Coordination and Cooperation Problems in Network Good Production

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Abstract

If actors want to reach a particular goal, they are in many situations better off by forming collaborative relations and invest together rather than investing separately. In this paper we study the coordination and cooperation problems that hinder successful collaboration in such situations (which we label the production of a 'network good with complementarities'). Using a game-theoretic model, we were able to predict the outcomes in a computerized experiment in continuous time remarkably well. First, groups of subjects nearly always create a pairwise stable network configuration, i.e., they end up either in the empty or the full network. As the costs of forming links increase groups succeed less often in coordinating on the full network, which can yield higher payoffs than the empty network. Second, given the created network structure, subjects invest mostly according to their Nash strategy. This implies a suboptimal amount of network good production, because if linked subjects cooperate by investing more than in their Nash strategy, everybody can be better off. If cooperation is successful, this is mostly in the experimental condition in which subjects can monitor how much their partners invest. Finally, we were able to gain some insight in the individual level mechanisms underlying these outcomes. We find that groups consisting of more foresighted subjects are better able to solve the coordination and cooperation problems. Moreover, subjects learn to deal with the problems better as they gain experience. These results provide stimulating leads for further research into the mechanisms at the individual level.

Keywords: Social network formation, coordination, cooperation, experiments, collective goods, strategic complements

1. Introduction

In this paper we study situations where actors look to form relations with others to produce – what we label – a network good with complementarities. A "network good" can be seen as a special form of a collective good. A classic collective good is characterized by non-excludability: the contributions of one benefit the whole collectivity (Olson, 1971; Taylor, 1987). However, for a network good, non-excludability only takes place along social or geographical lines (cf. Bramoullé & Kranton, 2007). In other words, the contributions of one actor only benefit the actors that are linked to this actor (that are in his or her *network*). A network good with *complementarities* has the characteristic that the investments in this good made by actors become worth more when they are linked to others who also invest (cf. Ballester et al., 2006). Therefore, joining forces brings more benefits than each investing separately.

We can think, for example, of innovation efforts to develop environmentally friendlier cars. One car company often does not have the capacity and expertise to innovate on all aspects on its own. Building up all this know-how by itself would cost a lot of time and money. Therefore, the car company may choose to develop a more efficient engine with another car company specialized in engines. Furthermore, they could collaborate with a company that has expertise in the use of light materials such as aluminum. For a specified money and time budget, the car company can reach a lot more by building upon the knowledge of others. By the same token, the investments of the specialized car company and the aluminum company become worth more by teaming up with the car company because chances are increased that the developed product will be bought and put to use. In the automotive industry, as well as in other industries, we see a lot of such collaborations (Goyal & Moraga-Gonzalez, 2001; Eisenstein, 2006; PE, 2001).

Although all actors are typically better off by collaborating in the production of a network good with complementarities, it is certainly not self-evident that actors will succeed in doing so. There are coordination problems involved in creating the network of collaborative relations. Moreover, free-rider effects are likely to prevent actors from reaching the socially optimal investment level once relations are established. In this paper we look under what conditions actors are better able to solve such problems by studying the influence of the costs of forming relations and the availability of information about other actors. To recapitulate, we are interested in situations where actors simultaneously choose with whom they want to form relations as well as how much they want to invest in a related network good with complementarities. Firms creating Research & Development (R&D) alliances is our main example for these situations, but we can also think, e.g., of scientists looking to collaborate with researchers interdisciplinary, countries forming pacts to develop uniform rules and laws, or persons with an eccentric hobby searching for others to share their interests with.

Coordination problems and link costs

Forming and maintaining a link with another actor is costly. Therefore, for each link, a pair of actors has to decide whether the benefits of collaborating outweigh the costs. The problem may arise that the benefits of a network structure as a whole outweigh its costs for all actors, but that the creation of each link individually (i.e., when no other links of the structure are formed yet) do not outweigh the costs of that link. We can explain this as following. The complementarity of the network good makes that the optimal investment level of actors increases when they have a link with another actor. The more an actor invests, the more benefits it brings to link to this actor. Thus, the more links an actor has, the more he will invest and the more beneficial it becomes to link to this actor. Therefore it may occur that linking to an actor without other links is not profitable, but linking to an actor who does have other links is.

In terms of our example, a collaboration between the car and aluminum company may not be beneficial for the car company because the optimal investment level in know-how of the aluminum company is not high enough. The aluminum company can increase its know-how by starting a collaborative relation with a technical department of a university. However, this relation may only be beneficial for both if their innovative efforts have a good chance of seeing the production line, which would be the case if the aluminum company has a collaborative relation with the car company. Concluding, both a relation between the car company and the aluminum company as well as between the aluminum company and the university department are inefficient in their own right, but they would be efficient if both were formed.

If link costs are very low, there are no coordination problems because any link that is established will be profitable in itself. However, more complex structures are needed before collaboration becomes worthwhile for higher levels of link costs. It is therefore an interesting question what network configurations actors choose depending on the level of link costs.

- What is the effect of link costs on the network configurations that actors are likely to coordinate on?

A network configuration consists of two dimensions: the network structure and the investment levels of the actors in this structure. We will identify potential candidates by first analyzing which network configurations are pairwise stable. A second set of potential candidates are socially efficient network configurations. As we will argue next, pairwise stable and socially efficient configurations are not likely to coincide.

Cooperation problems and information availability about others

In the production of a network good with complementarities, we can expect incentives for each to free-ride on the investments of their partners to prevent a network of actors to reach the socially optimal investment level. To illustrate, consider the Prisoner's Dilemma structure that the car and aluminum company face. The aluminum company can spend all of their R&D budget on the innovation of the car, or spend part on an innovation of another application. The large investments would pay off if the car is sold well, which depends on how much the car company invests in other aspects of the car such as the efficient engine and marketing the car. However, the car company may reason that given the large investments of the aluminum company they can already pitch the car as environmentally friendly. Instead of putting their resources in developing an efficient engine, they prefer therefore to develop a more powerful engine. This way they may sell fewer environmentally friendly cars, but this does not weigh off against introducing a new sports car as well. If the aluminum company only spends part of their R&D budget on the car, the amount of cars sold would not be enough to make investments in an efficient engine profitable. So also in this case the car company does better by developing the powerful engine rather than developing the efficient engine. We can come up with similar arguments why the aluminum company is also always inclined to spend only part of their budget on the car. This way, if both companies follow their material interests, the car will become hardly innovative and will sell bad. If both cooperate by making high investments they would produce a great product and make higher profits than when both make only partial investments.

If both companies can monitor the progress of the other well, such cooperation problems are reduced to some extent. If one company slants towards underinvesting, the other can credibly threat to lower investment as well, or stop the collaboration altogether. However, it is often problematic in collaborations for one company to see how many resources the other is investing exactly. This makes opportunistic behavior more attractive and cooperation less likely to emerge. Therefore, we expect that actors reach the socially optimal level of investments less often if they cannot observe others' investments. We may also wonder whether actors have more trouble forming collaborative relations at all because actors cannot signal to one another that they are profitable partners. In other words:

- Does the amount of information actors have about the investments made by other actors influence
  - which network structure actors coordinate on?
  - the level of cooperation reached in network goods with complementarities?

In order to answer these questions we develop a game-theoretical model where actors' returns to their investments are the sum of an individual component and a collaborative component. The returns to individual investments are concave while the collaborative component is a multiplicative function of one's own investments and the sum of his neighbors investments (cf. Ballester et al., 2006). Two actors both pay link costs if they agree to become neighbors (link costs are constant across all relations). The hypotheses derived from our model are tested by the means of a computerized experiment in real-time. Each participant was able to invest in a network good with complementarities and to simultaneously propose links to other participants.

We contribute to at least two branches of literature. First, many have been concerned with the problematic production of collective goods (and other goods with externalities) (Olson, 1971; Hardin, 1982; Taylor, 1987; Heckathorn, 1996) and in particular the role that social relations play (Coleman, 1990; Gould, 1993; Marwell & Oliver, 1993; Flache, 1996; Chwe, 1999). Second, there is a growing body of literature that aims at explaining how networks are formed (Jackson & Wolinsky, 1996; Bala & Goyal, 2000) and in particular how network formation co-evolves with individual behavior (Jackson & Watts, 2002; Snijders et al., 2007).

Most literature on network goods assumes that the network is a given. Bramoullé & Kranton (2007) develop a game-theoretical model for the production of network goods with substitutability in a static context, while Ballester et al. (2006) develop a model that allows for both substitutability as well as complementarity. For many situations it is realistic to take the network as exogenous, since relations indeed came into being for other reasons than producing a particular network good together. However, in the situations we are interested in (such as firms creating R&D alliances), actors do purposively create their links and the network is essentially endogenous.

Most literature that assumes the network to co-evolve with individual behavior does not look at the production of network goods. Several dynamic network studies focus on other forms of coordination problems (see, e.g., Jackson & Watts, 2002; Goyal & Vega-Redondo, 2005; Buskens et al., 2008; Corten & Buskens, 2009) and cooperation problems (see, e.g., Ule, 2005; Takács & Janky, 2007; Eguíluz et al., 2005). Nevertheless, there are two studies who do analyze the production of a network good in a dynamic context. First, Galeotti & Goyal (2009) take a quite similar approach as we do here in building the model, but they look at network goods that are characterized by substitutability. For the production of these goods, they predict that star-networks will form with investors in the center and actors on the periphery who pay for access to these investments by linking up. The dynamics for a network good with complementarites are expected to be very different. Second, a working paper by Cabrales et al. (2007) comes close to what we are doing here in the sense that they also look at the production of network goods with complementarities in an endogenous network context. However, they assume that actors choose a level of resources that they devote to socialization in general, but do not choose with whom they socialize. Cabrales et al. (2007) argue that this is realistic for larger networks such as scientists who attend congresses: they go to listen to and meet other researchers in general. Moreover, they argue that this shortcuts the severe coordination problem that arise when two actors have to consent on a link, because this often causes games to display a multiplicity of Nash equilibria. We are interested in exactly studying these coordination problems – the conditions under which (relatively small) groups are better able to leave one equilibrium and coordinate individual actions such that they together reach another equilibrium in which everybody is better off.

A significant advantage of our study is that we actually test our model. With the exception of a great body of experimental literature, many studies on collective goods as well as on network formation remain on the (game-)theoretical level. In general, testing game-theoretical models is essential to prove their worth, and for our model in particular since we encounter multiple candidates as outcomes of our game. It is in part an empirical question which of these outcomes, if any, is observed most likely and under which conditions if the game is actually being played.

2. Theory

First, we present our model formally and comment on it. Our model is based on Ballester et al. (2006), who study investments in a network good with complementarities for an exogenously given network. By adding opportunities to create and sever links as well as link costs to their model we can analyze situations where the network can be expected to co-evolve with the investments made. Galeotti & Goyal (2009) took a similar approach by developing a 'dynamic' version of the 'static' model of network goods with substitutes by Bramoullé & Kranton (2007). Our notation also follows closely Galeotti & Goyal (2009). Second, we give the reader an intuition of the dynamics in our model by discussing our experimental case as an example typical for all cases. Third, we predict for three different levels of link costs which network structures are likely outcomes based on a pairwise stability concept. Also, we hypothesize which factors facilitate solving the coordination problems (i.e., leaving one stable state for another stable state in which everybody is better off). Finally, we discuss the cooperation problems involved in the production of the network good and the expected influence of, amongst others, the availability of information about other actors.

2.1 The model

Let $N = \{1, 2, \ldots, n\}$ be the set of actors and let i and j be typical members of this set. Each actor i selects an investment level $x_i \in X = [0, \infty)$ and expresses also with which other actors he would like to form links, which is denoted by the row vector $\boldsymbol{h_i} \in H_i = \{(h_{i1}, \ldots, h_{in}): h_{ij} \in \{0, 1\}$ for each $j \in N\}$. If actor i would like to be linked to j we have $h_{ij} = 1$, and if actor i does not want to be linked to j we have $h_{ij} = 0$. Note that i cannot link with himself ($h_{ii} = 0$).

We say that actors i and j have a link if and only if $g_{ij} = h_{ij} \cdot h_{ji} = 1$. The absence of a link between i and j is thus denoted by $g_{ij} = h_{ij} \cdot h_{ji} = 0$. In other words, it is necessary and sufficient that both i and j want a link to establish the link. We assume this because the type of relations we are interested in here, such as collaborations between firms in R&D or pacts between nations, need the consent of both parties almost by definition. The relations an actor i has can be represented by the row vector $\boldsymbol{g_i} = (g_{i1}, \dots, g_{in})$. The set of the vectors of relations for all n actors constitutes the $n \times n$ matrix of the network of relations $\boldsymbol{g} = (\boldsymbol{g_1}, \dots, \boldsymbol{g_n})$. Since $g_{ij} = 1$ if and only if $g_{ji} = 1$, this matrix is symmetric and the network is an undirected graph. Let H be the set of all possible directed matrices $\boldsymbol{h}$ of desired links of size n and G the set of all possible undirected networks $\boldsymbol{g}$ of size n. Note that above we then defined a relation $g: H \to G$ with $g(\boldsymbol{h}) = \boldsymbol{g}$ (where each undirected network $\boldsymbol{g}$ can be the result of more than one different directed network $\boldsymbol{h}$, but each $\boldsymbol{h}$ has exactly one $\boldsymbol{g}$ associated with it). We will use $\boldsymbol{g}$ as shorthand for $g(\boldsymbol{h})$ throughout the rest of this paper, but be aware of the relation. If we consider a particular network $\boldsymbol{g}$, let then $\boldsymbol{g_{-ij}}$ ($\boldsymbol{g_{+ij}}$) be the same network but with the link between i and j deleted (added). Define $N_i(\boldsymbol{g}) = \{j \in N: g_{ij} = 1\}$ as the set of actors with whom i has formed a link. Let then $\eta_i(\boldsymbol{g}) = |N_i(\boldsymbol{g})| = \boldsymbol{g_i} \cdot \boldsymbol{1}$ be the degree of actor i. In regular networks each actor has the same degree $\eta_i(\boldsymbol{g_{reg}}) = \eta$ (which becomes $n-1$ for the full network).

Actor i can choose from the set of strategies $S_i = X \times H_i$. Define $S = S_1 \times \dots \times S_n$ as the set of strategies of all actors. A strategy profile $\boldsymbol{s} = (\boldsymbol{x}, \boldsymbol{h}) \in S$ specifies the investment level of each actor, $\boldsymbol{x} = (x_1, \dots, x_n)$, and the set of links that each actor desires, $\boldsymbol{h} = (\boldsymbol{h_1}, \dots, \boldsymbol{h_n})$. The payoffs of actor i under strategy profile $\boldsymbol{s} = (\boldsymbol{x}, \boldsymbol{h})$ are then given by

$$\Pi_i(\boldsymbol{s}) = \alpha x_i - \frac{1}{2}\beta x_i^2 + \lambda \sum_{j=1}^{n} \left(g_{ij} x_i x_j\right) - c\eta_i(\boldsymbol{g}), \tag{1}$$

with $\alpha > 0$ and $\partial^2 \Pi_i / \partial^2 x_i = \beta > 0$, meaning that Π_i is strictly concave in own investment. In other words, an actor faces decreasing marginal returns to the individual part of his investments. This ensures that the optimal individual investment level and payoffs are finite. We set the cross-derivatives $\partial^2 \Pi_i / \partial^2 x_i x_j = \lambda > 0$, indicating that if i and j have a link their investments are strategic complements: an increase in j's investment increases the optimal investment level of i. How large this increase is depends on the size of λ. With each link that i makes to another investing actor his own investments become more beneficial. In other words, by adding a link an actor receives a 'complementarity bonus' to his investments with the size of λ times the investment of the newly created neighbor. We could say that λ offsets the decelerating effect of β to some extent. If λ would become too large, it would even prevail over β and actors could form a tie and invest infinitely to earn infinite payoffs. Ballester et al. (2006) therefore require that $\beta > \lambda(n-1)$, which is sufficient if actors invest according to their Nash strategy, i.e., if given the network actors' investments are best responses to the investments of others. However, benefits can still go to infinity if we consider the possibility that actors cooperate and invest more than their Nash strategy. Therefore, we limit ourselves to $\beta > 2\lambda(n-1)$, which implies that there is a finite upper bound on Π_i whatever the network is and whatever actors invest. Finally, the costs of forming and maintaining a link are given by $c > 0$. In our experiment we look at networks consisting of four actors, with $\alpha = 48, \beta = 16, \lambda = 2$, while c is varied.

2.2 Remarks on simplifying assumptions

We assume that actors are homogeneous with respect to the benefits they receive from investing and making links, as well as with respect to the costs of forming links. In real life actors differ, e.g., in their efficiency of investing. As a consequence, actors want to make links not only to actors who invest a lot but who also invest efficiently. Letting actors be heterogeneous introduces many interesting dynamics. However, such dynamics could seriously confound the effects of link costs – the subject of interest here. In order to isolate the effect of link costs we assume homogeneous actors.

We assume that, other things being equal, each additional link gives the same extra benefits to one's investments. However, we can expect that a next link brings less extra benefits than the previous link. For example, it is likely that a company will see some overlap in the know-how that it accesses in a first strategic partner with that in a second strategic partner. Depending on the situation at hand, the simplifying assumption of constant marginal complementary benefits may be more or less realistic. In particular, with our focus on small groups the assumption is less problematic.

In our model each additional link has the same costs attached. One could argue, e.g., that links become more costly the more links an actor has. For instance, monitoring one collaborative relation is relatively manageable for a company, but keeping track of ten such relations requires a complete different organizational structure. Since we study small groups of actors, we argue that assuming constant marginal link costs is reasonable. Moreover, as we will see, the increase in marginal link costs has to be very large in order to change the predicted outcomes.

2.3 Investments and payoffs for a given network structure

For our model, Ballester et al. (2006) show that *given the network structure* each actor's Nash equilibrium investment is proportional to his Bonacich centrality (in Nash equilibrium all actors choose an investment level that is a best reply to the investment levels chosen by the others (Binmore, 2007)). The Bonacich centrality is a network centrality measure that counts for each actor the total number of all possible paths that start at this actor, with the possibility of giving a lower weight to longer paths (Bonacich, 1987). The Bonacich centrality of an actor thus increases when a link is added by or to someone with whom the actor is connected to by a path of any length. The measure reflects the feedback effects within the network: how much an actor invests does not only depend on the investments of his neighbors, but also on the investments of their neighbors, which in turn depends on the investments of their neighbors, and so on. Here, paths of length k are discounted by $(\lambda/\beta)^k$: the larger the ratio λ/β the more interdependent the network is and the more beneficial it becomes to collaborate. Calculating the Bonacich centrality measure by hand is a tedious task. Fortunately, for regular networks where each actor has degree η we can check (see Appendix A.1) that the Nash equilibrium investment x^* of every actor is

$$x^*_{reg} = \frac{\alpha}{\beta - \eta\lambda}. \tag{2}$$

We can calculate how much each actor earns in equilibrium in regular networks by imputing (2) into (1) to obtain:

$$\begin{aligned} \Pi^*_{reg}\left(\boldsymbol{x}^*_{\boldsymbol{reg}} \middle| \boldsymbol{h}_{\boldsymbol{reg}}\right) &= \frac{\frac{1}{2}\alpha^2}{(\beta - \eta\lambda)^2} - c\eta \\ &= \frac{\frac{1}{2}\alpha^2\beta}{\beta - 2\eta\lambda + \frac{\eta^2\lambda^2}{\beta}} - c\eta \end{aligned} \tag{3}$$

Ballester et al. (2006) predict that actors will set their investment level according to their Nash strategy if the network is exogenously given. Although the Nash equilibrium is an obvious solution concept, it ignores the possibility of cooperation by actors. Actors may cooperate by investing according to the socially optimal investment strategy instead of their Nash strategy, which is attractive if it makes nobody worse off, i.e. when it is Pareto efficient. The social optimum for a given structure is reached when actors choose investment levels such that the sum of all actors' payoffs (i.e. social welfare) is highest. If the social optimum does not coincide with the Nash equilibrium, at least one actor must earn more in the social optimum than in the Nash equilibrium. In regular network this means that everybody earns more because by symmetry everybody must invest and earn the same. In other words, the social optimum is also Pareto efficient in regular networks (in irregular network structures it is possible that at least one actor is worse off in the social optimum than in the Nash equilibrium). We can check (see Appendix A.2) that in regular networks the socially optimal investment x^{so} is

$$x_{reg}^{so} = \frac{\alpha}{\beta - 2\eta\lambda}, \tag{4}$$

and by imputing (4) into (1) that each actor then earns

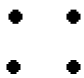
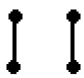
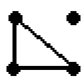
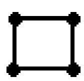
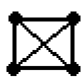
$$\Pi_{reg}^{so}\left(\boldsymbol{x_{reg}^{so}} \middle| \boldsymbol{h_{reg}}\right) = \frac{\frac{1}{2}\alpha^2}{\beta - 2\eta\lambda} - c\eta \tag{5}$$

2.3.1 Investments and payoffs: an example

We calculated all Nash equilibria and socially optimal investments for the parameter configuration and network size as used in our experiment ($\alpha = 48, \beta = 16, \lambda = 2, n = 4$). To get a better feeling for the dynamics in our model, we present in Table 1 the results of these calculations for the regular networks and the triangle, which are illustrative for our model in general.

If we ignore link costs ($c = 0$), we see that investments and payoffs grow increasingly with the degree of the regular network (both in Nash as well as in social optimum). This 'explosion' of the benefits of making a collaborative relation with growing n means that actors are best off

Table 1: Investments and payoffs for selected structures – the experimental case as example

$\alpha = 48, \beta = 16, \lambda = 2, n = 4$		Investments		Benefits without link costs		Payoffs					
						$c = 10$		$c = 30$		$c = 50$	
Networks		Nash	SO	Nash	SO	Nash	SO	Nash	SO	Nash	SO
	$(\eta = 0)$	3	3	72	72	72	72	72	72	72	72
	$(\eta = 1)$	3.43	4	94.04	96	84.04	86	64.04	66	44.04	46
	Isolate	3	3	72	72	72	72	72	72	72	72
	Triangle	4	6	128	144	108	124	68	84	28	44
	$(\eta = 2)$	4	6	128	144	108	124	68	84	28	44
	$(\eta = 3)$	4.8	12	184.32	288	154.32	258	94.32	198	34.32	138

= Pairwise Stable = Socially Efficient

either in the empty network or in the full network, depending on the costs of making a link. Namely, if the benefits of having links are higher than the corresponding link costs in a regular network structure of degree $n > 0$, due to increasing marginal benefits the payoffs must be even higher in the regular structure of degree $n + 1$. By an inductive argument the full network must then have the highest payoffs. If actors fail to cooperate and invest according to their Nash strategy, one can check in Table 1 that the full network gives the highest payoffs as long as link costs are lower than $(184.32 - 72)/3 = 37.44$. The empty network yields the highest payoffs when link costs are higher than 37.44. If actors do cooperate, the full network is more profitable than the empty network as long as link costs are lower than $(288 - 72)/3 = 72$.

2.4 The dynamic context

Let us now leave the context where actors only set their investment level in an exogenously given network structure, and turn to the context where actors additionally decide themselves which links to create. The first context may be seen as a subgame of the latter, which is the complete game as defined in §2.1. However, if we refer to actors investing according to their Nash strategy, we mean their Nash strategy for the subgame as discussed in the previous section, not their Nash strategy in our complete game (which would also involve proposing and deleting links), unless stated otherwise. To identify likely outcomes of our game under different cost conditions (see first research question), we first assume that actors always adapt their investment levels according to their Nash strategy after a change in the network structure (in the next section we will worry about the possibility of actors cooperating by investing more than in Nash). It should not matter which network a group of actors created or which cost condition they are in. We test how realistic this assumption is.

H1. Groups of actors are more likely to invest Nash than invest according to another strategy

a. This does not differ for the network structure that they created
b. This does not differ between the cost conditions they are in.

2.4.1 Pairwise stability

To hypothesize which network structures are likely outcomes of our game, candidates should satisfy some stability criterion. To identify which networks are stable, we use the definition of pairwise stability (Jackson & Wolinsky, 1996) that contains a value function of the network that is based on the assumption that actors instantaneously adapt investments in correspondence to the Nash investments of the new structure.

Definition. Let $\boldsymbol{x}^*$ be the Nash investments given network $\boldsymbol{g}$, and let $\boldsymbol{x}^*_{-ij}$ respectively $\boldsymbol{x}^*_{+ij}$ be the Nash investments given the new network, $\boldsymbol{g}_{-ij}$ respectively $\boldsymbol{g}_{+ij}$. A strategy profile $\boldsymbol{s} = (\boldsymbol{x}^*, \boldsymbol{g})$ is *pairwise stable* if and only if for all $i, j \in N$:

(i) $\Pi_i(\boldsymbol{x}^*, \boldsymbol{g}) \geq \Pi_i(\boldsymbol{x}^*_{-\boldsymbol{ij}}, \boldsymbol{g}_{-\boldsymbol{ij}})$,

(ii) if $\Pi_i(\boldsymbol{x}^*_{+\boldsymbol{ij}}, \boldsymbol{g}_{+\boldsymbol{ij}}) > \Pi_i(\boldsymbol{x}^*, \boldsymbol{g})$, then $\Pi_j(\boldsymbol{x}^*_{+\boldsymbol{ij}}, \boldsymbol{g}_{+\boldsymbol{ij}}) < \Pi_j(\boldsymbol{x}^*, \boldsymbol{g})$.

This definition says that a network is pairwise stable if – given that the rest of the structure remains the same – (i) no actor wants to delete any link (because his payoffs are at least as high in the structure with the link as in the structure without the link), and if (ii) no pair of actors want to form a link (because at least one actor receives lower payoffs in the structure with the link than in the structure without the link). All network configurations that are pairwise stable for our experimental case are the dark-shaded configurations in Table 1. A stability concept based on pairwise interaction is useful because it acknowledges that the consent of both actors is needed for a link to be formed, as opposed to, e.g., a concept based on Nash equilibrium. Therefore, the pairwise stability concept is on one hand much stricter than the Nash equilibrium concept (be aware: this time in the sense of the complete game). For example, in the low cost condition the empty network with everybody investing 3 is not pairwise stable (each pair would create a link) but it is Nash stable (no actor can add a link by himself given that the strategies of the others remain the same). On the other hand, the pairwise concept is less strict than the Nash concept because in the Nash concept actors can delete more than one link. For example, in the intermediate cost condition the triangle is pairwise stable but not a Nash equilibrium.

2.4 Coordination problems and link costs

We illustrate, again with our experimental case, the coordination problems that may arise when actors try to reach the most profitable network together. Still assuming that actors invest according to their Nash strategy and do not cooperate, we saw that actors are best off if they create the full network as long as link costs remain below the threshold (here: $c < 37.44$). The full network cannot be created at once, but pairs of actors successively need to create the necessary links and adapt their investments. We included a low cost condition ($c = 10$) where this is unproblematic as a baseline: because the benefits of creating a link always outweigh the costs, the incentives within each pairwise interaction are such that we expect actors to create all links and thus automatically end up in the full network. We could also say, in the low cost condition only the full network is pairwise stable (see dark shaded box in Table 1), which leads to the following prediction.

H2. In the low cost condition ($c = 10$), actors are more likely to coordinate on the full network than on any other network structures.

However, not for all cost levels below the threshold it is unproblematic to coordinate the steps that need to be taken by pairs of actors such that the full network is created. The problem may arise that within a pairwise interaction at least one of the actors becomes worse off by creating a necessary link. For example, the dyad is inevitably the first step in creating the full network, but if $c = 30$ both actors earn maximally 66 in this structure while investing separately yields them maximally 72 (see Table 1). Therefore, if actors fail to see the bigger picture and are only concerned with their short-term payoffs that can be earned within the pairwise interaction, they will not create the link and stay in the empty network. In other words, the empty network is pairwise stable. However, also the full network is pairwise stable because each actor would become worse off by deleting an existing link (the actor would then earn 78.0 in the new structure – not in Table 1). Moreover, the triangle is pairwise stable: an actor in the triangle would become worse off by deleting a link (earns 67.1 – not in Table 1), while the isolate would not become better off by creating a link (earns 71.3 – not in Table 1).

We see that for the intermediate cost condition it is less straightforward to predict which network configuration actors will coordinate on since there are three candidates. We do not expect actors to coordinate on the triangle because actors earn less than in the empty network (see Table 1), and actors can independently delete their two links (put otherwise: as pointed out above, the triangle is not a Nash equilibrium in the complete game). This leaves the empty and the full network as remaining candidates, of which the full network yields all actors higher payoffs. If we really belief that no actor can calculate costs and benefits beyond the effects of the creation or deletion of a single link, we would predict that actors never get out of the empty network. We do not really belief this. On the contrary, we expect that many actors realize that the full network yields the highest payoffs. However, the problem is that if there is only one actor in a group who does not look further than the pairwise interaction the consequences for the rest of the group are considerable. The remaining three actors can collaborate at most in the form of the triangle, but they are wise to break off all ties since in the triangle they are worse off than in the empty network. In other words, one nearsighted actor would cause a whole group to end up in the empty network. We therefore expect that groups of actors will sometimes succeed and sometimes fail in solving the coordination problems.

H3. In the intermediate cost condition ($c = 30$), actors are more likely to coordinate on the empty network or on the full network than on other network structures.

We would thus expect that if a group consists of actors who are able to look ahead further than the pairwise interaction and who can anticipate well on what the others will do, this group is more likely to solve the coordination problems. Let us call such actors 'foresighted'.

H3a. In the intermediate cost condition, the full network will be reached more often relative to the empty network when the group of actors is more foresighted on average.

Actors can gain more insight in the situation over time through several learning mechanisms (Selten, 1993), which makes solving the coordination problems more likely (Camerer et al., 2002). In our experiment, subjects play the intermediate cost condition for multiple rounds. Subjects are likely to gain more insight (certainly not less) as they play more rounds.

H3b. In the intermediate cost condition, the full network will be reached more often relative to the empty network the more rounds are played.

Moreover, half of the subjects play the intermediate cost condition after they played the low condition (low-to-high ordering) and the other half after they played the high cost condition (high-to-low ordering). By first playing the low cost condition, subjects are likely to gain insight in the benefits of collaborating in the full network.

H3c. In the intermediate cost condition, the full network will be reached more often relative to the empty network in the low-to-high ordering as compared to the high-to-low ordering.

Actors who are themselves less foresighted, can learn from and imitate those that understand the problem situation better (Camerer et al., 2002). When actors can see how much others invest, it is easier to learn from each other than when actors do not have this information. Moreover, actors can attract others to link to them by increasing their investments as a signal that they are interesting partners.

H3d. In the intermediate cost condition, the full network will be reached more often relative to the empty network when actors have information about the investments of others than when they do not have this information.

In the high cost condition, collaboration stands a low chance of succeeding. Even if all actors are able to look ahead further than the pairwise interactions the full network is not pairwise stable, only the empty network is. In order for collaboration to be profitable, actors would need to overcome an extra problem, namely the cooperation problem to which we will turn in the next section.

H4. In the high cost condition ($c = 50$), actors are more likely to coordinate on the empty network than any other network structure.

2.6 Cooperation problems and information availability

Linked actors face a Prisoner's Dilemma (PD) structure in setting their investments, where investing according to their Nash strategy is 'defecting' and investing according to their socially optimal strategy is 'cooperating'. In a one-shot PD everybody has a dominant strategy to defect, which makes the predictions by Ballester et al. (2006) that everybody invests Nash understandable. However, the situations we are interested in most likely consist of repeated interactions: a R&D joint venture, for example, is an ongoing relation in which the level of investment by the partners can be altered during the collaboration. Moreover, it is often unknown when the joint venture will exactly end. Also, the companies may want to work with each other on other projects in the future again. Together, we could argue, this makes the interactions as if they are infinitely repeated. It has been argued and shown that cooperation can form a stable equilibrium in infinitely iterated PD encounters through conditional strategies (Taylor, 1987; Raub & Weesie, 1990; Putnam, 1993). An actor can cooperate conditionally on the actions of others: he contributes at the current and/or future time points if and only if the other actor(s) contributed at the previous time point. An actor may even decide to sever a relation altogether if a neighbor is caught free-riding (Ule, 2005). In our model this is often not a credible threat, because in many cases an actor becomes worse off himself by excluding a free-rider. However, it has been shown that actors punish even if this constitutes a material loss for them, the argument being that punishment also brings 'emotional gains', e.g., because of a human disposition to fair outcomes (Fehr & Gächter, 2002).

To make ones strategy conditional upon the strategy of the others, one must see what the strategy of the others is. With perfect information availability, if a neighbor lowers his investments, an actor can immediately react by also lowering his investments or severing the tie with this neighbor. The threat alone will prevent a rational actor from defecting if the gains of mutual cooperation in the future are larger than the short-term gains of free-riding in the present (Raub & Weesie, 1990). However, in collaborations such as joint ventures it is often unclear how many resources exactly a partner is devoting to the common project. Since such information is imperfectly available an increase or decrease of investments by a partner will not necessarily be detected. The threat of provoking a partner to defect if one defects himself is not as imminent anymore and an equilibrium of cooperation through conditional strategies becomes less sustainable. This leads to the following prediction.

H5. The level of cooperation will be higher when subjects have information about the investments of others than when they do not have this information.

Our arguments for this prediction are so far based on the assumption that all actors are perfectly rational and expect others to be so as well. Let us now consider again – as we did in discussing the coordination problems above – the more refined assumption that some actors understand the problem situation they are in better than others (Selten, 1993). Some actors may be simply unaware of the possibility of cooperation. For example, in the full network if everybody invests Nash, the increase in investments by one actor leads to significantly lower earnings for this actor, which may trigger a nearsighted actor to conclude that this is necessarily a wrong move (Macy, 1991). In other words, actors must really have the insight that increasing investment above Nash can make them better off. One way to gain this insight for unaware actors is learning from actors who are aware (Camerer et al., 2002). If a nearsighted actor sees everyone around him investing and earning more than in Nash, he may come to understand the incentive structure or simply start imitating the others. Learning by nearsighted actors from foresighted actors is only possible if the information about others' investments and earnings is available. Therefore, also if we do not assume that all actors are perfectly foresighted (but actors do learn) we come to the prediction of H5. Moreover, we test whether groups consisting on average of more foresighted subjects indeed cooperate more often.

H6. The level of cooperation will be higher when the group of actors is more foresighted on average.

We expect subjects to gain more insight the more rounds they play, for example because the opportunities to learn from others are likely to increase.

H7. The level of cooperation will be higher the more rounds are played.

Finally, if actors start out in the condition where they have information, they can use the insight they are likely to gain in these rounds subsequently in the more difficult context where they do not information anymore. Starting in the no information condition will not give much of a headstart in the information condition.

H8. The level of cooperation will be higher if groups start with having information about others' investments followed by having no information as compared to starting with no information followed by information.

3. Experimental Design

3.1 Data Collection

In total 12 experimental sessions were conducted in December 2008 at the ELSE laboratory of the Utrecht University. A total of 1420 subjects from a self-selected database were invited to participate in a study called “Investing in networks” using the Online Recruitment System for Economic Experiments (ORSEE) (Greiner, 2004). They were told that earnings would be around €16, but that exact earnings depended on their own and others’ decisions. A total of 238 subjects signed up, of which 212 actually participated in one of the sessions. However, during one of the sessions there was a network crash. The 12 subjects participating in this session were not able to finish playing all rounds and neither to fill in the questionnaire at the end. Nevertheless, the rounds that they did play will be used in the analyses. The other sessions consisted either of 16 subjects (in 5 sessions) or 20 subjects (in 6 sessions). Since the experimental game requires exact groups of four, some subjects showed up but were not able to participate. The majority of subjects were students at Utrecht University from a wide range of disciplines and nationalities, although non-students also participated. The group of 200 subjects that completed the experiment was between 17 and 39 years old (with a mean age of 21.7), for 67.5% female and 77.0% Dutch.

3.2 Procedure

Upon entering the computer laboratory subjects were randomly assigned to a cubicle. After a short oral introduction (mentioning practicalities) the subjects received printed instructions in the language of their choice (English or Dutch). These instructions explained to the subjects that they could ask questions at any time and that 150 points in the experiment equaled a €1 pay. Above all, the instructions explained how the game was to be played and how the choices of subjects in the game influenced their earnings (see Appendix B for the English instructions and Appendix C for the Dutch instructions). Once finished reading the instructions, subjects chose on their computer screen to play in English or in Dutch, which meant the start of the actual game (for a description see the next section).

After playing the game there was an additional task – a “Beauty Contest” (Nagel, 1999) – in which subjects were asked to enter a number between 0 and 100. They were told that the person entering the number closest to *half* of the average of all numbers entered would win this contest and receive an additional €5. The "Beauty Contest" was included to measure how far actors look ahead and how far they expect others to look ahead. Finally, subjects were asked to complete a standard questionnaire covering background information and social preferences (the latter not used in this research) after which they received their monetary earnings. This whole procedure lasted around 1.75 hours and earnings resulting from playing all rounds of the game ranged from €11.50 to €20, with mean earnings being €17.19 (this excludes the additional earnings of the "Beauty Contest" winner). The 12 subjects that did not complete the experiment were paid the expected average of €16 each.

3.3 Description of the computerized game

The model as presented in §2.1 was operationalized in a computerized game for four actors and with $\alpha = 48, \beta = 16, \lambda = 2$ using the z-Tree software (Fischbacher, 2007). The game consisted of 6 different scenarios: in a scenario one of the 3 link cost conditions ($c = 10, 30, 50$) is combined with one of the 2 information conditions (information available about others' investments and payoffs, no such information available) (see Table 2). The order in which the subjects played the 6 scenarios differed between sessions. In total there were 4 different orderings each presented in 3 sessions (see Table 2). Each scenario consisted of 5 rounds: 1 trial round to gain experience with the scenario and 4 rounds that actually mattered for a person's final earnings. In total the subjects thus played $6 \times 5 = 30$ rounds of which 24 rounds earned the subjects money.

Subjects were randomly drawn with three other subjects into a group of four at the start of each round. Each subject in a group was depicted as a circle on the screen (see Figure 1). Each subject saw him or herself as a blue circle, while the others in the group appeared as black circles. The instructions stated that at the beginning of a new round subjects were randomly shuffled into new groups. Therefore, actors knew that the persons they were playing with in one round were very likely to be different from those they were playing with in another. During the entire experiment actors were not allowed to talk with each other.

Since points were converted to actual money, subjects are expected to have a real incentive to try to earn as many points as possible. How many points a subject earned in a round only

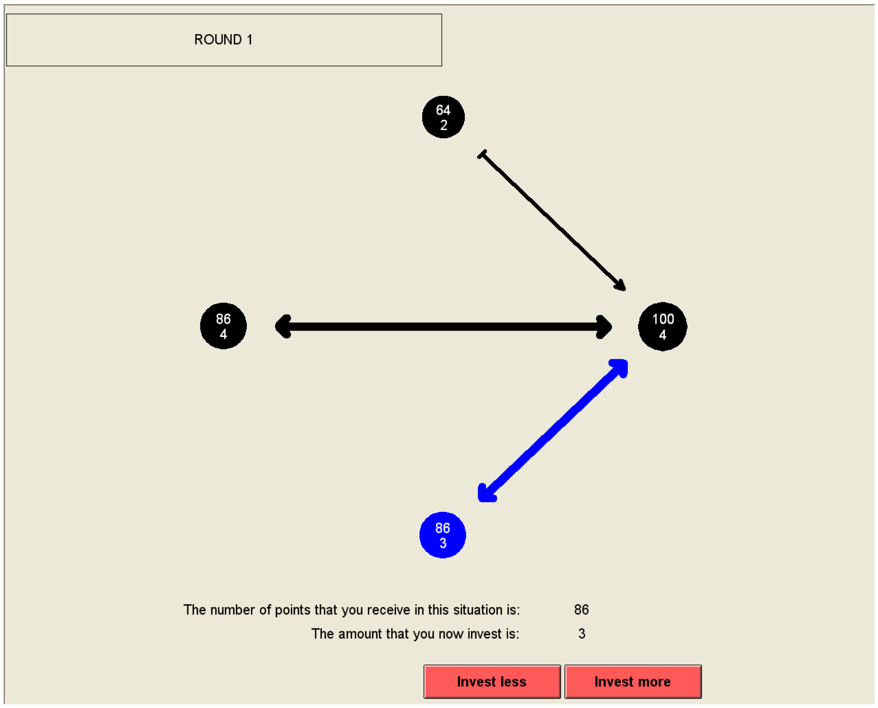
Table 2: The six scenarios and four orderings of scenarios that subjects faced

		Scenario Number					
Ordering	Conditions	1	2	3	4	5	6
1	Link costs, Information	10, yes	30, yes	50, yes	10, no	30, no	50, no
2	Link costs, Information	50, yes	30, yes	10, yes	50, no	30, no	10, no
3	Link costs, Information	10, no	30, no	50, no	10, yes	30, yes	50, yes
4	Link costs, Information	50, no	30, no	10, no	50, yes	30, yes	10, yes

depended on the situation as it was at the end of that round. Actors knew that each round ended at a random and unknown moment between 90-120 seconds after the start of that round. Actors' earnings depended on their own investment level, the number of neighbors they had and how much their neighbors invested, and how high link costs were in that particular scenario.

Subjects could set their investment level in steps of whole numbers by clicking the 'invest more' and 'invest less' buttons on their screen (see Figure 1). The instructions contained a table which presented how many points were earned for all integers from 0 to 14 when a subject did not have any links and invested individually. The investments of a subject became worth more when linked to another in the group who also invested: in addition to the individual earnings a bonus of 2 × own investment level × neighbor's investment level was received. At the beginning of a new scenario it was stated how much link costs were. The individual earnings from investing, the joint earnings from being linked to another investor and the associated link costs together formed the total earnings. In each circle one could see the entire round how much that subject invested at that moment and how much points this subject would earn in total if the round would finish at that moment. Also, circles increased in size when more points were about to be earned. The exceptions were the three no information-scenarios, in which the circles of the other

Figure 1: Screen shot of the computerized game



subjects were completely black and the circles did not change in size. In these scenarios, a subject only saw this information for own investments and earnings.

A subject could propose a link to another subject by clicking on the circle of this subject: a one-sided arrow would appear to show the desire for a link. A link would be established if the other also clicked on the circle of the proposing subject: the arrow then changed into a thick double-headed arrow. Proposals for links did not earn or cost anything, only fully established links affected earnings. Links and proposals for links could be removed at any time by clicking on the circle of the other again. Since earnings only depended on the final situation, subjects were only ‘charged’ for the links they were involved in when a round ended.

3.4 Specifics of the experimental design

We made several choices in the design of our computerized game that deserve further attention. First of all, many experiments have a simultaneous-move discrete time design, whereas our subjects were able to make their choices in continuous time. In the former, subjects decide, e.g., at the same moment on their strategy, then the results of these choices are made known to them, and then they get another opportunity to simultaneously choose their strategy, and so on. In a continuous time design actors can change their strategy at any given moment, as often as they want and not necessarily at the same moment as other actors. The advantage is that subjects do not need to infer what others are going to do as is the case when subjects have to move at the same time. When players have to move in rounds, many may change their strategy simultaneously, which makes reaching any stable configuration difficult (Berninghaus et al., 2008). In continuous time each choice of a subject is immediately common knowledge for the whole group, so subjects always know what they are reacting to. Moreover, since the effect of an action is updated immediately, a subject can promptly revoke an action if it turns out to be unsatisfactory. Together with the facilitation of sending signals to group members, subjects thus have more possibilities to coordinate individual actions (Berninghaus et al., 2006). A final advantage is that this design is more true to reality: in the situations we attempt to model actors can take their decisions in continuous time as well.

Second, although virtual earnings are updated instantly, the actual payoffs are not calculated in continuous time but only at the end of the round. This makes that subjects can display a great deal of costless trial-and-error in changing investments and links. In real life it is of course not possible to, e.g., build and break off links without any costs involved. Moreover, the coordination problem as described in the theory section is reduced to some extent. We argued here that in some cases actors have to create networks in which they are temporarily worse off in order to get to networks in which they are much better off. In our design, subjects are strictly speaking not worse off in such intermediate networks since only the end situation matters. However, we regard this simplification less problematic as it may seem at first sight. Since subjects did not know the exact ending of a round, there was the threat of ending up in an intermediate network configuration in which a subject was worse off than in the empty network. We expected that the threat of being worse off would already make for a real coordination problem. Indeed, observing the behavior in our experiment shows that subjects are rather sensitive to the changes in their earnings (even though they are virtual) and that it was not necessarily easy to coordinate actions.

Third, another simplification we made is that the investment level can only be set at an integer. Therefore, setting the investment level at the Nash equilibrium as presented in the theory section is not always possible. In most instances this leads to merely quantitative differences. One qualitative difference is the disappearance of the (small) cooperation problem that theoretically exists in some of the sparser networks (dyad, 2 dyad, 2-star, 3-star): due to the rounding the Nash equilibrium investments and socially optimal investments coincide. Another consequence is that some network structures display multiple Nash equilibria in investments, although theoretically there is a unique equilibrium for each structure.

Finally, as argued, we regard our model representative for situations involving relatively small groups. We consider groups of four to be small, yet large enough to yield sufficient interesting dynamics.

4. Description experimental results

Table 3 shows the number of times that a group of subjects ended up in a particular network structure in (the different conditions of) the experiment. We see that groups mostly create either the empty or the full network, and not so much the other possible structures in between. We may conclude – in correspondence with the hypotheses – that actors are most likely to coordinate on the full network in the low cost condition (H2), on the empty or the full in the intermediate cost condition (H3), and on the empty network structure in the high cost condition (H4). These patterns are so clear-cut that there is little added value in additional significance tests. The estimation of parameters becomes even problematic exactly because the outcomes are so strict. Thus, pairwise stability as defined is a strong predictor for at least the resulting network structure. Therefore, the focus of our analyses will be on testing the expected patterns in the data that are less apparent.

Table 4 contains information about the observed investment profiles of the groups given the network structure they created. Since the network structures between the empty and the full network are observed so little, we decided to collapse them into a category 'other'. We distinguish between groups where actors invest according to their Nash strategy, groups where actors cooperate, and a rest category for all other investment profiles.

It is rather stringent to require that all four subjects in a group invest exactly according to their Nash strategy in order to classify the group as 'Nash'. It is not unreasonable to allow for the possibility that subjects mean to invest Nash but make a small mistake (for example, because they are caught out by the time). With this in mind we also qualify a group as *Nash* if at most one subject in the group deviates only one from the Nash investment.

Table 3: Observed network structures in total and per condition for all 24 paid rounds

	$c = 10$			$c = 30$			$c = 50$			All link costs		
Network Structure	Info	No Info	Total	Info	No Info	Total	Info	No info	Total	Info	No Info	Total
Empty	0	0	0	46	49	95	195	192	387	241	241	482
Dyad	0	0	0	9	12	21	10	13	23	19	25	44
2 Dyad	0	0	0	0	0	0	0	1	1	0	1	1
2-star	0	0	0	4	5	9	1	1	2	5	6	11
Line	0	0	0	0	1	1	0	1	1	0	2	2
Triangle	1	0	1	5	7	12	1	3	4	7	10	17
3-star	0	0	0	1	0	1	0	0	0	1	0	1
Square	0	0	0	0	0	0	0	0	0	0	0	0
Stem	4	3	7	8	4	12	0	0	0	12	7	19
D-Box	8	5	13	21	16	37	0	0	0	29	21	50
Full	199	192	391	118	115	233	5	1	6	322	308	630
All	212	200	412	212	209	421	212	212	424	636	621	1257

We define *cooperation* to take place when at least two actors who are linked invest more than in Nash and both benefit from investing more. We believe it is central to cooperation that both actors become better off because they invest more than their Nash strategy. Therefore we exclude those cases where two linked actors invest more than in Nash, but they are not both better off (e.g., because at least one of them invests too much, or they are linked to a third actor who invests too little). Also, we exclude cases where the increase in payoffs of both actors is not really because of their own increase in investment, but because, e.g., they are linked to a third actor with an extremely high investment level.[1]

[1] Such a third actor 'sponsors' the pair of actors by sacrificing his own payoffs. To exclude such cases, we require that the social welfare of the two cooperating actors and all their neighbors must be at least as high as would be the case if all those actors invested according to their Nash strategy.

Table 2: Observed investment profiles in total and per condition for all 24 paid rounds

Network Structure *Welfare*	$c = 10$ Info	No Info	Total	$c = 30$ Info	No Info	Total	$c = 50$ Info	No info	Total	All link costs Info	No Info	Total
Empty												
rest	0	0	0	3	3	6	4	7	11	7	10	17
Nash	0	0	0	43	46	89	191	185	376	234	231	465
coop	-	-	-	-	-	-	-	-	-	-	-	-
all	0	0	0	46	49	95	195	192	387	241	241	482
Other												
rest	8	6	14	10	11	21	6	11	17	24	28	52
Nash	3	2	5	26	33	59	5	8	13	34	43	77
coop	2	0	2	12	1	13	1	0	1	15	1	16
all	13	8	21	48	45	93	12	19	31	73	72	145
Full												
rest	30	35	65	15	15	30	0	1	1	45	51	96
Nash	136	149	285	81	89	170	0	0	0	217	238	455
coop	33	8	41	22	11	33	5	0	5	60	19	79
all	199	192	391	118	115	233	5	1	6	322	308	630
All												
rest	38	41	79	28	29	57	10	19	29	76	89	165
Nash	139	151	290	150	168	318	196	193	389	485	512	997
coop	35	8	43	34	12	46	6	0	6	75	20	95
all	212	200	412	212	209	421	212	212	424	636	621	1257

We see in Table 4 that – in line with H1 – groups invested extremely often Nash: in 997[2] of the 1257 cases (i.e., 79%). Especially in the empty network many groups invest Nash (465, 96%

[2] If we require all four actors to invest exactly according to their Nash strategy we would have 786 cases. We also performed our analyses using this strict definition. This does not lead to qualitatively different conclusions.

of 482), followed by the full network (455, 72% of 630), and the ‘other’ networks (77, 53% of 145). In the results section we test whether these differences are a reason to reject the expectation that it should not matter which network is created (H1a).

Cooperation takes place on a moderate scale: only 95 times out of 1257 cases (8%). We see these cases as attempts to reach the socially optimal investment levels. The exact socially efficient network configuration (the full network where everybody invests 12) was realized by just one group. Cooperation occurs by far most in the full network where the possible gains of cooperation are also largest (79 times versus 16 in ‘other’ networks). Conditional on the network that was created, cooperation succeeds almost equally often in the full network (13%) and in the other networks (11%). Cooperation is theoretically not possible in the empty network and by design (see §3.4) not in some of the ‘other’ networks. Groups created 718 times a network in which cooperation is possible. With the 95 successful cases, this means thus that groups were able to materialize this potential 13% of the time. In line with H5, cooperation was realized more often in the information condition (75 times) than in the no information condition (20 times). In the results section we will analyze in more detail which factors promote cooperation.

5. Analyses

5.1 Strategy

We test our hypotheses using the conditional logit model (CLM). This model is appropriate when dealing with a dependent variable with nominal outcome categories as we are (Scott Long, 1997). In our case, the outcomes that a group of actors can realize at the end of a round are, e.g., ‘the empty network where everybody invests Nash’, or ‘the full network where cooperation takes place’. In the CLM characteristics of the outcomes are used to predict the outcome that is realized. The likelihood of one outcome is always evaluated relative to another outcome, the reference category. To test H1, for example, we look whether an outcome in which everybody invests Nash is more likely to occur than outcomes characterized by another investment profile. The network structure is another example of a characteristic of the outcomes.

Formally, the predicted probability that outcome m of the J outcomes is observed for the ith observation can be written as:

$$\Pr(y_i = m|\boldsymbol{x_i}) = \frac{\exp(\boldsymbol{bx_{im}})}{\sum_{j=1}^{J}\exp(\boldsymbol{bx_{ij}})}.$$

The predicted probability is a function of the linear predictors $\boldsymbol{bx}$, where x represents an independent variable of which the effect is equal on all outcome categories, but its values differ for each outcome. In our case these take the form of dummies such as whether an outcome is 'Nash' or not, or consists of 'the full network' or not.

Group characteristics – such as which link cost condition the group is in, how many rounds the actors in a group have played or how foresighted the group is on average – cannot directly be used as predictors, since their values do not differ for the outcomes. However, we can still answer questions such as 'do groups invest Nash equally often in the different cost conditions?' (see H1b). For this end, we must interact the outcome characteristic 'Nash' with the group characteristic 'cost condition'. This way we allow the effect of Nash to differ for the different cost conditions.[3]

The CLM is often referred to as the discrete choice model, since it was developed in economics to predict consumer choice between different products (McFadden, 1973). Presenting the CLM here as a discrete choice model would be misleading since the groups do not really choose the outcomes, but the outcomes are the result of the combination of choices made by the individuals within the group. It would be more elegant and correct to include the individual level, but since this is not simply done and we are interested in this study mostly in group level factors and outcomes we simplify by leaving out the individual level.

The CLM assumes that observations are independent, which is likely to be violated in our dataset. Our observations – the groups – are nested within sessions: the groups within a session may share characteristics that they do not share with the groups in another session. A multilevel

[3] The CLM is mathematically equivalent to the more common multinomial logit model (MNLM). In the MNLM the effects of independent variables are allowed to differ between the outcome categories, whereas in the CLM the effects on the outcomes are constant but their values are allowed to differ between outcomes. Interacting independent variables that do not differ in values between the outcomes with the outcome categories of the dependent variable is equivalent to allowing the effects of independent variables to differ between outcome categories as in the MNLM. Therefore, the models we use are sometimes called 'mixed models' (Scott Long, 1997).

model that controls for the dependencies between groups would be most appropriate. Dependency between groups is most likely the result of the fact that groups within a session are randomly formed out of the same set of individuals: within a session the same individuals appear in multiple observations. However, modeling such dependencies between groups correctly is far from trivial and outside the scope of this study.[4]

5.1.1 Dependent and independent variables

In principle, our outcome set could consist of all strategy profiles (i.e., all possible network structures multiplied by all possible investment profiles). However, we collapse some of these different outcomes into one category quite similar as we did in the description of the experimental results. First, we test H1-H1b using a set of six outcomes: (the empty network with a Nash investment profile; empty with an investment profile other than Nash; full Nash; full non-Nash; other Nash; other non-Nash). Second, we test H3a-d with the same six outcome categories. Finally, we test H5-8 using three outcome categories: (Nash, cooperation, rest). The first set was tailored to test hypotheses mostly concerned with the network structure of the outcomes, and the second set to test hypotheses focusing on cooperation.

As a measure of how foresighted subjects are, we looked at how well actors performed in the Beauty Contest (see §3.2). The subjects were ranked according to how close they got to the winning number, with the winner ranked 1, the second closest ranked 2, and so forth. This score was divided by the total number of contestants. This gives a score roughly between 0 and 1. We subtracted this score from 1 to assure that higher scores mean more foresighted subjects. The average score of the four group members was taken (which ranged from .088 to .828 with a mean of .473). We coded 'the number of rounds played' to start at 0 – rather than 1 – so that the first round forms the reference category.

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[4] Clustering the observations by sessions is another method, which assumes that the sessions are independent and not the observations within. We were able to use clustering for our smaller models. The standard errors typically increase, but we would not come to qualitatively different conclusions for these models. Model identification becomes problematic for the larger models because we only have 12 clusters (the method is most appropriate when one has many small clusters). Therefore we present the models without clustering, but the smaller models with clustering give an indication that not controlling for dependency of observations is not very harmful for our results.

5.2 Results

As predicted in H1, groups are – given the network structure they created – much more likely to invest according to their Nash strategy than all other possible strategies together (b = 1.344, S.E. = .070, p<.001; model not shown here). We expected that the type of network that was created would not be related to whether a group invests Nash or something else (H1a). However, as we see in model 1 in Table 5, Nash investment is significantly lower in the full network (see

Table 5: Conditional logit. Nash investments for different network structures (model 1) and cost conditions (model 3)

	Model 1[a]			Model 2[b]			Model 3[b]		
	b	(S.E.)	p	b	(S.E.)	p	b	(S.E.)	p
Nash	3.309	.247	.000	3.309	.247	.000	3.785	.381	.000
Full	2.332	.254	.000	2.961	.275	.000	3.357	.398	.000
Other	1.386	.271	.000	2.566	.293	.000	2.951	.384	.000
Nash×Full	-2.353	.262	.000	-2.353	.262	.000	-2.738	.395	.000
Nash×Other	-3.185	.298	.000	-3.185	.298	.000	-3.519	.370	.000
Full×c10				17.962	629.6	.977	18.524	848.6	.983
Other×c10				15.956	629.6	.980	16.495	848.6	.984
Full×c50				-5.064	.429	.000	-5.228	.445	.000
Other×c50				-2.503	.237	.000	-2.772	.294	.000
Nash×c10							-.137	.173	.431
Nash×c50							-.567	.332	.088
N		1257			1257			1257	
Log Likelihood		-1756			-1191			-1189	
Chi2[c]		991.73			2123.17			2126.53	
Df		5			9			11	

[a] Reference: non-Nash, empty network

[b] Reference: non-Nash investment profiles, empty network, intermediate link costs ($c = 30$)

[c] LR test statistic for H_0 : $\boldsymbol{b}$ = 0.

Nash×Full) as well as in other networks (see Nash×Other) than in the empty network. In turn, in other networks, Nash investment is significantly lower than in the full network (b = -3.185 – -2.353 = -.831, S.E. = .189, p<.001). In the empty network subjects can optimize their investment level independent of what the others do. Therefore, it is understandable that subjects succeed more often in setting their optimal investment level in the empty network than in all other networks, where subjects have to coordinate their actions with those of the others. Moreover, in the full and some of the other networks there exists the possibility to cooperate: subjects may thus purposively try to coordinate their actions away from the Nash equilibrium.

If we want to test whether the occurrence of Nash investment differs per cost condition, we have to control for the fact that the type of networks created is unequally likely for the cost conditions and that the likelihood of Nash investment in turn differs for the type of network. These controls in model 2 uphold our earlier confirmation of H2-H4 based on the descriptive results: the higher the link costs the less often a group creates the full network compared to the empty network (see Full×c10, Full×c50). Since the empty network was not even created once in the low cost condition, the model has difficulty estimating the standard errors (see Full×c10, Other×c10). In accordance with H1b, we see in model 3 that there are no compelling reasons to believe that the Nash investment occurs more often in the low cost condition (see Nash×c10) and the high cost condition (see Nash×c50) than in the intermediate cost condition. Moreover, we do not find that the model with the Nash investment differentiated for the cost conditions (model 3) fits better than the model where the Nash investment is assumed to be equally likely for the different cost conditions (model 2) (LR chi2(2) = 2126.53 – 2123.17 = 3.36, p(2-sided) = .187).

5.2.1 Solving the coordination problem

In this section we test possible explanations (H3a-d) why some groups would solve the coordination problems in the intermediate cost condition (i.e., create the full network) and others do not (i.e., create the empty network). In Table 6 we see that overall the full network is significantly more often created by groups than the empty network in the intermediate cost condition (see Full in model 4). However, if we add how foresighted the groups on average are, the number of rounds played, the ordering of cost conditions, and whether information about others' was available, we see that we can refine this conclusion. Groups that are not foresighted

Table 6: Conditional logit. Effects on solving the coordination problem in $c = 30$

	Model 4[a]			Model 5[b]		
	b	(S.E.)	p	b	(S.E.)	p
Full	.879	.123	.000	-1.521	.544	.005
Other	-.114	.146	.451	-1.579	.635	.013
Full×Foresight *(0-1)*				2.236	.984	.023
Other×Foresight *(0-1)*				2.191	1.159	.059
Full×Round *(0-7)*				.301	.060	.000
Other×Round *(0-7)*				.057	.070	.416
Full×Low/High				.678	.262	.010
Other×Low/High				.510	.307	.097
Full×Info				.051	.261	.845
Other×Info				.109	.306	.721
N		400			400	
Log Likelihood		-673			-649	
Chi2[c]		86.73			134.46	
Df		2			10	

[a] Reference: empty network

[b] Reference: empty network, average foresight = 0, 1st round, high/low ordering, no information

[c] LR test statistic for H_0 : $\boldsymbol{b} = 0$.

at all and play their first round in the high to low ordering while they have no information, create the full network less often than the empty network (see Full in model 5). In line with H3a, the more foresighted the subjects in a group are on average, the better able they are to reach the full network together (see Full×Foresight). We also find that groups create the full network more often when they have played more rounds (see Full×Round). This supports the idea that as subjects gain experience with the coordination problem, they are better able to solve it (H3b). Moreover, we find evidence for the expectation (H3c) that groups who are in the low to high ordering more often reach the full network (see Full×Low/High). We do not find convincing evidence for the expectation (H3d) that having information about the investments that others make increases the ability of groups to solve the coordination problem (see Full×Info).

Table 7: Conditional logit. Effects on solving the cooperation problems.

	Model 6[a]			Model 7[b]		
	b	(S.E.)	p	*b*	(S.E.)	p
Cooperation	-1.904	.160	.000	-4.762	.653	.000
Rest	-1.740	.149	.000	-1.382	.391	.000
Cooperation×c10	.027	.229	.907	-.007	.237	.978
Rest×c10	.433	.197	.028	.420	.198	.034
Cooperation×c50	-2.221	.441	.000	-2.317	.446	.000
Rest×c50	-1.041	.261	.000	-1.038	.262	.000
Cooperation×Info				1.471	.288	.000
Rest×Info				-.078	.182	.668
Cooperation×Foresight *(0-1)*				1.846	.847	.029
Rest×Foresight *(0-1)*				.148	.678	.828
Cooperation×Round *(0-23)*				.072	.020	.000
Rest×Round *(0-23)*				-.035	.013	.008
Cooperation×Info/No Info				.230	.278	.408
Rest×Info/No Info				-.028	.182	.877
N		1200			1200	
Log Likelihood		-730			-697	
Chi2[c]		1175.75			1242.43	
Df		6			14	

[a] Reference: Nash investment profile, intermediate link costs ($c = 30$)

[b] Reference: Nash investment profile, intermediate link costs ($c = 30$), no information, average foresight = 0, 1st round, no info/info ordering

[c] LR test statistic for $H_0 : \boldsymbol{b} = 0$.

5.2.2 Solving the cooperation problems

In this section we test which factors promote cooperation (H5-H8). In Table 7 we see that in all cost conditions cooperation is less often successful than investing Nash (see model 6). For the low cost condition and the intermediate cost condition the level of cooperation is comparable (see Cooperation×c10), but it is much lower in the high cost condition (see Cooperation×c50; also apparent in descriptive Table 4). Additionally, we see that all other investment profiles also occur less often than the Nash investment profile (see Rest, Rest×c10, Rest×c50).

We find support for the idea (H5) that cooperation is more easily achieved when actors have information about what the others in their group invest and earn than when actors cannot directly monitor others' investing behavior (see Cooperation×Info in model 7). We also find support for the notion that the amount of insight the subjects in a group have influences the success rate of cooperation. First of all, groups consisting of subjects who are more foresighted on average are better able to solve the cooperation problems they face (H6; see Cooperation×Foresight). Secondly, as subjects have played more rounds they more often succeed to cooperate (H7; see Cooperation×Round). Additionally, the occurrence of investment profiles other than Nash or cooperation decreases as more rounds are played (see Rest×Round). In other words, as subjects gain experience we are better able to predict their behavior. Finally, however, it does not seem to matter whether groups first face the information condition and then the no information condition instead of the other way around (see Cooperation×Info/No Info). This contradicts our expectation (H8) that subjects can effectively use their gained experiences under the more facilitative circumstances (information condition) subsequently in the more difficult setting (no information condition). It seems that cooperating in the no information condition is simply too difficult, no matter whether subjects had the chance to gain some experience first.

6. Conclusion and Discussion

The puzzle why and how people form and sever relations, why they sometimes come to successful collaboration and why they sometimes fail, has occupied many ever since Hobbes (Coleman, 1990). In this paper we looked at a small piece of this puzzle by studying the coordination and cooperation problems that hinder actors in successfully creating collaborative relations to jointly produce – what we have labeled – a network good with complementarities. As opposed to everybody investing individually, all actors benefit by forming relations and adjusting investment levels upwards because a network good with complementarities has the characteristic that investments become worth more when an investor is linked to others who also invest. However, coordination problems may restrain a group of actors from successfully creating the structure of collaborative relations, while cooperation problems may lead to underinvestment, both resulting in suboptimal production of the good. We used a game-theoretical model to analyze which network structures and investment levels groups of actors are likely to choose depending on the level of the link costs and the information availability about the investments of others. We tested these predictions using a computerized experiment in continuous time.

Regarding the structure, we found – in support of our expectations based on a pairwise stability concept – that subjects either created the empty or the full network (and not so much any intermediate structures). Also as expected, the higher the link costs the more often the empty network and the less often the full network was created. Since there are no coordination problems to be solved in the low link cost condition, groups almost always created the full network. In the intermediate cost condition, groups sometimes solved the coordination problems and reached the full network, and sometimes they did not resulting in the empty network. Because in the high cost condition the full network only becomes more profitable than the empty network when the cooperation problems are solved in addition to the coordination problems, this proved to be too difficult for almost all groups.

In order to solve the coordination problems, actors need to look ahead far enough and anticipate well on the actions of the others in their group. Indeed we found that if subjects in a group were on average more foresighted in the above sense, they solved the coordination problems more often. The bright side of this finding is that actors could then learn and gain insight in the coordination problems they face. Indeed, we found that groups solved the coordination problems more frequently if they played more rounds or started in the low cost condition (making them familiar with the benefits of collaboration) instead of the high cost condition. It does not seem to be the case that coordination is facilitated if actors can see how much others invest. This last finding would be explained if creating the structure of relations is the primal problem in coordinating actions, and not so much the adjustment of investments given the creation of new relations.

Regarding investments, we found in accordance with predictions of Ballester et al. (2006) that groups of actors mostly – almost 80% of the time – invested according to their Nash strategy given the network structure they created. This means that an actor's Bonacich centrality is a good predictor for how much he will invest (Ballester et al., 2006). It also implies an enormous suboptimal production of the network good, for if all actors would collaborate and invest more than in Nash everybody would be better off. In our experiment, groups of subjects had great trouble in solving this cooperation problem.

However, the prospects for overcoming this social dilemma are not equally unfavorable under all conditions. If subjects had information about how much the others in their group invested, cooperation was much more often successful than without this information. This is understandable from the argument that in repeated interactions actors can cooperate conditional on the actions of others (Taylor, 1987; Raub & Weesie, 1990): making one's own strategy conditional on those of the others is extremely hampered when one has trouble monitoring the behavior of the others. There may also be another mechanism at work: some actors may simply not realize that they are underinvesting because they do not recognize the social dilemma structure they are in. These actors can learn from and imitate those that are aware of the possibilities of cooperation (Camerer et al., 2002), but of course only if information about others' investments is available to them. In other words, cooperation may fail both because of 'egoism' and because of unawareness of its potential. This last view was supported by our findings that cooperation was more often successful when subjects in a group were more foresighted on average as well as when they played more rounds.

We additionally found that the level of cooperation was much higher in the low and intermediate cost condition than in the high cost condition. We can explain this as follows. For successful cooperation, actors do not only have to increase investments together, they also have to create a structure in which cooperation is possible. The potential benefits of cooperation are highest in the full network. In the low and intermediate cost condition the full network is already more profitable than the empty network when everybody invests Nash. Therefore, it is safe for subjects to first create the full network and invest Nash, and from there on try to increase investments together. In the high cost condition the full network cannot perform this role of 'stepping stone', because actors are better off investing alone if everybody invests Nash.

Therefore, in the high cost condition some subjects already break off the relations before cooperation can start to develop.

What do these findings mean for the companies in our introduction who want to develop an environmentally friendly car? The good news is that, as long as the costs of starting Research & Development (R&D) relations are not too high, it seems that the companies sooner or later are likely to realize their common interest and create an R&D platform. The bad news is that it may be very difficult to reach the full potential of an established collaboration because of free-rider problems. If the companies truly want an innovative product, they are wise to design their collaboration such that it is transparent how many resources each is devoting to the joint venture.

We should be careful inferring implications since there are discrepancies between our approach and reality, which may influence the results. First of all, in real life the car companies would be able to communicate with each other while the subjects in our experiment could not. Since it seems that failure to solve the coordination and cooperation problems is partly due to lack of insight on behalf of some of the subjects, communication between subjects could spread insight quicker through the population. It would be interesting to see what the effect is for the level of network good production if the subjects can, e.g., send other group members text messages.

Second, in our model the benefits of collaboration increase rapidly with each new collaborative partner. Therefore, the full network is extremely beneficial and often the predicted and observed outcome. However, this does not mean that we expect that, e.g., all car companies in the automobile industry are best off if they all work together. On the contrary, we expect that decreasing marginal returns to the number of collaborative partners puts in reality often a limit to the optimal number of partners. Future research could try to model decreasing marginal complementary benefits. It is not so much the question which network structure is then predicted or observed, because this is to a large extent the direct outcome of the model specification. The relevant question is whether with a different specification of the benefit function the coordination and cooperation problems occur to the same extent, and more importantly, whether the same factors facilitate and inhibit solving these problems as we found with our specification.

Third, besides the above suggestions for gathering new data, there is still a lot to be learned from the data of this study. As a starting point we simplified by taking the group or network as the unit of analyses, while the observed outcomes are in actuality of course the result of (the combination of) individual decisions. We found some leads for mechanisms that seem to be at work at the individual level, although these findings should be interpreted with some caution as we did not control for the dependency of our observations. A next step would be taking the individual as the unit of analyses and hypothesize explicitly the interdependency of actors and how their decisions aggregate to solving or not solving the coordination and cooperation problems. For example, with respect to the cooperation problems, by looking at the individual decisions made in the experiment we could establish to what extent the mechanisms 'conditional cooperation' and 'learning/imitation' are at work under the different conditions.

Notwithstanding the mentioned limitations, we believe we gained valuable insight for a small piece of the puzzle why actors sometimes create successful forms of relations, while at other times such social structures are inefficient, break down or never even start to develop. For the specific context of producing a network good with complementarities, we developed theory that predicted the outcomes in an experimental setting notably well. In addition to the robust findings regarding the macro-structural outcomes, we were able to gain some insight on the individual level mechanisms underlying these outcomes. This provides us with a solid ground to build future investigations into the mechanisms and conditions in more detail.

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Appendix A.1 (Nash investment in regular networks)

We wish to show that the Nash investment x^* of each actor in a regular network equals

$$x^*_{reg} = \frac{\alpha}{\beta - \eta\lambda}. \tag{2}$$

Ballester et al. (2006) show that Nash investments x^* of actor i given the network $\boldsymbol{g}$ equals

$$x^*_i = \frac{\alpha}{\beta} b_i\left(\boldsymbol{g}, \frac{\lambda}{\beta}\right), \tag{2a}$$

where b_i is the Bonacich centrality of actor i. It is sufficient to show that the Bonacich centrality of an actor in a regular network equals $\beta/(\beta - \eta\lambda)$, since imputing this into (2a) leads directly to (2).

The Bonacich centrality of actor i counts the total number of paths in $\boldsymbol{g}$ that start at i and end at j, where paths of length k are weighted by $(\lambda/\beta)^k$:

$$b_i\left(\boldsymbol{g}, \frac{\lambda}{\beta}\right) = \sum_{j=1}^{n}\sum_{k=0}^{\infty} g_{ij}\left(\frac{\lambda}{\beta}\right)^k$$

How can we count the total number of paths in a regular network? In each network there is always exactly one path of length 0 starting at i, namely the path to i himself. The number of paths of length 1 starting at i equals obviously the number of neighbors actor i has (here: η). We can see a path of length 2 as two subsequent paths of length 1. The first step of a path of length 2 starting at i can go to η neighbors. The second step of the path of length 2 can in turn can go in as many directions as the reached actor has neighbors, which is also η since everybody has the same number of neighbors in a regular network. In other words, the total possible number of paths of length 2 starting at i equals the number of paths of length 1 starting at i multiplied by the number of paths of length 1 starting at one of i his neighbors: $\eta \times \eta = \eta^2$. We can extent this argument in the same manner for paths of length 3, of length 4, and so forth. We thus get

$$\begin{aligned} b_i\left(\boldsymbol{g_{reg}}, \tfrac{\lambda}{\beta}\right) &= \eta^0\left(\tfrac{\lambda}{\beta}\right)^0 + \eta^1\left(\tfrac{\lambda}{\beta}\right)^1 + \eta^2\left(\tfrac{\lambda}{\beta}\right)^2 + \cdots \\ &= \sum_{k=0}^{\infty}\left(\eta\tfrac{\lambda}{\beta}\right)^k = \frac{1}{1-\eta\frac{\lambda}{\beta}} = \frac{\beta}{\beta-\eta\lambda}, \end{aligned}$$

as we wanted (the next to last equation holds as long as $\beta > \eta\lambda$).

Appendix A.2 (Socially optimal investments in regular networks)

We wish to show that the socially optimal investment x^{so} of each actor in a regular network equals

$$x_{reg}^{so} = \frac{\alpha}{\beta - 2\eta\lambda}, \qquad (4)$$

For this purpose, we show that the socially optimal investment x^{so} for actor i given network $\boldsymbol{g}$ equals

$$x_i^{so} = \frac{\alpha}{\beta} b_i\left(\boldsymbol{g}, \tfrac{2\lambda}{\beta}\right), \qquad (4a)$$

We can then derive (4) from (4a) in the same manner as we derived (2) from (2a) above.
To optimize individual payoffs Π_i each actor i has to solve $\partial\Pi_i/\partial x_i = 0$, or

$$\frac{\partial\Pi_i}{\partial x_i} = \frac{\partial\left(\alpha x_i - \frac{1}{2}\beta x_i^2 + \lambda\sum_{j=1}^{n}\left(g_{ij}x_i x_j\right) - c\eta_i(\boldsymbol{g})\right)}{\partial x_i}$$

$$= \alpha - \beta x_i + \lambda\sum_{j=1}^{n}\left(g_{ij}x_j\right) = 0. \tag{2b}$$

From Ballester et al. (2006) we know that (2b) solves for (2a). However, to reach social optimum each actor has to take into account that his investments have positive externalities for his neighbors. Each actor i must optimize social welfare, i.e., the sum of all actors' payoffs ($\sum_{\mathrm{j=1}}^{\mathrm{n}}\Pi_j$), thus solve

$$\frac{\partial\sum_{\mathrm{j=1}}^{\mathrm{n}}\Pi_j}{\partial x_i} =$$

$$\left(\left(\alpha x_1 - \frac{1}{2}\beta x_1^2 + \lambda\sum_{j=1}^{n}\left(g_{1j}x_1x_j\right) - c\eta_1(\boldsymbol{g})\right) + \left(\alpha x_2 - \frac{1}{2}\beta x_2^2 + \lambda\sum_{j=1}^{n}\left(g_{2j}x_2x_j\right) - c\eta_2(\boldsymbol{g})\right) + \cdots + \right.$$
$$\left.\left(\alpha x_i - \frac{1}{2}\beta x_i^2\lambda\sum_{j=1}^{n}\left(g_{ij}x_ix_j\right) - c\eta_i(\boldsymbol{g})\right) + \cdots + \left(\alpha x_n - \frac{1}{2}\beta x_n^2 + \lambda\sum_{j=1}^{n}\left(g_{nj}x_nx_j\right) - c\eta_n(\boldsymbol{g})\right)\right)\Big/\partial x_i$$

$$= \lambda(g_{1i}x_1) + \lambda(g_{2i}x_2) + \cdots + \alpha - \beta x_i + \lambda\sum_{j=1}^{n}\left(g_{ij}x_j\right) + \cdots + \lambda(g_{ni}x_n)$$

$$= \alpha - \beta x_i + \lambda\sum_{j=1}^{n}\left(g_{ij}x_j\right) + \lambda\sum_{j=1}^{n}\left(g_{ji}x_j\right)$$

$$= \alpha - \beta x_i + 2\lambda\sum_{j=1}^{n}\left(g_{ij}x_j\right) = 0. \tag{4b}$$

The last equality follows from the fact that $g_{ij} = g_{ji}$. From the result of Ballester et al. (2006) we know that (4b) solves for (4a) (by taking 2λ instead of λ in (2b)), as we wanted. The appeal of deriving (4) in this way lies in the additional general result that all results of Ballester et al. (2006) related to Nash investments have their direct equivalent for socially optimal investments.

Appendix B.1 (English Instructions)

Experimental Laboratory for Sociology and Economics Universiteit Utrecht

- Instructions -

You are participating in a sociological experiment. Please read the following instructions carefully. These instructions are equal for all the participants. The instructions state everything you need to know in order to participate in the experiment. If you have any questions, please raise your hand. One of the experimenters will approach you in order to answer your question.

You can earn money by means of earning points during the experiment. The number of points that you earn depends on your own choices and the choices of other participants. At the end of the experiment, the total number of points that you earn during the experiment will be exchanged at an exchange rate of:

150 points = 1 Euro

The money you earn will be paid out in cash at the end of the experiment without other participants being able to see how much you earned. Further instructions on this will follow in due time. During the experiment you are not allowed to communicate with other participants. Turn off your mobile phone and put it in your bag. Also, you may only use the functions on the screen that are necessary to carry out the experiment. Thank you very much.

- Overview of the experiment -

The experiment consists of *six scenarios*. Each scenario consists of *one trial round* and *four paid rounds* (altogether 30 rounds of which 24 are relevant for your earnings).

In all scenarios you will be *grouped* with three other randomly selected participants in a group of four. At the beginning of each of the 30 rounds, the groups and the positions within the groups will be randomly changed. Therefore, the participants that you are grouped with in one round are very likely different participants from those you will be grouped with in the next round. It will not be revealed with whom you were grouped at any moment during or after the experiment.

The participants in your group will be shown as circles on the screen (see Figure 1). You are displayed as a **blue** circle, while the other participants are displayed as **black** circles. Please be aware: your blue circle will not be at the same position in each round due to the changing of groups and positions at the beginning of a new round.

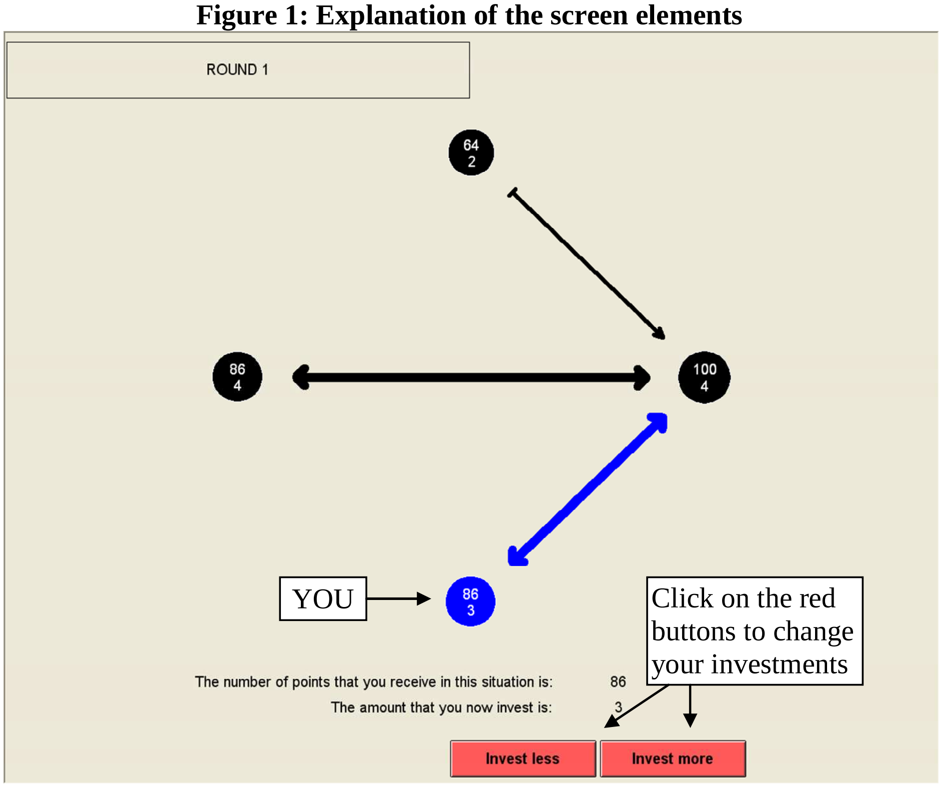
Earning Points

You can earn points in a round by *investing*. By clicking on one of the two red buttons at the bottom of the screen you increase or decrease your investment (see Figure 1). Also, you will be able to *connect* to other participants in your group during each round. All participants that are connected to you will be called your *neighbors* (all the details about how you can become neighbors with other participants can be found in the next paragraph ***Forming Links*** of this instructions manual). Your investments pay off more when you are connected to a participant who also invests. However, there are also *costs* attached to having a link with another participant: you both pay some points for being neighbors. Therefore, the points you will receive depend on your own investment, how many neighbors you have and how much your neighbors invest. How your earnings are exactly calculated will be discussed at the end of these instructions, so you do not need to worry about this yet.

At the end of each round you receive the amount of points that is shown on the screen at that moment in time. In other words, your final earnings only depend on the situation at the end of every round. The points you will *receive* can be seen as the *top number* in your circle (see Figure 1). Your circle will be blue on the screen while the other circles will be black. The *bottom number* in your circle indicates the amount you *invest*. These numbers can also be found at the bottom of your screen. Moreover, the *size of your circle* changes with the points that you will receive: a larger circle means that you will receive more points. For half of the six scenarios you will be able to see how much the others in your group earn and how much they invest by looking at the numbers in their black circles. For the other half of the scenarios you do not have this information: the circles of others will be completely black and will not change in size (see Figure 2a-2c).

Each round lasts *between 90 and 120 seconds*. The end will be at an unknown and random moment in this time interval. Therefore, different rounds will not last equally long.

Figure 1: Explanation of the screen elements



Forming Links

As indicated above, you will be able to connect to other participants in your group during each round. Starting from an empty network (see Figure 2a), you can let other participants know that you want to create a link with them by clicking once on the particular participant. A thin blue arrow from you to the other participant will appear (see Figure 2b). The other participant can accept your proposal for a link by clicking on

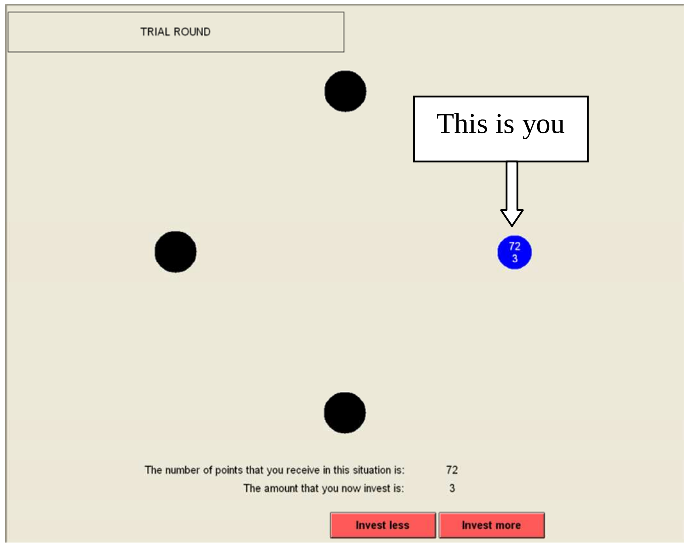


Figure 2a:
Starting situation at the beginning of each round

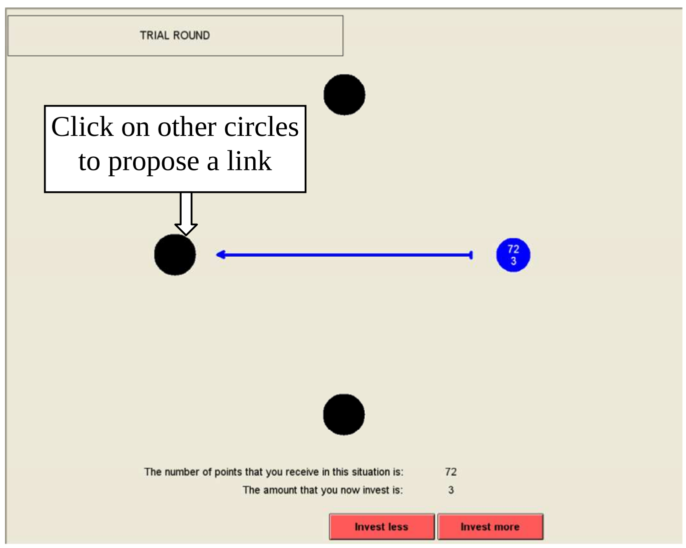


Figure 2b:
You proposed a link to one of the other participants

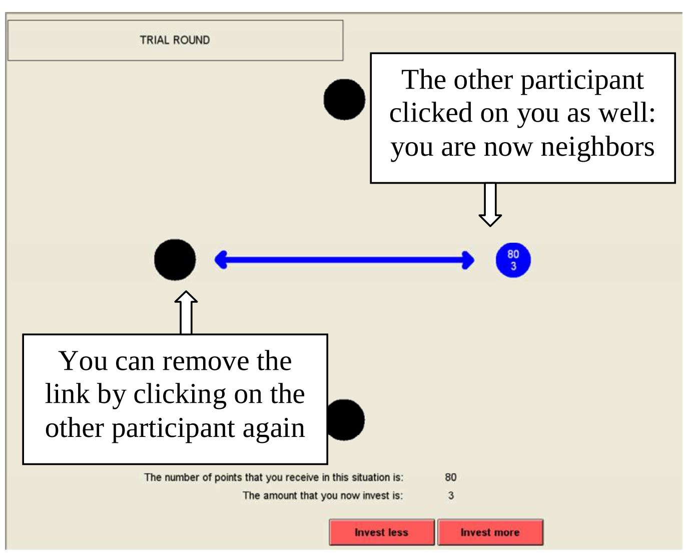


Figure 2c:
A link is established between you and the other participant

you. If he does so, the thin blue arrow will change into a thick **blue** arrow pointing in both directions (see Figure 2c). You have now become neighbors. If the other participant does not accept the link, you may choose to withdraw your request by clicking again on the participant: the thin blue arrow would then disappear.

Similarly, other participants can propose a link to you by clicking on your circle. A thin blue arrow from the other participant to you will appear. You can accept the link by clicking on the participant who wants to become neighbors with you. If you do so, the thin blue arrow will change into a thick **blue** arrow pointing in both directions. If you do not want to become neighbors, you simply ignore the thin blue arrow. The other participant may withdraw the request for a link after a while by clicking on you again: the thin blue arrow would then disappear.

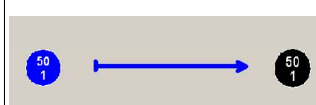
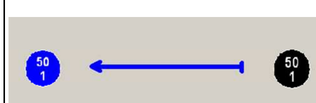
Once you have become neighbors with another participant, you can end this link at all times by clicking on the particular participant (see Figure 2c). Similarly, one of your neighbors may decide to end the link that you share by clicking on you (there is nothing you can do to prevent this).

In Figure 3 we summarize how all the possible situations where you are involved in look like on your screen. All (proposals for) links you are involved in will be blue on your screen, while (proposals for) links you are not part of will be black.

Important Remarks:

- It may occur that there is a time-lag between your click and the changes of the numbers on the screen because the computer needs some time to process your orders. One click is enough to change a link or to change your investment by one unit. A subsequent click will not be effective before the previous click is effectuated.
- **Therefore wait until a link is changed/your investment is adapted before making further changes!**

Figure 3: Link or no link? An overview of what you will encounter on your screen.

No link	You Other
Both you (**blue** circle) as well as the other participant (**black** circle) do not show interest in the creation of a link at this moment.	
You propose a link to the other participant, showing that you are interested in creating a link with him or her. This is however not (yet) a mutual interest. You can withdraw your proposal by clicking on this participant another time	
The other participant proposes a link to you, making clear to you that he or she wants to form a link with you. If you want to, you can establish a link with the other participant by clicking once on this participant.	
Link present	
You and another participant both have indicated that they want to have a link with each another. The link is formed and is shown as a **thick**, **blue** colored, double-headed arrow. You can both remove this link by clicking on the other participant.	

- Your earnings -

Now we explain in detail how the number of points that you earn depends on the investments you make and the links you have. Read this carefully. Do not worry if you find it difficult to grasp immediately. We also present an example with calculations below. Next to this, there is a trial round for each scenario to gain experience with how investments and links affect your earnings.

General idea in all scenarios

All scenarios are basically the same. In all scenarios, the points you receive at the end of each round depend in a similar way on

- how much you invest
- how many neighbors you have
- how much your neighbors invest (if you have any)

There are two differences between the scenarios. As mentioned already, in three of the six scenarios you will be able to see how much the others in your group invest and earn, while in the other three scenarios you will not be able to see this. The other difference will be the number of points that it costs you to have a link. There will be three different cost levels (10, 30 or 50 points). You will face each cost level twice: once in a scenario with information about others' investments and earnings and once in a scenario without this information ($2 \times 3 = 6$ scenarios).

If you do not have any neighbors, you can see in each scenario in Table 1 (see next page) how many points each investment level earns you. These points are called your *Individual Earnings* (from investing).

If you do have one or more neighbors and you want to calculate your total earnings, you have to add additional points to these Individuals Earnings. However, you also have to subtract some points for each link that you have.

How many points do you have to add for the joint investments of you and your neighbor? In each scenario, these *Joint Earnings* are equal to twice your own investment level times the investment level of your neighbor:

$$\text{Joint Earnings} = 2 \times \text{Own investment} \times \text{Neighbor's investment}$$

For example, if you invest 2 and your neighbor 3, these investments lead to Joint Earnings of $2 \times 2 \times 3 = 12$ points for each of you. Of course, when you are in the scenarios where the other circles are completely black you cannot calculate this number yourself (but the computer still does this for you). How much each link will cost depends on the scenario. Before the start of a new scenario, you will get a message on your screen that tells you how much the *Link Costs* are for that scenario (10, 30 or 50 points). This screen also tells you whether you will or will not be able to see how much the others in your group invest and earn. Please read these messages carefully.

As indicated before, each scenario starts with a trial round. At the top of the screen you can also see whether you are in a trial round or a paid round. Trial rounds are indicated by "TRIAL ROUND" (see, for example, Figure 2a-c) while paying rounds are indicated by "ROUND" (see, for example, Figure 4).

To summarize, the total earnings as displayed on your screen during the experiment can be calculated as following:

Total Earnings = Individual Earnings + Joint Earnings – Link Costs

- **Individual Earnings:**

Table 1: Individual Earnings from investing

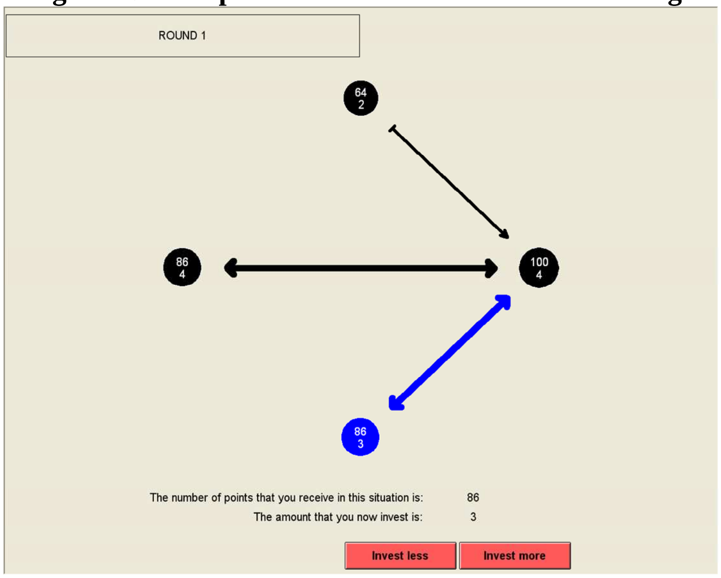
Investment level	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Individual Earnings	0	40	64	72	64	40	0	-56	-128	-216	-320	-440	-576	-728	-896

- **Joint Earnings:** **2 × Own investment × Neighbor's investment**
- **Link Costs:** **Differs per scenario**

Example Scenario: calculating total earnings

Suppose the situation is as shown in Figure 4, and the Link Costs for this scenario are 10 points for each link that you have. We will now calculate the total earnings for you and the person to your right hand. You could try to calculate the total earnings for the other two participants yourself.

Figure 4: Example situation to calculate total earnings



You have:

- investment level 3, which gives you Individual Earnings of 72 (see Table 1);
- one link to someone with investment level 4, which gives you Joint Earnings equal to 2 × 3 × 4 = 24;
- Link Costs for one link are 1 × 10 = 10.

Together this leads to the following Total Earnings for you:

Total Earnings	=	Individual Earnings	+	Joint Earnings	–	Link Costs
86	=	72	+	24	–	10

The person to your right has:

- investment level 4 which gives Individual Earnings of 64;
- one link to you with investment level 3, which gives this person Joint Earnings equal to $2 \times 4 \times 3 = 24$;
- one link to someone with investment level 4, which gives this person Joint Earnings equal to $2 \times 4 \times 4 = 32$;
- Link Costs for two links are $2 \times 10 = 20$.

Together this leads to:

Total Earnings	=	Individual Earnings	+	Joint Earnings	–	Link Costs
100	=	64	+	24 + 32	–	20

- Questionnaire -

After the 30 rounds you will be asked to do one small additional task through which you can earn some money. We also ask to fill in a questionnaire. Please take your time to fill in this questionnaire accurately. In the mean time your earnings will be counted. Please remain seated until the payment has taken place.

Appendix B.2 (Dutch Instructions)

Experimental Laboratory for Sociology and Economics Universiteit Utrecht

- Instructies -

U neemt nu deel aan een sociologisch experiment. Neemt u alstublieft de volgende instructies aandachtig door. Deze instructies zijn hetzelfde voor alle deelnemers. Hierin staat alles wat u moet weten om deel te nemen aan het experiment. Indien u vragen hebt, steekt u uw hand op. Er zal een experimentleider bij u komen om uw vraag te beantwoorden.

U kunt geld verdienen tijdens dit experiment door het verzamelen van punten. Het aantal punten dat u verdient, hangt af van uw eigen keuzes en van de keuzes van andere deelnemers. Het totaal aantal punten dat u verdient in het experiment zal aan het einde van het experiment omgewisseld worden tegen de wisselkoers van:

150 punten = 1 Euro

Aan het einde van het experiment krijgt u het geld dat u verdiend hebt tijdens het experiment contant uitbetaald zonder dat anderen kunnen zien hoeveel u verdiend hebt. Later volgen hierover verdere instructies. Tijdens het experiment is het niet toegestaan te communiceren met andere deelnemers. Zet uw mobiele telefoon uit en berg hem op in uw tas. Tevens mag u alleen de functies op het scherm activeren die nodig zijn voor het uitvoeren van het experiment. Hartelijk dank.

- Overzicht van het experiment -

Het experiment bestaat uit *zes scenario's*. Elk scenario bestaat op zijn beurt uit *één proefronde* en *vier betaalde rondes* (bij elkaar dus 30 rondes waarvan er 24 relevant zijn voor uw verdiensten).

In alle scenario's wordt u in een *groep* van vier geplaatst met drie andere willekeurig gekozen deelnemers. Aan het begin van elk van de 30 rondes worden de groepen en de posities binnen de groepen willekeurig veranderd. De deelnemers waarmee u in de ene ronde in een groep zit, zijn daarom zeer waarschijnlijk andere deelnemers dan diegene waarmee u in de volgende ronde in een groep zit. Tijdens of na het experiment zal het niet bekend worden gemaakt met wie u in een groep gezeten hebt.

De deelnemers in uw groep worden als cirkels weergegeven op het scherm (zie Figuur 1). U wordt zelf weergegeven met een **blauwe** cirkel, terwijl de andere deelnemers worden weergegeven als **zwarte** cirkels. Let op: uw blauwe cirkel zal zich niet in elke ronde op dezelfde positie bevinden als gevolg van het veranderen van de groepen en posities aan het begin van een nieuwe ronde.

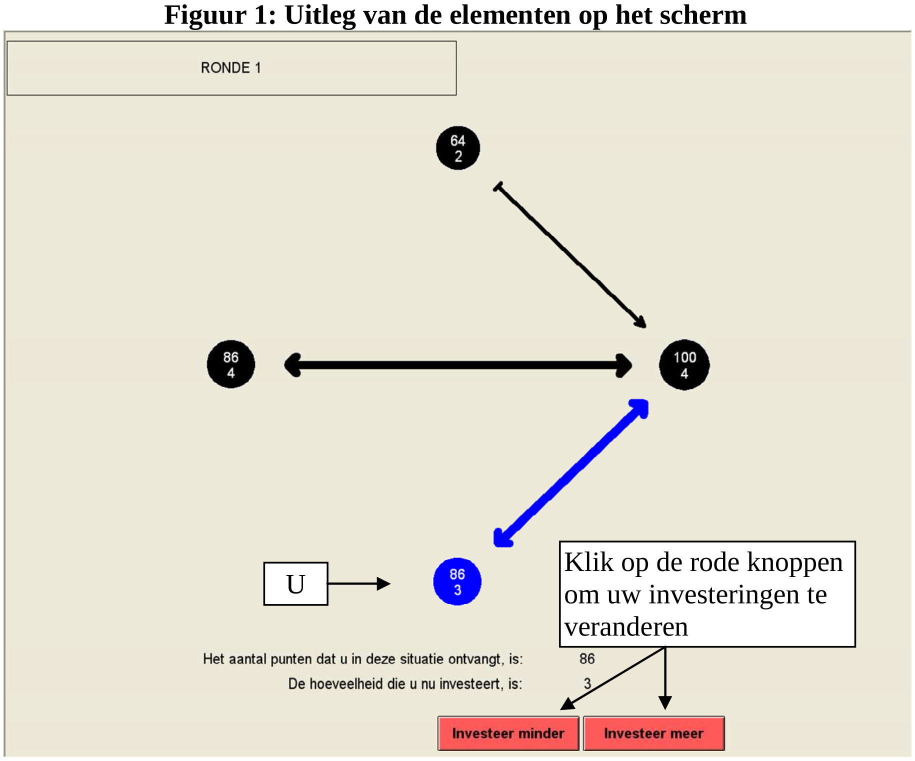
Punten Verdienen

U kunt punten verdienen in elke ronde door te *investeren*. Door op één van de rode knoppen onderaan uw scherm te klikken, kunt u uw investeringen verlagen of verhogen (zie Figuur 1). Bovendien kunt u in elke ronde *verbindingen maken* met één of meer andere deelnemers in uw groep. Alle deelnemers waar u mee verbonden bent, zullen uw *buren* worden genoemd (hoe u precies buren kunt worden met andere deelnemers zal uitgelegd worden in de volgende paragraaf ***Verbindingen Maken*** van deze instructie handleiding). Uw investeringen leveren meer punten op wanneer u een verbinding hebt met een deelnemer die ook investeert. Echter, er zijn ook *kosten* verbonden aan het hebben van een verbinding met een andere deelnemer: u betaalt beide een aantal punten om buren van elkaar te zijn. Hoeveel punten u ontvangt aan het einde hangt daarom af van uw eigen investeringen, hoeveel buren u hebt en hoeveel deze buren investeren. De precieze manier waarop uw punten worden berekenend, wordt aan het einde van deze instructie handleiding uitgelegd, dus u hoeft zich hierover nog niet druk te maken.

Aan het einde van elke ronde ontvangt u het aantal punten dat op dat moment op het scherm wordt weergegeven. Uw uitbetaling hangt dus alleen af van de situatie aan het einde van elke ronde. Het aantal punten dat u zult *ontvangen* is weergegeven als het *bovenste getal* in uw cirkel (zie Figuur 1). Uw eigen cirkel zal blauw zijn op het scherm en de andere cirkels zwart. Het *onderste getal* in uw cirkel geeft weer hoeveel u *investeert*. Deze getallen staan bovendien ook onderaan uw scherm. Daarnaast verandert *de grootte van de cirkels* met het aantal punten dat u zult krijgen: een grotere cirkel betekent dat u meer punten zult verdienen. In de helft van de zes scenario's kunt u zien hoeveel de anderen in uw groep verdienen en hoeveel ze investeren door naar de getallen in hun zwarte cirkels te kijken. Voor de andere helft van de scenario's hebt u deze informatie niet: de cirkels van anderen zullen geheel zwart zijn en niet van grootte veranderen (zie Figuur 2a-2c).

Elke ronde duurt *tussen de 90 en 120 seconden*. Het einde zal op een onbekend en willekeurig moment in dit tijdsinterval plaatsvinden. Verschillende rondes zullen dan ook niet even lang duren.

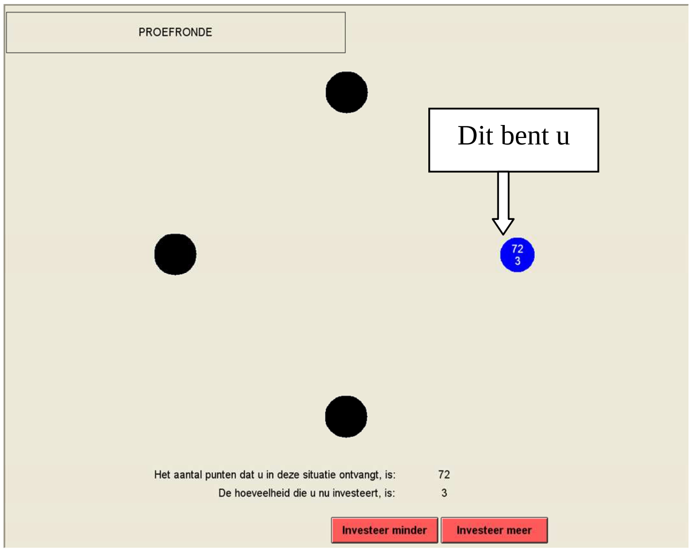
Figuur 1: Uitleg van de elementen op het scherm



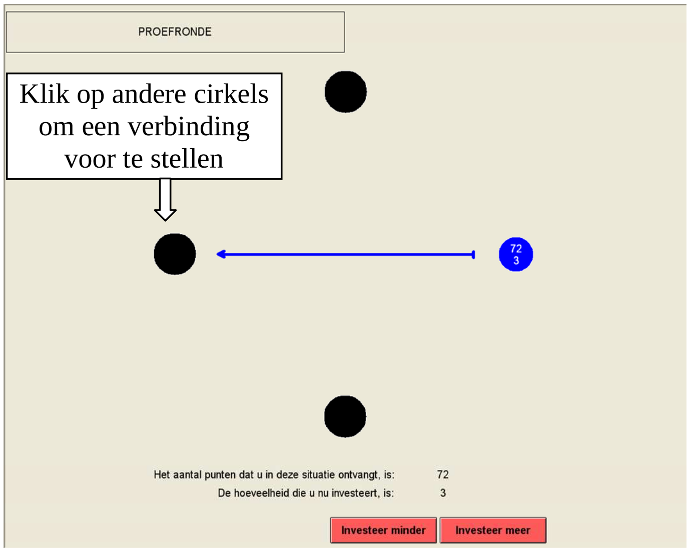
Verbindingen Maken

Zoals vermeld, hebt u in elke ronde de mogelijkheid om verbindingen te maken met andere deelnemers in uw groep. Startend vanuit een leeg netwerk (zie Figuur 2a) kunt u kenbaar maken met wie u een verbinding wilt door eenmalig op de desbetreffende deelnemer te klikken. Er verschijnt dan een dunne blauwe pijl van u naar deze deelnemer (zie Figuur 2b). De andere deelnemer kan uw voorstel voor een verbinding accepteren door op u te klikken. In dat geval zal de dunne eenzijdige blauwe pijl veranderen in een dikke **blauwe** pijl die beide kanten uitwijst (zie Figuur 2c). U bent nu buren van elkaar geworden. Mocht de

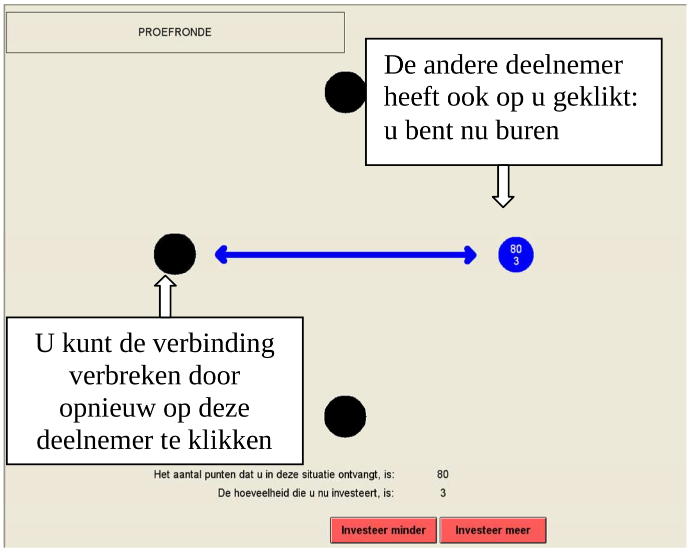
Figuur 2a:
Start situatie aan het begin van elke ronde



Figuur 2b:
U hebt een verbinding voorgesteld aan één van de andere deelnemers



Figuur 2c:
Er is een verbinding tot stand gekomen tussen u en de andere deelnemer



andere deelnemer uw voorstel voor een verbinding niet accepteren, dan zou u er voor kunnen kiezen het verzoek weer in te trekken door opnieuw op de desbetreffende deelnemer te klikken: de dunne blauwe lijn zal dan verdwijnen.

Andere deelnemers kunnen op vergelijkbare wijze ook een verbinding aan u voorstellen door op uw cirkel te klikken. Er zal een dunne blauwe pijl van de andere deelnemer naar u verschijnen. U kunt het voorstel voor een verbinding accepteren door op de deelnemer te klikken die buren met u wil worden. Als u inderdaad op de andere deelnemer klikt, zal de dunne eenzijdige blauwe pijl veranderen in een dikke **blauwe** pijl die beide kanten uitwijst. Als u geen buren wilt worden, negeert u simpelweg de dunne blauwe pijl. De andere deelnemer zou er voor kunnen kiezen om het voorstel weer in te trekken door nogmaals op u te klikken: de dunne blauwe pijl zal in dat geval weer verdwijnen.

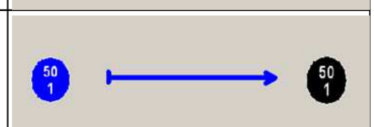
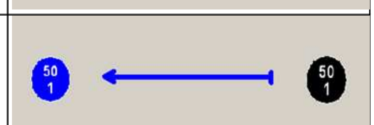
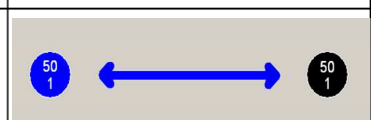
Indien u buren bent geworden met een andere deelnemer, kunt u deze verbinding te allen tijde weer verbreken door op de betreffende deelnemer te klikken (zie Figuur 2c). Evenzo kan een van uw buren besluiten een verbinding die jullie hebben weer te verbreken door op u te klikken (er is niets dat u kunt doen om dit te voorkomen).

In Figuur 3 hebben we samengevat hoe alle mogelijke situaties waar u onderdeel van bent er op uw scherm uitzien. Alle (voorstellen voor) verbindingen waar u in betrokken bent zullen blauw zijn op uw scherm, terwijl de (voorstellen voor) verbindingen waar u geen deel van uitmaakt zwart zullen zijn.

Belangrijke Opmerkingen:

- Het kan gebeuren dat er een vertraging is tussen uw klik en de veranderingen van de getallen op het scherm omdat de computer even tijd nodig heeft om uw opdracht te verwerken. Eén klik is voldoende om een verbinding te veranderen of uw investering met één eenheid te veranderen. Een volgende klik zal pas effect hebben als de vorige klik is verwerkt.
- **Wacht daarom totdat een verbinding is veranderd/uw investering is aangepast voordat u nieuwe veranderingen gaat maken!**

Figuur 3: Verbinding of geen verbinding? Een overzicht van wat u op uw scherm ziet.

Geen verbinding	U Ander
Zowel u (**blauwe** cirkel) als een van de andere deelnemers (**zwarte** cirkel) toont op dit moment geen interesse in het vormen van een verbinding.	
U laat aan de andere deelnemer weten dat u geïnteresseerd bent in een verbinding met hem of haar. Dit is echter (nog) geen wederzijdse interesse. U kunt uw voorstel weer intrekken door nogmaals op deze deelnemer te klikken.	
De andere deelnemer geeft aan een verbinding met u te willen. Indien u wilt, kunt u een verbinding met deze deelnemer vormen door éénmalig op deze deelnemer te klikken.	
Wel een verbinding	
U en een andere deelnemer hebben beide te kennen gegegeven een verbinding met elkaar te willen. De gevormde verbinding komt als een **dikke**, **blauw** gekleurde tweezijdige pijl in beeld. U kunt beide de verbinding weer verbreken door nogmaals op de andere deelnemer te klikken.	

- Uw verdiensten -

Nu leggen we uit hoe het aantal punten dat u verdient, afhangt van uw investeringen en uw verbindingen. Lees dit zorgvuldig. Wees niet bezorgd als u het niet meteen helemaal begrijpt. We zullen zodadelijk ook een rekenvoorbeeld laten zien. Daarnaast is er bij elk scenario een proefronde om ervaring te krijgen met hoe verbindingen en investeringen uw verdiensten bepalen.

Algemene idee in alle scenario's

Alle scenario's werken op vergelijkbare wijze. In alle scenario's hangt het aantal punten dat u ontvangt aan het einde van een ronde op een soortgelijke manier af van:

- hoeveel u investeert
- hoeveel buren u hebt
- hoeveel uw buren investeren (als u buren hebt)

De scenario's zullen op twee punten verschillen. Zoals vermeld, zult u in drie van de zes scenario's kunnen zien hoeveel de anderen in uw groep investeren en verdienen, terwijl u dit in de andere drie scenario's niet zult kunnen zien. Het andere verschil zal zijn hoeveel punten het u zal kosten om een verbinding te hebben. Er zullen drie verschillende kostenniveaus zijn (10, 30 of 50 punten). Elk kostenniveau zal twee maal voorbij komen: één keer in een scenario met informatie over de investeringen en verdiensten van anderen en één keer in een scenario zonder deze informatie ($2 \times 3 = 6$ scenario's).

Als u geen enkele buur hebt, kunt u voor elk scenario in Tabel 1 (zie volgende pagina) aflezen hoeveel punten elk investeringsniveau u oplevert. Deze punten noemen we uw *Individuele Verdiensten* (van investeren).

Als u wel een of meer buren hebt en u wilt uw totale verdiensten berekenen, dan moet u extra punten aan de Individuele Verdiensten toevoegen. U moet echter ook enkele punten aftrekken voor elke verbinding die u hebt.

Hoeveel punten moet u toevoegen voor de gecombineerde investeringen van u en uw buur? In elk scenario zijn deze *Gemeenschappelijke Verdiensten* gelijk aan twee maal uw eigen investeringen vermenigvuldigd met de investeringen van uw buur:

$$\text{Gemeenschappelijke Verdiensten} = 2 \times \text{Eigen investering} \times \text{Investering buur}$$

Dus als u bijvoorbeeld 2 investeert en uw buur 3, leiden deze investeringen tot Gemeenschappelijke Verdiensten gelijk aan $2 \times 2 \times 3 = 12$ punten voor elk van beide. In de scenario's waar de cirkels van anderen geheel zwart zijn, kunt u dit getal niet zelf berekenen (maar de computer doet dit nog wel steeds voor u). Hoeveel elke verbinding die u hebt kost, verschilt per scenario. Voordat een nieuw scenario start, krijgt u elke keer een scherm te zien waarop vermeld staat hoeveel de *Verbindingskosten* zullen zijn voor dat scenario (10, 30 of 50 punten). Dit scherm vermeldt ook of u wel of niet informatie zult hebben over hoeveel de anderen in uw groep investeren en verdienen. Lees deze mededelingen zorgvuldig.

Zoals gezegd begint elk scenario met een proefronde. Bovenaan het scherm kunt u ook zien of u in een proefronde zit of in een betaalde ronde. Proefrondes worden aangegeven met "PROEFRONDE" (zie bijvoorbeeld Figuur 2a-c) terwijl betaalde rondes worden aangegeven met "RONDE" (zie bijvoorbeeld Figuur 4).

Kortom, uw totale verdiensten zoals weergegeven op uw scherm gedurende het experiment kunnen als volgt worden berekend:

Totale Verdiensten = Individuele Verdiensten + Gemeenschappelijke Verdiensten – Verbindingskosten

- **Individuele Verdiensten:**

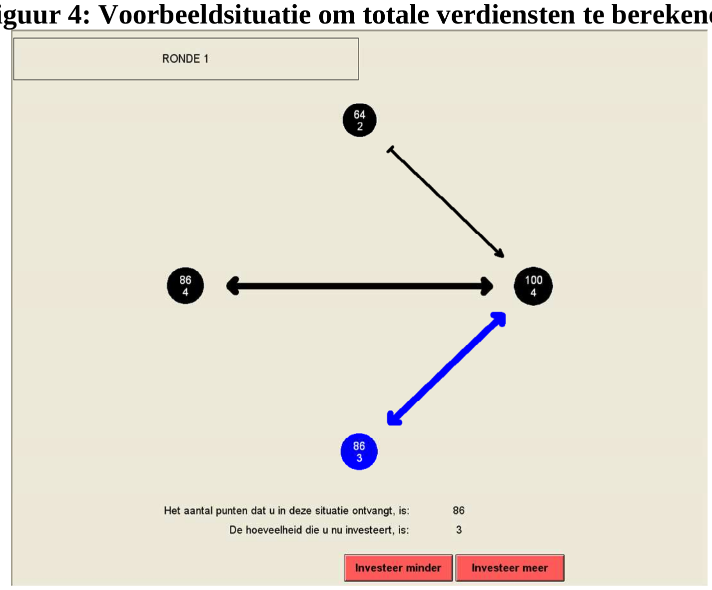
Tabel 1: Individuele Verdiensten van investeren

Investerings-niveau	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Individuele Verdiensten	0	40	64	72	64	40	0	-56	-128	-216	-320	-440	-576	-728	-896

- **Gemeenschappelijke Verdiensten:** **2 × Eigen investering × Investering buur**
- **Verbindingskosten:** **Verschilt per scenario**

Voorbeeldscenario: berekenen van totale verdiensten
Stel dat de situatie is zoals in Figuur 4 en de Verbindingskosten voor dit scenario zijn 10 punten per verbinding die u hebt. We zullen nu de totale verdiensten berekenen voor u en de persoon aan uw rechter hand. De verdiensten van de overige twee deelnemers zou u zelf kunnen proberen te berekenen.

Figuur 4: Voorbeeldsituatie om totale verdiensten te berekenen



U hebt:
- investeringsniveau 3, dit levert u 72 punten aan Individuele Verdiensten op (zie Tabel 1);
- één verbinding met een persoon met investeringsniveau 4, dit levert u 2 × 3 × 4 = 24 punten aan Gemeenschappelijke Verdiensten op;
- Verbindingskosten voor één verbinding zijn 1 × 10 = 10.

Bij elkaar leidt dit tot de volgende Totale Verdiensten voor u:

Totale Verdiensten = Individuele Verdiensten + Gemeenschappelijke Verdiensten – Verbindingskosten
86 = 72 + 24 – 10

De persoon aan uw rechter hand heeft:

- investeringsniveau 4, dit levert 64 punten aan Individuele Verdiensten op;
- 1 verbinding met u met investeringsniveau 3, dit levert deze persoon $2 \times 4 \times 3 = 24$ punten aan Gemeenschappelijke Verdiensten op;
- 1 verbinding met een persoon met investeringsniveau 4, dit levert deze persoon $2 \times 4 \times 4 = 32$ punten aan Gemeenschappelijke Verdiensten op;
- Verbindingskosten voor twee verbindingen zijn $2 \times 10 = 20$.

Bij elkaar leidt dit tot:

Totale Verdiensten	=	Individuele Verdiensten	+	Gemeenschappelijke Verdiensten	–	Verbindingskosten
100	=	64	+	24 + 32	–	20

- Vragenlijst -

Aan het einde van de 30 rondes zult u gevraagd worden om nog een kleine taak uit te voeren waarmee u nog wat geld kunt verdienen. Ook vragen we een vragenlijst in te vullen. Neem rustig de tijd en vul deze vragenlijst zorgvuldig in. Ondertussen zal het geld dat u tijdens het experiment verdiend hebt voor u worden uitgeteld. Blijf alstublieft op uw plaats tot de uitbetaling heeft plaatsgevonden.