongly stable, in the sense that no coalition can improve upon it, and features no farsighted deviations. Thus, beyond being VNMFS set, the complete network can be seen as attractive in many ways.[5] In the other two treatments we vary those features to ascertain their contribution to the stability of an outcome.

A group composed of farsighted agents would form a triangle "club" network[6] or a line network among all the players, in treatments 2 and 3, respectively. In both, the payoffs are unequal, with the disadvantaged players earning around half the payoffs of the others. We remove strong stability in treatment 2, as a

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[3]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.

[4]A discount factor of zero, properly corresponds to myopia. At the same time, we argue that a discount factor of one leads the process close to one in which people only care about the end state, as in the notions of farsighted stability. For intermediate values, the stream of future payoffs matters in a way that cannot be captured by static stability notions.

[5]The complete network can be a focal point in itself - only for being the complete network.

[6]A network formed by a single clique (complete sub-network) of three players.

coalition of three players can improve upon the networks in the VNMFS. In treatment 3 the networks in the VNMFS are strongly stable, but feature a farsighted deviation in two steps. We derive across-treatment hypothesis based on those properties.

In all the treatments farsighted stability refines the set of pairwise stable networks (PWS) by selecting the (unique) Pareto dominant network within the set of PWS.[7] Note, however, that the underlying behavioral assumptions of both notions - myopia versus farsightedness - are at odds with each other, providing us with general within-treatment hypothesis.

On aggregate, 75 percent of the network finally reached are pairwise stable. In treatments 1 and 2 most of the groups (up to 70 percent of the overall population) reach a VNMFS set, supporting farsighted network formation. In treatment 3, only one out of five groups reach a VNMFS set, with half of the groups ending the game in the empty network. In this treatment, VNMFS sets are accessed almost as often as in the other treatments, but, after some time, most groups leave them.

Given the properties of the VNMFS sets, this asymmetric result is inconsistent with strong stability - present in treatment 1 and 3, absent in treatment 2 - and can not be attributed to the inequality in the payoffs - equal in treatment 1, unequal in treatment 2 and 3. Nor it can be explained by other refinements of pairwise stabilility, such as Nash stability, or Pareto dominance - both present in all treatments. It is, however, perfectly consistent with the hypothesis derived from limited farsightedness.

We then show that individual behavior supports the interpretation of the aggregate results as an instance of limited farsightedness. Subjects respond to myopic incentives as well as to farsighted improving paths of short length. As a consequence if a farsightedly stable outcome features a farsighted deviation of limited length, the subjects are likely to follow it: they do not recognize the full chain of reactions that would prevent a fully farsighted agent to deviate.

Consequently, neither perfect myopia nor perfect farsightedness seem to be good models of actual behavior. A model of limited farsightedness would be a valuable development in network formation.

The number of experiments addressing networks and network formation is

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[7]The farsightedly stable networks, however, are not Pareto dominant within the set of all networks. Actually no network Pareto dominates all other networks in our treatments.

rapidly increasing. 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 et al. [2009] and Falk and Kosfeld [2012]. They investigate the predictive power of a strict Nash network in the framework of Bala and Goyal [2003]. 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 Ziegelmeyer and Pantz [2005], 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 stable and thus there is no tension between myopia and farsightedness.[8]

Finally, Berninghaus et al. [2012] address limited forward-looking behavior with an experiment on network formation. 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 forward-looking 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.

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[8]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.

2 Networks: notation and definitions

Let $N = \{1, \ldots, n\}$ 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 $g - ij$. We say that g' is adjacent to g if $g' = g + ij$ or $g' = g - ij$ for some ij. Let us denote with A_g the networks that are adjacent to g so that $A_g = \{g' \mid g' = g + ij \vee g' = g - ij, \text{ for some } ij\}$, and let $\bar{A}_g$ be its complement.

The material payoffs associated to a network are represented by a function $x : \mathbb{G} \to \mathbb{R}^n$ 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 $u_i(g) : \mathbb{R}^n \to \mathbb{R}$ that associates a value to the vector of material payoffs associated to network g. This might include all sorts of costs, benefits, and externalities.

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 $k \in \{0, 1, \ldots, n-1\}$. 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, i.e., $P(k) = (\#S_k(g))/n$. Given a degree distribution, $\overline{P}$, we define a *class of networks* as $C_{\overline{P}} = \{g \in \mathbb{G} \mid P(k) = \overline{P}(k), \forall k\}$. 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 $u_j(g) > u_j(g + ij)$.

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 an adjacent network. Agents are assumed to consider only their own incentives when making their linking choices and not that of other agents. 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.

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 1. *A farsighted improving path from a network g to a network $g' \neq g$ is a finite sequence of graphs $g_1, \ldots, g_K$ with $g_1 = g$ and $g_K = g'$ such that for any $k \in \{1, \ldots, K - 1\}$ 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 $g \to g'$. For a given network g, let $F(g) = \{g' \in \mathbb{G} \mid g \to g'\}$. This is the set of networks that can be reached by a farsighted improving path from g. The von Neumann-Morgenstern pairwise farsightedly stable set is obtained by introducing the notion of farsighted improving path into the standard definition of a von Neumann-Morgenstern stable set. In other words, we define a set of networks G to be von Neumann-Morgenstern pairwise farsightedly stable (VNMFS) if there is no farsighted improving path connecting any two networks in G and if there exists a farsighted improving path from any network outside G leading to some network in G. Formally,

Definition 2. *The set of networks G is a von Neumann-Morgenstern pairwise farsightedly stable set if*

(i) $\forall g \in G, F(g) \cap G = \varnothing$ *(internal stability) and*

(ii) $\forall g' \in \mathbb{G} \backslash G, F(g') \cap G \neq \varnothing$ *(external stability).*

Although the existence of a VNMFS set is not guaranteed in general, when a VNMFS set exists it provides narrower predictions than other definitions of farsighted stability, a feature that is particularly welcome in experimental testing. For instance, a VNMFS set is always included within the pairwise farsightedly stable sets, as defined by Herings et al. [2009].[9]

We now turn to individual behavior. We provide a comprehensive evaluation of the players' actions by assessing their consistency with progressive levels of farsightedness. The definition states that an action prescribing to form (break) a link that is not formed (has been formed) is consistent with farsightedness of level k, if building (breaking) the link lies on a farsighted improving path of length smaller or equal than k. An action prescribing not to form (keep) a link that is not formed (has been formed) is consistent with farsightedness of level k if forming (breaking) the link does not lie on a farsighted improving path of length smaller or equal than k. Let the length of a path be the number of steps in the sequence.

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[9]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).

Call $\mathcal{P}_g^k$ a generic farsighted improving path of length k, starting from network g, and $\{\mathcal{P}_g^k\}$ be the set containing all such paths.[10] At time t the link ij is selected, the action of agent i is $a_{it} \in \{0,1\}$, where 0 means not to form (to break) the selected link ij, and 1 means to form (to keep) the link ij.

Definition 3. *An action a_{it} is consistent with farsightedness of level k if either*

$$(i)\ ij \notin g_t \text{ and } ((\exists l \leq k \text{ and a } \mathcal{P}_{g_t}^l \in \{\mathcal{P}_{g_t}^l\} \text{ s.t } g_t + ij \in \mathcal{P}_{g_t}^l) \text{ and } a_{it} = 1) \vee$$
$$((\nexists l \leq k \text{ and a } \mathcal{P}_{g_t}^l \in \{\mathcal{P}_{g_t}^l\} \text{ s.t } g_t + ij \in \mathcal{P}_{g_t}^l) \text{ and } a_{it} = 0)$$

or

$$(ii)\ ij \in g_t \text{ and } ((\exists l \leq k \text{ and a } \mathcal{P}_{g_t}^l \in \{\mathcal{P}_{g_t}^l\} \text{ s.t } g_t - ij \in \mathcal{P}_{g_t}^l) \text{ and } a_{it} = 0) \vee$$
$$((\nexists l \leq k \text{ and a } \mathcal{P}_{g_t}^l \in \{\mathcal{P}_{g_t}^l\} \text{ s.t } g_t - ij \in \mathcal{P}_{g_t}^l) \text{ and } a_{it} = 1)$$

As they are equivalent, we call myopic an action that is consistent with farsightedness of level one - i.e. one that looks at the profitability of adjacent networks. Two aspects in this definition should be noted. First, an action that aims at changing the current network and is consistent with some level of farsightedness, including myopia, is also consistent with higher levels. Second, for an action that does not change the current network, we implicitly impose a strong assumption on farsighted behavior: that a farsighted agent should always take a profitable deviation, if available.

Indeed, given that the building blocks of farsightedness are sequences of networks, farsighted behavior is unambiguously defined only if a choice aims at changing the current network. When it does not, we are forced either to draw some further assumptions or give up categorizing those choices. In the statistical analysis of individual behavior we pursue both of the alternatives.

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[10]Note that a path of length k will have a sequence of $k+1$ networks.

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: $T = 0, 1, ..., t, ...$; 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. Once the individuals involved in the link have taken their decisions, 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 want to modify the current network or not. If they unanimously declare they do not want to, the game ends; otherwise, they move to the next stage.[11] 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). These identity letters 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

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[11]Subjects are informed about the outcome of the *satisfaction* choices - i.e. end of the repetition or not - but not about individual choices.

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.
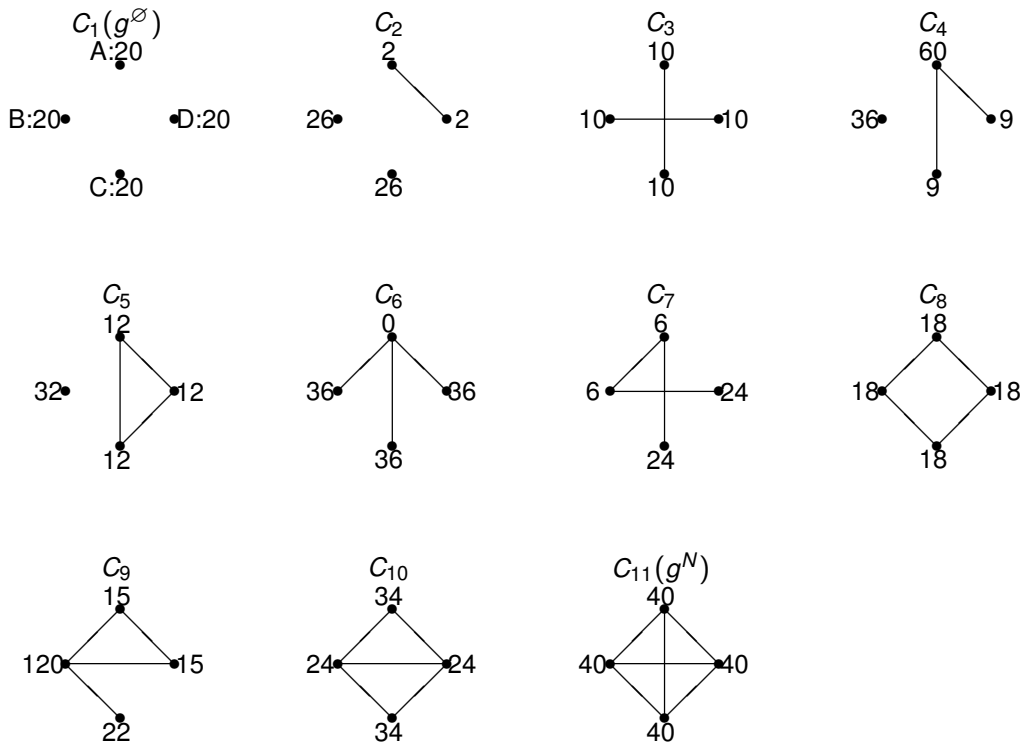

Figure 1: Payoffs for T1

3.2 Treatments and hypothesis

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

We run three treatments (T1, T2, T3) where we manipulate the payoffs in some networks to obtain VNMFS set(s) with different properties. Figures 1, 2 and 3 display the payoffs that were used in the three treatments for each class of networks,
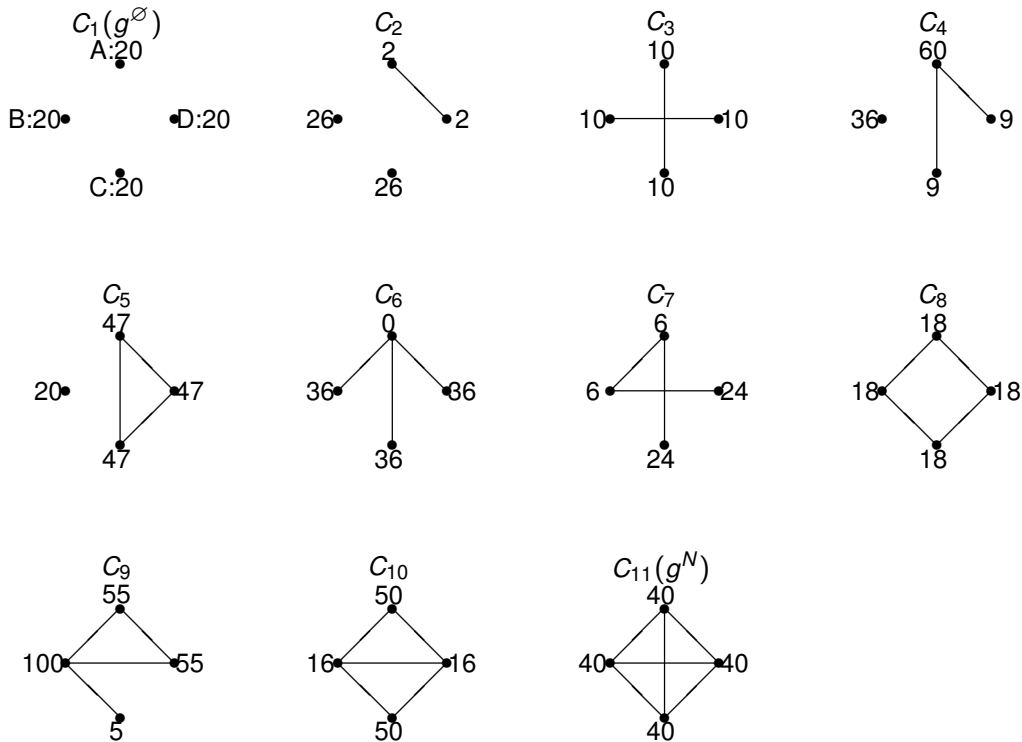
Figure 2: Payoffs for T2

$C_{\bar{p}}$. Since the function of material payoffs satisfies anonymity,[12] this representation is sufficient to assign a payoff to each player in each possible network configuration. The numbers were chosen in order to provide the resulting predictions with a set of nice properties for each treatment that are described below and are summarized in Table 1.[13]

The empty network, $g^{\varnothing}$, and the four networks in class C_5 are PWS in all treatments. These are the only PWS networks in T2, whereas g^N is also PWS under T1, and the networks in C_7 are also PWS in T3. Furthermore, in T1 and T3, in every network in C_5, the connected agents can improve their situation by cutting both of their links. These networks (contrary to the others PWS) are not

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[12] Anonimity holds if payoffs in a network are assigned to each player independently of his or his partners' identity.

[13] In general, the following considerations are valid for self-regarding agents. In some cases they hold for other-regarding preferences (for an overview, see Sobel [2005]). Most notably, in T1, applying the inequity model of Fehr and Schmidt [1999] does not affect our predictions.

$C_1(g^\varnothing)$
A:20

B:20   D:20

C:20

C_2
2

26   2

26

C_3
10

10   10

10

C_4
60

36   9

9

C_5
12

32   12

12

C_6
0

36   36

36

C_7
26

26   48

48

C_8
18

18   18

18

C_9
15

120   15

22

C_{10}
50

16   16

50

$C_{11}(g^N)$
40

40   40

40
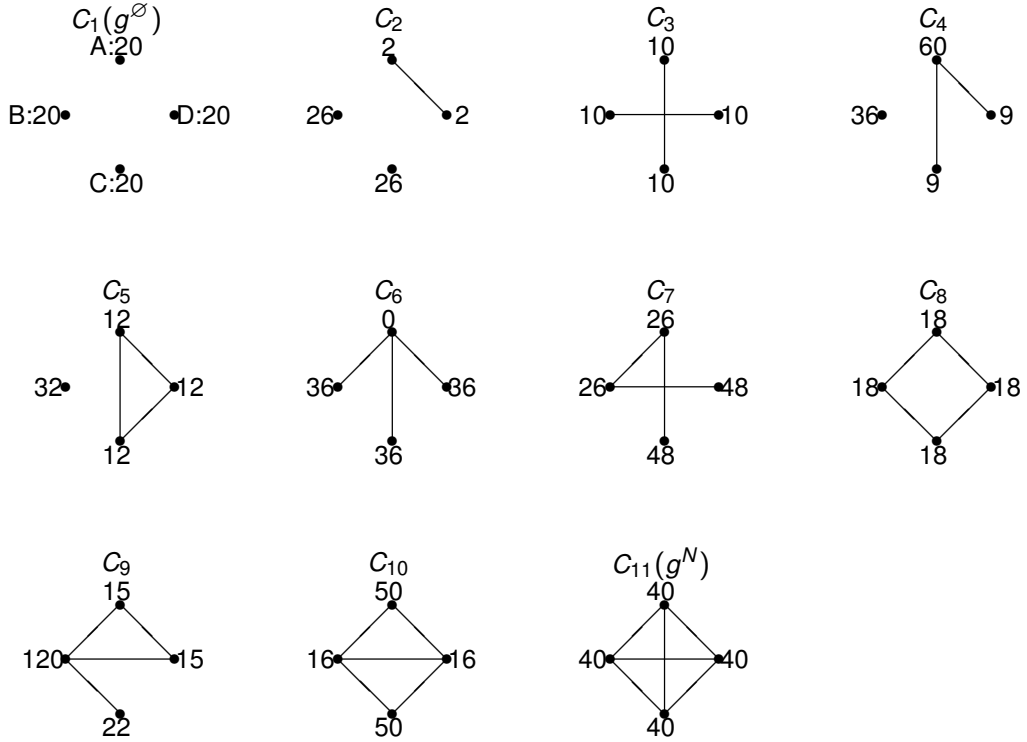
Figure 3: Payoffs for T3

Nash stable in the terminology of Bloch and Jackson [2006].[14]

In all treatments, all groups start at $g^\varnothing$. Groups composed of myopic players are expected not to move from $g^\varnothing$. This prediction is robust to errors. A sequence of at least three (T1) or two (T2, T3) links added consecutively by error 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 players is to end up in $g^\varnothing$.

To identify the VNMFS sets, we need to compute $F(g)$ for every g. We can prove the following results.

Proposition 1. *Consider a set of four self-regarding agents ($u_i(g) = x_i(g)$). Then,*

i *in T1 the set $G = \{g^N\}$ is the unique VNMFS set.*

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[14]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.

ii *in T2 the set $G = \{g|g \in C_5\}$ is the unique VNMFS set.*

iii *in T3 a set G is a VNMFS set if and only if $G = \{g \mid g \in C_7$ and $,d_i(g) = d_i(g'), \forall i \in N, g' \in G\}$.*

The proof of this proposition can be found in Appendix A.

In T1 and T2 there is a unique VNMFS set: the complete network (i) and the set composed of the four networks in C_5 (ii), respectively. We will refer to the latter as club networks. In T3 there are six VNMFS sets. Their union is C_7, i.e. it encompasses all line networks. Each set consists of a pair of line networks with identical degree distribution (iii).[15]

We expect a group composed by farsighted agents to end up in a network included in some VNMFS set. This prediction is robust to errors in the sense that the farsighted prediction does not depend on the starting point: from any other network, there is a farsighted improving path leading to a network in G.

	PWS	VNMFS	Myopic Prediction	Farsighted Prediction	Unequal Payoffs	Strongly Stable	Farsighted Deviations
T1	$g^\varnothing, C_5^*, g^N$	$\{g^N\}$	$g^\varnothing$	g^N	No	g^N	–
T2	$g^\varnothing, C_5$	$\{g|g \in C_5\}$	$g^\varnothing$	C_5	Yes	–	Three steps**
T3	$g^\varnothing, C_5^*, C_7$	$\{g,g'|g,g' \in C_7$ and $d_i(g)=d_i(g'), \forall i \in N\}$	$g^\varnothing$	C_7	Yes	$g \in C_7$	Two steps

* not Nash stable.

** Weak deviation, based on indifference breaking rule.

Table 1: Summary of treatment properties and predictions

Let $frac_{MYO}(T_i)$ and $frac_{FAR}(T_i)$ be the fraction of groups ending in the myopic and in the farsighted prediction, respectively, in treatment i. We state the following, mutually exclusive, hypothesis, regarding perfect myopia and farsightedness.

Hypothesis 1. *(Myopia) In all treatments, a relative majority of the groups end the game in $g^\varnothing$. This implies, in particular, that, for $i = 1, 2, 3$:*

$$frac_{MYO}(T_i) > frac_{FAR}(T_i).$$

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[15]The pair of line networks in a VNMFS, are equal up to a single permutation of players with the same degree. For example, there are two networks in C_7 where A and B have 2 links each, call them g and g'. A and B are linked to one another in both networks, but A will be linked to C, and B to D, in g; vice versa in g'. The set $\{g, g'\}$ is a VNMFS.

Hypothesis 2. *(Farsightedness) In all treatments, a relative majority of the groups end the game in a VNMFS set. This implies, in particular, that, for $i = 1, 2, 3$:*

$$frac_{MYO}(T_i) < frac_{FAR}(T_i).$$

In our experiment, if a network is in a VNMFS set, it is also PWS. Even myopic agents will stay at the farsighted stable network once it is reached. Therefore, one cannot find direct experimental evidence against PWS as opposed to farsighted stability. 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 essentially unique, in the sense that all the networks included in a VNMFS set are isomorphic. Moreover, the predicted networks are neither strongly efficient in the sense of Jackson and Wolinsky [1996][16] nor Pareto dominant within the set of all networks. Previous experimental studies have shown that efficiency considerations can drive individual's behavior (see Engelmann and Strobel [2004]). But generic efficiency arguments could not explain if a network in some VNMFS set or $g^{\varnothing}$ were observed in the experiment. The networks included in VNMFS sets are (weakly) Pareto dominant within the set of pairwise Nash stable networks.[17]

On top of these general hypothesis, the different VNMFS sets differ on three important properties, providing some testable across-treatment hypothesis (see Table 1).

First, the payoffs are equal in the VNMFS set in T1 (g^N) and unequal in T2 (C_5) and T3 (C_7). In the latter, the players gaining more obtain around twice as much as the least well off. Under both conditions, the disadvantaged players can lead the group to leave the VNMFS set, if they so wish, by severing a link in T3, by adding a link in T2.[18] If other-regarding preferences are sufficiently strong, the VNMFS sets could be less stable in T2 and in T3, with respect to T1.

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[16]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 $g' \in \mathbb{G}$.

[17]Recently, Carrillo and Gaduh [2012] suggested that the players are able to select the PWS networks that are Pareto dominant. Our results show that Pareto dominance is not a sufficient criterion to select among PWS networks.

[18]Despite needing the agreement of his partner to add a link, adding a link in C_5 is highly beneficial to the already connected agents, so that they are likely to agree on that.

Hypothesis 3. *The fraction of groups ending the game in a VNMFS set is higher if the networks that are there included feature equal payoffs for the players. Thus:*

i $frac_{FAR}(T_1) > frac_{FAR}(T_2)$, *and*

ii $frac_{FAR}(T_1) > frac_{FAR}(T_3)$.

Second, we also consider stability against changes in links by any coalition of individuals - i.e. look for strongly stable networks (immune to coalitional deviations). In T1 and T3 the networks included in VNMFS sets are also strongly stable. This is not true in T2, where strongly stable networks fail to exist.[19] In this view the VNMFS set seems more robust in T1 and in T3 than in T2.

Hypothesis 4. *The fraction of groups ending the game in a VNMFS set is higher if the networks that are there included are strongly stable. Thus:*

i $frac_{FAR}(T_1) > frac_{FAR}(T_2)$, *and*

ii $frac_{FAR}(T_3) > frac_{FAR}(T_2)$.

Finally, the networks belonging to the VNMFS sets differ with respect to the presence and length of farsighted deviations leaving the set. Table 2 provides an overview and an example for each treatment. In T1, there are no farsighted improving paths leaving the complete network ($F(g^N) = \varnothing$).

In T2, $F(g \in C_5) = \{g' \mid g' \in C_9 \wedge g' \notin A_g\}$. This means that there are farsighted improving paths leaving the VNMFS set and leading to networks in C_9 that are not adjacent to the initial network g. The path is built as follows: from C_5 players move to C_9, then to C_{10} and finally back to another network in C_9. This path relies on the indifference-breaking convention stating that, in C_9, a player with two links is willing to build another one in order to (move to C_{10} and then) be exactly in the same situation in another network in C_9.[20] Finally, $F(g \in C_9)$ includes, beyond the neighboring network in C_5 and the other networks in C_9, only the networks in C_4, reached with a four-step farsighted improving path. This implies that even groups that leave the VNMFS set for C_9 are somewhat stuck there. As such, this is a "weak" deviation, that is unlikely to drive the subjects elsewhere

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[19]As shown by Jackson and van den Nouweland [2005] this is equivalent to an empty core in the derived cooperative game.

[20]One may question how reasonable it is to keep the same indifference-breaking conventions in the case of farsighted moves as in the myopic case.

from C_5 as a final outcome: the subjects are less likely to move, because the deviation is longer; in case they do, they are not likely to go beyond C_9, as moving from there implies either a move by an indifferent player or a very long and twisted deviation to C_4; finally, those that are stuck in C_9 are likely to move back to C_5.[21]

	Origin	Destination	Lenght	Example
T1	g^N	–	–	–
T2	C_5	C_9	3	
T3	C_7	C_7	2	

Table 2: Farsighted deviations from VNMFS sets

In T3 there are two-steps farsighted improving paths from any network in a VNMFS set to any network in another VNMFS set.[22] Namely, one of the players with two links cut any of his existing links ($C_7 \rightarrow C_3$ or $C_7 \rightarrow C_4$). From there, another link will be added leading back to C_7, but in a network where the initial

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[21]This does not mean, however, that the presence of such a deviation should have no influence on the play throughout the game.

[22]There are other farsighted deviations, longer than four steps.

deviator is better off (because he has only one link). After the first move away from C_7 is made, other (short) deviations are feasible, driving the group away from the VNMFS set (and, most notably, toward $g^\varnothing$). Those differences bare little meaning in the context of perfect farsightedness. However, to the extent that the agents may be bounded in their ability to pursue farsighted deviations, the VNMFS set seems more robust in T1 and in T2 than in T3.

Hypothesis 5. *The fraction of groups ending the game in a VNMFS set is higher if the networks that are there included are robust to short farsighted deviations. Thus:*

i $frac_{FAR}(T_1) > frac_{FAR}(T_3)$, *and*

ii $frac_{FAR}(T_2) > frac_{FAR}(T_3)$.

3.3 Experimental procedures

The experiment took place at the EELAB of the University of Milan-Bicocca in June 2010 (T1) and April/May 2012 (T2,T3). The computerized program was developed using Z-tree [Fischbacher, 2007]. We run 16 sessions for a total of 288 participants and 72 groups. Those corresponds to 36 independent observations for T1, and 18 independent observations for T2 and T3. Table 3 summarizes sessions' details. Participants were undergraduate students from various disciplines,[23] recruited through an announcement on the EELAB website. No subject participated in more than one session.

Subjects were randomly assigned to individual terminals and were not allowed to communicate during the experiment. Instructions were read aloud (see Appendix B 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 32.40 Euro.

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[23]Sociology, economics, business, psychology, statistics, computer science, law, biology, medicine, mathematics, pedagogy and engineering.

	Date	Participants	Groups (Ind. Obs)	Treatment
1	Jun 2010	24	6	T1
2	Jun 2010	24	6	T1
3	Jun 2010	24	6	T1
4	Jun 2010	24	6	T1
5	Jun 2010	24	6	T1
6	Jun 2010	24	6	T1
7	Apr 2012	16	4	T2
8	Apr 2012	16	4	T2
9	Apr 2012	16	4	T2
10	May 2012	16	4	T3
11	May 2012	16	4	T3
12	May 2012	16	4	T3
13	May 2012	16	4	T3
14	May 2012	16	4	T2
15[*]	May 2012	8	2	T2
16[*]	May 2012	8	2	T3

[*] Sessions 15 and 16 were run at the same time.

Table 3: Sessions

4 Results

In this section we first show how both perfect myopia and farsightedness are inconsistent with the networks formed, whereas limited farsightedness can reconcile the different results in all treatments. We then investigate this hypothesis using individual data, finding clear evidence of the relevance of limited levels of farsightedness.

We start by considering groups' final networks. Figure 4 classifies groups with respect to their final network. Figure 5 provides the same information for each repetition (period). In every treatment, around three out of four groups reach a PWS network.[24] This percentage increases consistently across repetitions within each single treatment, except between the second and third repetition of T3.

The distribution within PWS networks shows different patterns across treatments. In T1 and T2 the fraction of groups ending up in the VNMFS set is consistently higher than that ending up in $g^{\varnothing}$. This difference increases across repetitions with the farsighted and the myopic outcome accounting for around 70 and

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[24]This high percentage is reassuring on the subjects' ability to understand the game, as it would hardly result from generalized non-meaningful play.
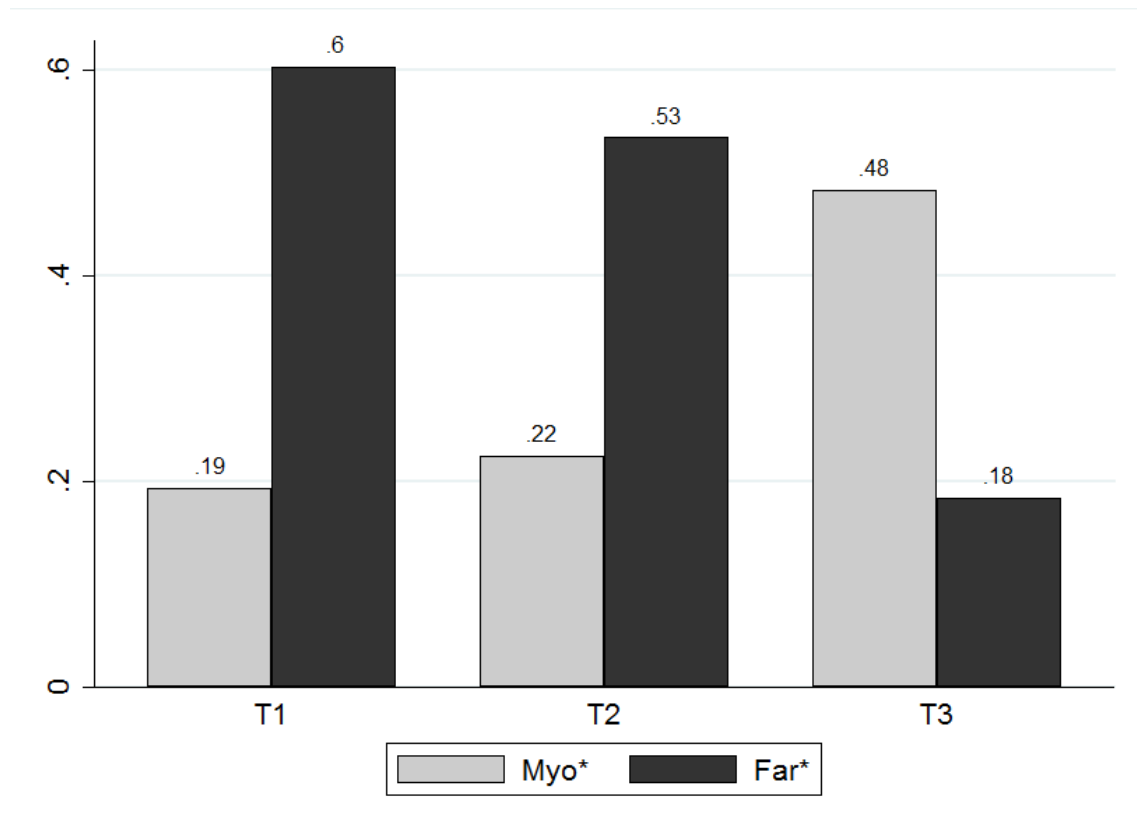
Figure 4: Group final network, by type of outcome

below 20 percent of the final networks, respectively, in the last repetition.

This pattern is almost reversed in T3. The final network is $g^{\varnothing}$ for half of the groups, with this percentage peaking at 60 percent in the second repetition. A VNMFS set is reached by about 20 percent of the groups in all repetitions.[25]

We use the Pearson's chi-square and the Likelihood Ratio test to determine whether the relative frequencies of the myopic and the farsighted outcome differ or not within treatments and conclude that those differences are statistically significant at the 0.05 level in each single treatment.[26] Running the tests for each single repetition leads to significant differences in repetitions two and three of T1

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[25]Around 90 percent of the groups move from the empty network. As a consequence we gather indirect evidence about the behavior of groups that do not start from a pairwise stable network.

[26]We run the tests on the distributions obtained for outcomes - i.e. myopic, farsighted, other -, for network classes and for single networks. We run them against different assumptions for the frequencies that are not being tested under the null hypothesis (H_0: equality of frequencies for myopic and fardighted outcome): uniform distribution, uniform given the actual cumulative frequency of myopic and farsighted, actual frequencies. The results are identical across all specifications.
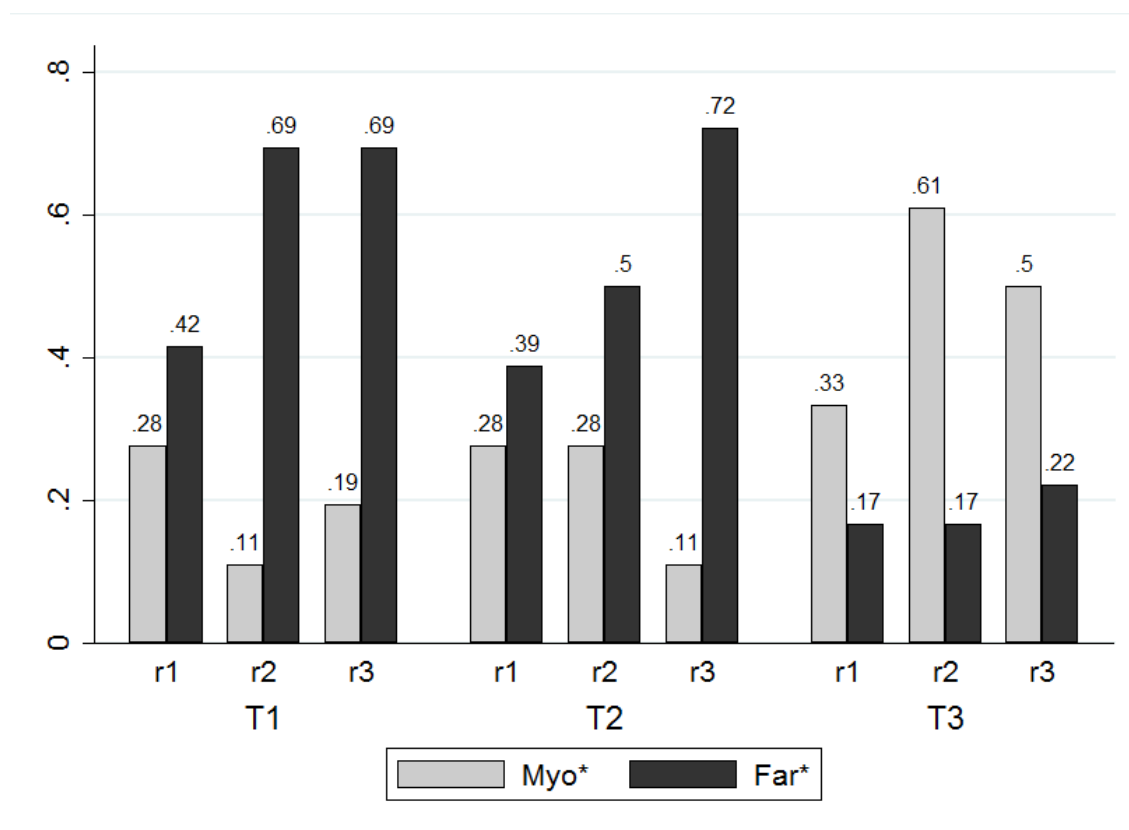
Figure 5: Group final network, by type of outcome and repetition

and repetition three of T2.[27] Given that those differences go in opposite direction in T3, with respect to T1 and T2, those results imply a rejection of both Hypothesis 1 and 2.

<u>Result 1</u>: *The networks predicted by myopia and farsightedness (see Table 1) account, on aggregate, for 75 percent of our groups' final outcomes. The VNMFS sets account for most of those observations in T1 and T2, but not in T3. The reverse holds for the myopic prediction, which shows some success only in T3. Thus, both perfect myopia (H.1) and farsightedness (H.2) fail to rationalize our results.*

We use a two-sample Kolmogorov-Smirnov test to compare the distribution of aggregate outcomes - i.e. myopic, farsighted, other - across treatments. As expected, we find that the distribution of outcomes in T1 and T2 are significantly different from that in T3 at the 0.05 level. When comparing T1 and T2 we do not find their distributions to be significantly different. This leads us to reject both

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[27]Repetition two of T2 is significant at the 0.1 level. Note that we collected fewer observations for T2 and T3 than for T1.

Hypothesis 3 and 4, as we do not find the inequality of the payoffs nor strong stability to affect systematically the stability of the VNMFS sets. The results are, instead, consistent with Hypothesis 5, supporting limited farsightedness.

<u>Result 2</u>: *The different performance of the VNMFS sets in T3, compared to T1 and T2, can not be explained by payoff inequality or coalitional stability, leading to a rejection of both Hypothesis 3 and 4. The results are, instead, consistent with limited farsightedness (H.5).*

Between one fifth and one third of the groups did not end up neither in the myopic nor in the farsighted prediction; we generally refer to this category as "other". Remarkably, a vast majority of those, between 72 and 77 percent, ended the game in networks that are direct neighbors of either of the two. The specific figures are as follows: in T1, 50 and 23 percent of those ended up at one step from the empty and the complete network, and thus in C_2 and C_{10}, respectively; in T2, 61 percent resulted in C_9, at one step from the VNMFS set, 16 percent in C_2; in T3, 39 percent were in C_2, while 33 percent in C_4. We note that in T2 and T3, the groups that were close to a VNMFS set happened to be precisely on the first step of the farsighted deviations outlined above.

Table 4 reports the change in the outcome of individual groups from Period 1 to 2 and from Period 2 to 3, for all treatments. For example, the row "Farsighted" from the upper-left panel (T1, Period 1 - Period 2) shows that in T1, among those groups who reached the complete network in period 1, only 7 percent switched to the empty, myopic network in period 2, whereas 93 percent of the groups also reached the complete network in period 2. But among those groups who ended up in the empty network in period 1 (row "Myopic"), only 20 percent stayed at the empty network in period 2, whereas 50 percent switched to the complete network, and 30 percent to an unstable network. Similarly, among the groups who ended up in some other network in period 1 (row "Other"), 55 percent of them switched to the complete network in period 2, while only 18 percent of them switched to the empty network.

Table 4 shows that groups that reached a VNMFS set in a previous period are able to replicate the result in T1 and T2: the Farsighted-Farsighted cell displays a fraction close or above 80 percent in the corresponding panels. The other categories display greater mobility across time. Some of them reach a VNMFS set,

		T1			T2			T3		
		Period 2			**Period 2**			**Period 2**		
		Myopic	**Farsighted**	**Other**	**Myopic**	**Farsighted**	**Other**	**Myopic**	**Farsighted**	**Other**
Period 1	**Myopic**	0.20	0.50	0.30	0.60	0.20	0.20	0.67	0.17	0.17
	Farsighted	0.07	0.93	0.00	0.00	0.86	0.14	0.33	0.33	0.33
	Other	0.18	0.55	0.27	0.33	0.33	0.33	0.67	0.11	0.22
		Period 3			**Period 3**			**Period 3**		
		Myopic	**Farsighted**	**Other**	**Myopic**	**Farsighted**	**Other**	**Myopic**	**Farsighted**	**Other**
Period 2	**Myopic**	0.60	0.00	0.40	0.20	0.40	0.40	0.64	0.09	0.27
	Farsighted	0.00	0.92	0.08	0.11	0.78	0.11	0.00	0.33	0.67
	Other	0.67	0.34	0.00	0.00	1.00	0.00	0.50	0.50	0.00

Table 4: Group flows by treatment and period

others fluctuate among the empty network and the Other category. Again, a striking difference appears comparing those results with the right-hand side panels, corresponding to T3. Around two thirds of the groups that end in the empty network in one repetition, replicate this outcome in the subsequent one. This is the only outcome showing some persistence; the farsighted outcome, in particular is much less stable across repetitions.

Table 5 displays, for each class of networks, a set of descriptive statistics regarding the groups' decision throughout the game, thus moving beyond the analysis of the final outcomes. The first three columns give us for each treatment the number of times groups leave and access each class of networks, together with their ratio. It is not surprising, from the previous analysis, that most networks are always left. More interesting is that even the networks that account for a significant fraction of the final outcomes, with the exception of the complete network in T1, are often left once accessed. This happens 47 percent of the time for C_5 in T2, and 71 and 76 percent for C_1 and C_7, respectively, in T3.

The columns labeled "Destinations" in Table 5 report the major receivers of the outflows from each class of network, and their share of those outflows. We are particularly interested in the results for C_7 in T3. It turns out that two thirds of the groups that left a VNMFS set in T3 did so consistently with the short farsighted deviation described above (destinations C_3 and C_4, see Table 2). Note also that of the groups that left the VNMFS set in T2 (C_5), more than 90 percent did so consistently with a farsighted deviation (destination C_9).

The last three columns display the average number of consecutive stages the groups stayed in a network, which we consider as another marker of the absorbing power of a network. In T1, when groups reach the complete network, they immediately decide to end the game.[28] In T2 and T3 the players cannot decide to stop the game when they reach a VNMFS set, probably due to the asymmetries in their payoffs. Nevertheless they spend more consecutive stages there than in any other class. In T2 this results in a high percentage of groups ending the game in C_5. In T3 the players leave C_7 more often before the end of the game, despite staying there for more than five rounds, on average.[29] Consistently, on average

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[28]This fact explains why g^N displays a low average stay, despite it is the final network for a majority of the groups.

[29]Note the relatively high numbers for C_5 in T1 and T3; those networks feature relatively low payoffs and are not Nash stable (the connected players can be better off by cutting two of their

	Out, In (Ratio)			Destinations (Share)			Average stay		
	T1	T2	T3	T1	T2	T3	T1	T2	T3
C_1	115, 136 (.85)	60, 72 (.83)	65, 91 (.71)	C_2(100%)	C_2(100%)	C_2(100%)	2.28	3.00	3.67
C_2	135, 146 (.92)	75, 77 (.97)	96, 103 (.93)	C_1(21%), C_3(12%), C_4(67%)	C_1(24%), C_3(7%), C_4(69%)	C_1(39%), C_3(10%), C_4(51%)	2.60	2.90	3.24
C_3	18, 18 (1)	10, 10 (1)	21, 21 (1)	C_2(18%), C_7(82%)	C_2(20%), C_7(80%)	C_2(76%), C_7(24%)	1.61	1.10	1.43
C_4	129, 135 (.96)	66, 66 (1)	70, 76 (.92)	C_2(26%), C_5(30%), C_7(24%)	C_2(23%), C_5(43%), C_7(26%)	C_2(31%), C_5(30%), C_7(33%)	2.12	1.99	1.84
C_5	46, 47 (.98)	26, 55 (.47)	24, 25 (.96)	C_4(50%), C_9(50%)	C_4(8%), C_9(92%)	C_4(58%), C_9(42%)	4.49	4.42	3.44
C_6	35, 35 (1)	8, 8 (1)	10, 10 (1)	C_4(43%), C_9(57%)	C_4(37%), C_9(62%)	C_4(90%), C_9(10%)	2.89	1.00	3.00
C_7	49, 50 (.98)	34, 36 (.94)	32, 42 (.76)	C_4(10%), C_8(22%), C_9(61%)	C_3(15%), C_4(26%), C_9(50%)	C_3(41%), C_4(25%), C_9(31%)	1.54	1.28	5.05
C_8	16, 16 (1)	11, 11 (1)	13, 13 (1)	C_7(19%), C_{10}(81%)	C_7(82%), C_{10}(18%)	C_7(69%), C_{10}(31%)	2.87	1.54	1.38
C_9	96, 96 (1)	51, 59 (.86)	31, 31 (1)	C_5(12%), C_6(12%), C_{10}(67%)	C_5(53%), C_{10}(39%)	C_6(19%), C_7(16%), C_{10}(51%)	1.94	4.03	1.32
C_{10}	72, 77 (.93)	24, 24 (1)	19, 21 (.90)	C_9(9%), C_{11}(90%)	C_8(33%), C_9(54%), C_{11}(12%)	C_8(47%), C_9(37%), C_{11}(17%)	4.06	2.96	3.05
C_{11}	0, 65 (0)	2, 3 (.66)	2, 3 (.66)	–	C_{10}(100%)	C_{10}(100%)	1.52	1.67	1.00

Table 5: Descriptive statistics, by treatment and class of networks

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a game lasted longer in T3 (22.93 stages), followed by T2 (21.5) and T1 (17.73).

All the results presented are in line with Hypothesis 5. Furthermore, they cannot be reconciled using traditional theoretical arguments. In T3, the VNMFS sets are Pareto efficient, Pareto dominant among the PWS networks, and strongly stable (a condition not met in T2). Our interpretation is that the VNMFS sets are less robust to limitedly farsighted deviations in T3. As discussed in Section 3.2 there are farsighted improving paths in two steps leaving any $g \in C_7$ and reaching another network in the same class. Both steps imply a strict improvement in the final network with respect to the current one (see table 2). Deviations leaving the VNMFS set in T2 are longer and less feasible as they include some players adding a link only to be as well off in the final network as they are in the current one.

An alternative interpretation would be that the multiplicity of networks that are in a VNMFS set generate coordination problems among the players. This problem is not present in T1 and has an obvious solution in T2, given the sequential nature of the game.[30] In T3, agents with two links are worse off than the agents with one link, in network class C_7. Hence, agents have a strategic incentive to build only one link, and let the others build two. However, this interpretation is refuted by our data. According to it, we would observe the agents having problems in reaching C_7, and not moving away once they are there. We observe almost the opposite. As shown in Table 5, in T3 the groups ended the game in C_7 only in ten out of the forty-two times they accessed it. The same ratio (for C_5) is twenty-nine out of fifty-five in T2. Thus, in T3 the groups have more problems staying in C_7 than accessing it.

Next we explore the relevance of limited farsightedness, analyzing individual behavior. Before doing so, we should stress that limited farsightedness, as its extreme counterparts, is meant to be a tool for assessing the stability of a certain state. As such, it should not be interpreted as a proper model of individual strategic behavior, and the following analysis should be understood accordingly.

We build the vectors of choices of virtual players endowed with different levels of limited farsightedness, including myopia, according to Definition 3. Those

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existing links), though they are PWS. Note also the high number for C_9 in T2. Those networks are often reached when an unsatisfied player in a VNMFS set takes a non-myopic move. As expected, this deviation is generally unsuccessful, in the sense that the group is stuck in C_9 until a backward move is taken by the same player.

[30]As the connected agents in a VNMFS set are better off, the first agents that are proposed a link on a path to C_5 should build them.

are vectors of dummies, $f_{i_k g_t}^{ij}$, for $k = 1, 2, \ldots$, containing the ideal actions of an individual i, with level of farsightedness k, choosing with respect to link ij in network g_t.

Recall that an action is consistent with farsightedness of level k if it lies on a farsighted improving path of length (weakly) shorter than k; $k = 1$ is identical to myopia. To lie on a farsighted improving path, an action must imply moving from the current network. Categorizing choices that imply inaction - i.e. staying in the current network - is more problematic. According to Definition 3, those actions are consistent with farsightedness of level k if moving would not be farsighted of level k, which equals assuming that a farsighted agent should always take any farsighted improving path, imposing a strong restriction on farsighted behavior.[31] As a throughout theoretical analysis of limited farsightedness goes beyond the scope of the present paper, we will tackle this issue by running the analysis twice, on two set of decisions: the full set of choices, and its restriction to the actions that imply moving from the current network - i.e. excluding those that result in inaction. We will refer to the former set as *choices*, and to the latter as *moves*.[32]

In Figure 6 we represent the fraction of choices that are consistent with myopia and progressive levels of limited farsightedness, over stages. Starting relatively low, the fraction of choices that are consistent with myopia remains approximately stable, above 60 percent, in the central part of the game, and is somewhat higher in the last stages. Including farsightedness of level two increases the fraction of consistent choices by about 15 percentage points. Another 10 percent is added by farsightedness of level three, whilst higher level of farsightedness result in improvements that are only marginal.[33] This picture suggests, once more, that myopic incentives were a main guide for decision making in our framework; however agents often departed from those, following short farsighted deviations, with relevant consequences on the final outcomes.

We perform a regression analysis to explore the relation between the actual choices, $a_{ig_t}^{ij}$, and the ideal benchmarks, $f_{i_k g_t}^{ij}$, up to a level of farsightedness of four. This exercise suffers from many statistical limitations. In particular, the number of choices each agent takes is endogenous, as groups can decide when to

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[31] This restriction is of course not problematic for myopic behavior.

[32] This set identifies the paths - i.e. sequences of different networks - the groups walk through.

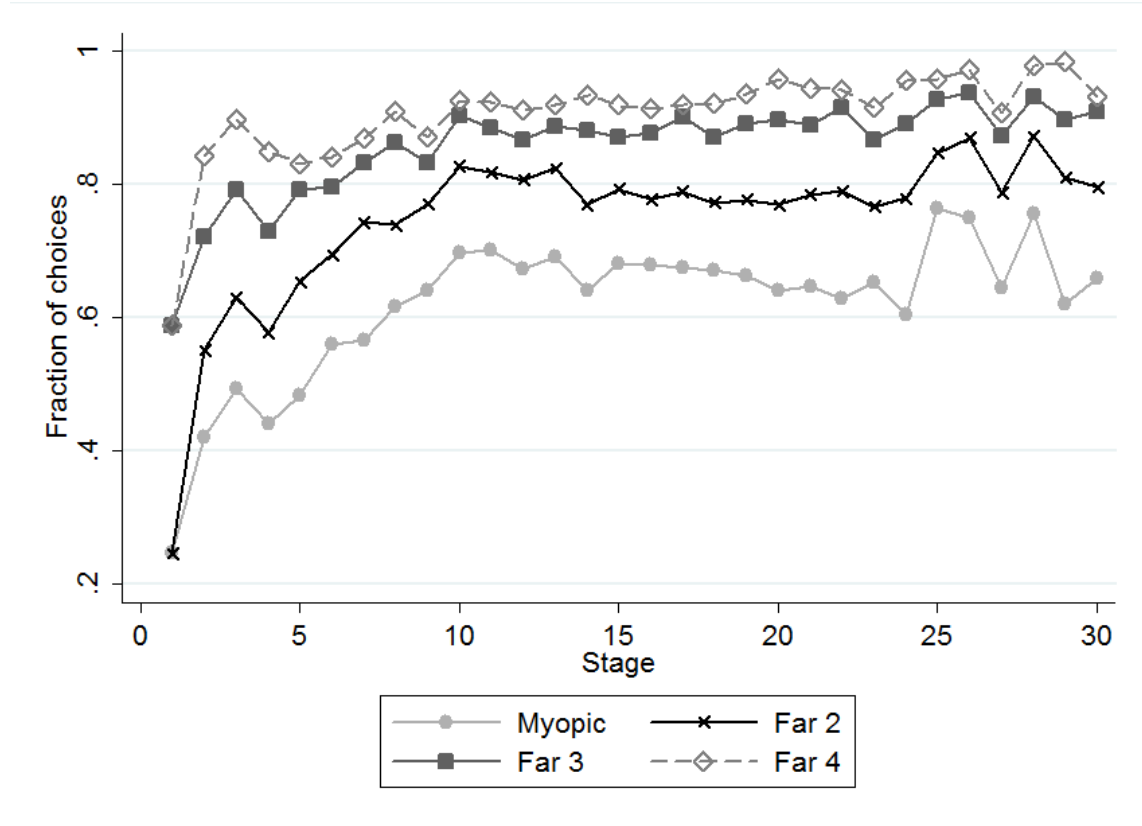[33] The picture is qualitatively similar across treatments.

Figure 6: Fraction of choices consistent with each behavioral benchmark

stop a game. We apply a two-steps Heckman selection model [Heckman, 1979] to address this issue.[34]

We estimate a (panel) linear probability model (LPM) with random effects, where the actions a_{igt}^{ij} are regressed, conditional on being observed, over the benchmark choices, $F_{igt}^{ij} = \{f_{ikgt}^{ij}\}_{k=1}^{4}$, and a set of controls, X_{igt}^{ij}, including characteristics of the choice problem and of the individual. The unobservable characteristics of the individual i, assumed independent from the attributes of the decision problem, are captured by ν_i, resulting in the LPM specification:

$$P(a_{igt}^{ij} = 1 \mid z_i^* > 0, F_{igt}^{ij}, X_{igt}^{ij}) = \beta_0 + F_{igt}^{ij}\beta + \hat{\lambda}_{it}\beta_\lambda + X_{igt}^{ij}\gamma + \nu_i \qquad (1)$$

where $\hat{\lambda}_{it}$ is the estimate of the inverse Mills ratio from the selection equation:

$$z_{it}^* = \delta W_{it} + u_i$$

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[34]As shown by Nicoletti and Peracchi [2001], the bias of two-stage methods in the case of a binary independent variable has a minor impact when the correlation of unobservables is low.

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$$z_{it} = \begin{cases} 1 & \text{if } z_{it}^* > 0 \\ 0 & \text{if } z_{it}^* \leq 0 \end{cases} \qquad (2)$$

where z_{it}^* is the latent variable capturing the propensity of a choice to be selected, z_{it} is a dummy variable indicating whether we observe the choice or not, and u_i is a normal error term. W_{it} is the set of regressors that explain the selection of observations, including all controls $X_{ig_t}^{ij}$ that are applicable,[35] plus a set of restrictions. We use as restrictions[36] in the selection equation dummies for each treatment and for each type of final outcome (myopic, farsighted, other). We do not include the treatments in the main regression because we have no reason to think that they have any effect on single decisions, but for the effect of the different payoffs, which are already accounted for through our main regressors. A similar reasoning holds for the final outcomes of the groups. The restrictions are justified as both the treatments and the group final outcomes are relevant determinants of the time when the agents stop the game.

We run this specification on both *choices* and *moves*, with and without group fixed effects,[37] giving the four specifications shown in Table 6. There is a major shift between the left-hand side and the right-hand side specifications. When considering choices, myopic behavior and farsightedness of level two have a positive and significant coefficient. For higher levels of farsightedness the coefficient is insignificant and eventually turns negative (and significant). The picture is reverted with *moves*. Myopia has a negative and significant coefficient, and those for all farsightedness levels are positive and significant. Level two is the only variable to show a stable explanatory power across specifications.

Combining the results, we see that subjects often refused to move from the current network, because of myopic incentives. When they move, they do so also against their immediate interest, following farsighted improving paths (even of relatively high length); nevertheless, they regularly do not move even if a lengthy farsighted improving path is available. The coefficients for farsightedness of level two (and myopia) suggest that agents generally take myopic and farsighted improving paths of length two when those are available, and refuse to move when

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[35]The controls that refer to the decision problem are unobservable is the observation is not selected.

[36]That is, we include those variables in W_{it}, but not in $X_{ig_t}^{ij}$.

[37]Errors are always clustered at the group level.

| | Choices | | Moves | |
| | Group effects: | | Group effects: | |
	No	Yes	No	Yes
Myopic	.175***	.165***	−.165***	−.180***
	(.024)	(.024)	(.014)	(.014)
Farsighted 2	.039**	.034*	.078***	.076***
	(.019)	(.019)	(.015)	(.015)
Farsighted 3	.019	.036	.017	.062***
	(.025)	(.024)	(.027)	(.018)
Farsighted 4	−.092***	−.096***	.399***	.384***
	(.019)	(.019)	(.029)	(.028)
Inv. Mills	.260***	.020	.219***	−.029
	(.084)	(.108)	(.040)	(.061)
Constant	.643***	.874***	.538***	.712***
	(.141)	(.167)	(.062)	(.074)
N. obs	8632	8632	3999	3999
N. subjects			288	
N. groups			72	

*,**,*** statistical significant at the 10%, 5% and 1% level, respectively.

Controls include the stage, the repetition and a set of individual characteristics.

Table 6: Estimates results for the main regressions of a two-steps Heckman selection model (Robust Std errors in parentheses)

neither of the two is.

This interpretation is consistent with the aggregate results, and in particular with the observation that PWS networks express a high absorbing power, even in those cases where they are eventually left by the subjects. The results for farsightedness of level two are suggestive, as it is exactly the level that would explain the differences between T3 and the other treatments. Overall, low levels of farsightedness look like important determinants of individual behavior.

Result 3: *Individual behavior is best explained by low level of farsightedness, including myopia. Despite the observed impact of myopic incentives, the subjects often disregard them and take farsighted deviations. This limitedly farsighted behavior consistently explains the differences across treatments, supporting Hypothesis 5 as a rationale for Result 1.*

We are aware that the statistical approach suffers from important limitations. We do not properly take into account the effect of the past choices of the same

individual and of the group, though it is likely that the path of a group has a huge influence on the behavior of the subjects. Moreover, the different results for moves and choices are, at least partially, an artifact of the way in which the regressors are constructed. In particular, the ex ante probability that modifying a network is consistent with some level of farsightedness is increasing in the level itself.

Although statistical problems notwithstanding, we think that our results clearly show that individual behavior is consistent with limited farsightedness.

5   Conclusion

This paper reports an experimental test of the most used stability notions for network formation. In particular, by studying the performance of pairwise stability and of von Neumann-Morgenstern farsighted stability, we test whether subjects behave according to myopia or farsightedness when forming a network, allowing for limited levels of farsightedness. As far as we know this is the first experimental investigation into this issue.

The results show that both of the extreme theories, perfect myopia and farsightedness, are inconsistent with our data, and suggest that the subjects are only limitedly farsighted. Agents reach a stable network in 75 percent of the cases, and more so as the game is repeated. In two of the treatments, a vast majority reach a von Neumann-Morgenstern farsightedly stable set. In the third treatment, where the farsighted prediction is not robust to limitedly farsighted deviations, they fail to do so, and 50 percent of them end up in the myopic prediction.

The properties of the treatments enable us to attribute this asymmetry to a form of limited farsightedness, and individual behavior analysis confirms this interpretation: low levels of farsightedness, nesting myopia as the lowest level, best explain our data.

Our results opens the way to new interesting research questions. While the literature has concentrated on the extreme cases of perfect myopia and perfect farsightedness, our experimental results suggests that an intermediate approach could provide a valuable alternative and a promising refinement of pairwise stability.

References

Bala, Venkatesh and Sanjeev Goyal, "A noncooperative model of network formation," *Econometrica*, 2003, *68* (5), 1181–1229.

Berninghaus, Siegfried K, Karl-Martin Ehrhart, and Marion Ott, "Forward-looking behavior in Hawk–Dove games in endogenous networks: Experimental evidence," *Games and Economic Behavior*, 2012, *75* (1), 35–52.

Bloch, Francis and Matthew O Jackson, "Definitions of equilibrium in network formation games," *International Journal of Game Theory*, 2006, *34* (3), 305–318.

Carrillo, Juan and Arya Gaduh, "The strategic formation of networks: experimental evidence," 2012.

Chwe, Michael Suk Young, "Farsighted coalitional stability," *Journal of Economic Theory*, 1994, *63* (2), 299–325.

Dutta, Bhaskar, Sayantan Ghosal, and Debraj Ray, "Farsighted network formation," *Journal of Economic Theory*, 2005, *122* (2), 143–164.

Engelmann, Dirk and Martin Strobel, "Inequality aversion, efficiency, and maximin preferences in simple distribution experiments," *The American Economic Review*, 2004, *94* (4), 857–869.

Falk, Armin and Michael Kosfeld, "It's all about connections: evidence on network formation," *Review of Network Economics*, 2012, *11* (3).

Fehr, Ernst and Klaus M Schmidt, "A theory of fairness, competition, and cooperation," *The Quarterly Journal of Economics*, 1999, *114* (3), 817–868.

Fischbacher, Urs, "z-Tree: Zurich toolbox for ready-made economic experiments," *Experimental Economics*, 2007, *10* (2), 171–178.

Goeree, Jacob K, Arno Riedl, and Aljaž Ule, "In search of stars: Network formation among heterogeneous agents," *Games and Economic Behavior*, 2009, *67* (2), 445–466.

Heckman, James J, "Sample selection bias as a specification error," *Econometrica*, 1979, pp. 153–161.

Herings, P, Ana Mauleon, and Vincent J Vannetelbosch, "Rationalizability for social environments," *Games and Economic Behavior*, 2004, *49* (1), 135–156.

— , — , and **Vincent Vannetelbosch**, "Farsightedly stable networks," *Games and Economic Behavior*, 2009, *67* (2), 526–541.

Jackson, Matthew O and Alison Watts, "The evolution of social and economic networks," *Journal of Economic Theory*, 2002, *106* (2), 265–295.

— **and Anne van den Nouweland**, "Strongly stable networks," *Games and Economic Behavior*, 2005, *51* (2), 420–444.

— **and Asher Wolinsky**, "A strategic model of social and economic networks," *Journal of Economic Theory*, 1996, *71* (1), 44–74.

Konishi, Hideo and Debraj Ray, "Coalition formation as a dynamic process," *Journal of Economic Theory*, 2003, *110* (1), 1–41.

Mauleon, Ana and Vincent Vannetelbosch, "Farsightedness and cautiousness in coalition formation games with positive spillovers," *Theory and Decision*, 2004, *56* (3), 291–324.

Nicoletti, Cheti and Franco Peracchi, "Two-step estimation of binary response models with sample selection," in "first British Household Panel Survey research conference held in Colchester, July" Citeseer 2001.

Page, Frank H and Myrna Wooders, "Strategic basins of attraction, the path dominance core, and network formation games," *Games and Economic Behavior*, 2009, *66* (1), 462–487.

— **, Myrna H Wooders, and Samir Kamat**, "Networks and farsighted stability," *Journal of Economic Theory*, 2005, *120* (2), 257–269.

Sobel, Joel, "Interdependent preferences and reciprocity," *Journal of Economic Literature*, 2005, *43* (2), 392–436.

Tercieux, Olivier and Vincent Vannetelbosch, "A characterization of stochastically stable networks," *International Journal of Game Theory*, 2006, *34* (3), 351–369.

Watts, Alison, "A dynamic model of network formation," *Games and Economic Behavior*, 2001, *34* (2), 331–341.

— , "Non-myopic formation of circle networks," *Economics Letters*, 2002, *74* (2), 277–282.

Xue, Licun, "Coalitional stability under perfect foresight," *Economic Theory*, 1998, *11* (3), 603–627.

Ziegelmeyer, Anthony and Katinka Pantz, "Collaborative networks in experimental triopolies," Technical Report, Max Planck Institute of Economics, Strategic Interaction Group 2005.

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 $g^i \rightarrow g$ with $g \in C_j$, and $g^i \rightarrow g$ with $g \in c_j$, 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.

i In T1 the list of farsighted improving paths among the networks in $\mathbb{G}$ is the following:

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

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

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

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

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

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

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

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

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

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

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

It follows that $g^N \in F(g)$, for all g in $\mathbb{G} \setminus g^N$ and $F(g^N) = \varnothing$. Thus $\{g^N\}$ is the unique VNMFS set.

ii In T2 the list of farsighted improving paths among the networks in $\mathbb{G}$ is the following:

$F(g^{\varnothing}) = \{g \mid g \in C_5\}$

$F(g^2) = \{g \mid g \in C_1 \cup C_5 \cup c_9\}$

$F(g^3) = \{g \mid g \in C_1 \cup c_2 \cup C_5 \cup C_9\}$

$F(g^4) = \{g \mid g \in C_1 \cup c_2 \cup c_4 \cup C_5 \cup c_9\}$

$F(g^5) = \{g \mid g \in C_9 \cap \bar{A}_{g^5}\}$

$F(g^6) = \{g \mid g \in C_1 \cup c_2 \cup c_4 \cup C_5 \cup C_9\}$

$F(g^7) = \{g \mid g \in C_1 \cup c_2 \cup c_3 \cup c_4 \cup C_5 \cup C_9\}$

$F(g^8) = \{g \mid g \in C_1 \cup c_2 \cup c_4 \cup C_5 \cup c_7 \cup C_9\}$

$F(g^9) = \{g \mid g \in c_4 \cup (C_5 \cap A_{g^9}) \cup (C_9 \setminus g^9)\}$

$F(g^{10}) = \{g \mid g \in C_1 \cup c_2 \cup c_4 \cup C_5 \cup c_7 \cup c_8 \cup C_9\}$

$F(g^N) = \{g \mid g \in C_5 \cup C_9 \cup C_{10}\}$

The set $\{g \mid g \in C_5\}$ is a VNMFS set. It is reached by any network outside the set and there are no paths between any two networks in the set. Let us check that it is unique.

Consider first a candidate set that does not include any network in C_5. It must then be reached by each single network in C_5, which implies this set should include at least two networks that belong to C_9. Given that $\{g' \mid g' \in C_9 \setminus g\} \subset F(g)$ for every $g \in C_9$, a set including two networks in C_9 is not internally stable.

Now consider a candidate that includes at least one network $g \in C_5$. Then it should include at least one network $g' \in C_9$, such that $g' \notin F(g)$ and $g \notin F(g')$. This condition is impossible as all networks in C_9 that are not adjacent to a network in C_5 are reached by a farsighted improving path from this network, and all networks in C_9 that are adjacent to a network in C_5 reach this network with a farsighted improving path. We conclude that $\{g \mid g \in C_5\}$ is the unique VNMFS set.

iii In T3 the list of farsighted improving paths among the networks in $\mathbb{G}$ is the following:

$F(g^{\varnothing}) = \{g \mid g \in C_7\}$

$F(g^2) = \{g \mid g \in C_1 \cup C_7 \cup c_{10}\}$

$F(g^3) = \{g \mid g \in C_1 \cup c_2 \cup C_7 \cup C_{10}\}$

$F(g^4) = \{g \mid g \in C_1 \cup c_2 \cup c_5 \cup C_7 \cup c_{10}\}$

$F(g^5) = \{g \mid g \in C_1 \cup c_2 \cup C_7 \cup c_{10}\}$

$F(g^6) = \{g \mid g \in C_1 \cup c_2 \cup c_4 \cup c_5 \cup C_7 \cup C_{10}\}$

$F(g^7) = \{g \mid (g \in C_7 \wedge \exists i \text{ s.t. } d_i(g) \neq d_i(g')) \vee g \in C_{10}\}$

$F(g^8) = \{g \mid g \in C_1 \cup c_4 \cup C_7 \cup C_{10}\}$

$F(g^9) = \{g \mid g \in C_1 \cup c_2 \cup c_4 \cup c_5 \cup c_6) \cup C_7 \cup C_{10}\}$

$F(g^{10}) = \{g \mid g \in C_1 \cup c_2 \cup c_4 \cup c_5 \cup c_6 \cup C_7 \cup c_8 \cup C_{10} \setminus g^{10}\}$

$F(g^N) = \{g \mid g \in C_7 \cup C_{10}\}$

A network $g \in C_7$ is reached with a farsighted improving path from any other network except for the network $g' \in C_7$, where each single agent has the same degree as in g. By definition each dyad $\{g, g'\}$ is a VNMFS set. Let

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us check there is no other VNMFS set.

Given the previous argument, any set containing $g \in C_7$ and any other network $g'' \neq g'$ (as defined above) does not satisfy internal stability. Consider now a candidate set that does not include any network in C_7. As it must be reached by networks in C_7, it will necessarily include one and only one (for internal stability) network in C_{10}. Then it must necessarily include $g^{\varnothing}$, which violates internal stability.

B Experimental 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:

  - *A link between you and another participant in your group is formed if you make a link to that person **AND** that person makes a link to you.*

  - *An existing link between you and another participant in your group is broken if you **OR** that participant decide to break that link.*

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 you are willing to modify the current network. You can answer YES or NO.

- If ALL the people in your group answer NO 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 YES, 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 willing to modify 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.