

Coordination in a 3-Player Network Formation Game

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Abstract

We experimentally investigate the coordination behaviour in a finitely repeated network formation game between one seller and two buyers. If a competitive network is formed the seller gets the entire surplus. Buyers can prevent the competitive network from being formed by anti-coordinating their link offers. Alternatively the seller can be induced to coordinate the formation of the non-competitive network. The equilibria of the stage-game are strongly dependent on the link costs. Forming the competitive network is the only equilibrium using undominated strategies if there are no link costs. In the repeated game, however, both buyer anti-coordination and seller coordination on forming the non-competitive network are equilibria irrespective of the link costs. The experimental results show that the link costs do not significantly affect the seller's or the buyers' link offers. We find evidence for both buyer anti-coordination and coordination facilitated by the seller regardless of the link costs. Interestingly, the number of coordinating groups does not increase with positive link costs.

1. Introduction

In many markets buyers and sellers need to establish or have connections with each other to be able to engage in trade. Such connections (i.e., links) between the buyers and the sellers in a market, and the structure of these connections (i.e., the network) have been the subject of a rapidly growing interest in economics. Various theoretical models identified the effect of the shape of the buyer-seller networks on the payoffs of agents (see Corominas-Bosch, 2004; Kranton and Minehart, 2000; and Wang and Watts, 2006). In these models, typically, agents with more links and trading opportunities get a better share of the surplus than more isolated agents. Also, link costs affect the links that are formed among the agents. Despite the sharp predictions of the theoretical models, there have been only a few studies that investigate buyer-seller networks in the laboratory (see Charness, Corominas-Bosch, and Fréchet, 2007; Gale and Kariv, 2008; Judd and Kearns, 2008). These studies focused on a fixed network structure, and analyzed the effect of the network structure on agents' payoffs. In general, in these experiments it was found that agents with fewer links attain lower payoffs. Note, however, that the formation of the network was not studied in these experiments¹.

The present paper contributes to the experimental literature on networks by studying the coordination behaviour in the formation of networks in a finitely repeated setting. In this game, if the long side of the market competes, the short side of the market gets the entire surplus. Moreover, competition leads to negative payoffs for the competing parties if they incur costs for getting the opportunity to trade. However, if the long side of the market anti-coordinates their actions such that only one player enters into trade with the short side, then that one player earns positive payoffs. Since positive earnings for the long side of the market are only possible by anti-coordination, in the one-shot game, it is not obvious who enters into trade and who stays out. Such a problem, however, can be solved if the game is repeated. It is possible for the agents in the long side of the market to enter into trade in turns (anti-coordination), or the short side of the market to trade with one agent at a time (coordination) if the long side punishes deviations. Whether agents engage in anti-coordination or coordination, and how link costs affect their behaviour are the main questions investigated in this paper.

¹ One notable exception is the work by Corbae and Duffy (2008). They studied a two-stage network game in which players first decided with whom to form links and then played the coordination game.

We focus on the simplest buyer-seller network formation game in which coordination strategies of players in a repeated game can be investigated. There is one seller who has one good and two potential buyers. All the players simultaneously make link offers; the seller decides whether to form a link with one buyer or two buyers and the buyers decide whether to form a link with the seller. If a competitive network is formed in which the seller is linked to both buyers, then the entire surplus goes to the seller. If the seller is linked to one buyer only, the surplus is shared, albeit not equally, between the seller and the linked buyer. In this non-competitive network, the seller earns two-thirds of the surplus, and the linked buyer one-third. In the one-shot game, offering two links is a weakly dominating strategy for the seller regardless of the link costs. It is a weakly dominating strategy for the buyers to offer a link to the seller only if the links are costless. So, playing the undominated one-shot game strategies results in the formation of the competitive network in every period if the links are costless. If the links are costly, however, the competitive network can not be supported as an equilibrium of the repeated game. Hence, link costs are predicted to reduce the occurrence of competitive networks. In a repeated game, there are other equilibria which ensure that the buyers maximize their total payoff while maintaining equality among each other. We focus on two repeated game equilibria that lead to such outcomes. First, it is possible for the buyers to anti-coordinate their link offers so as to form one link in an alternating fashion every period. Such anti-coordination constitutes a subgame perfect equilibrium *regardless* of the link costs. Second, instead of offering two links every period, the seller can coordinate on forming one link if the buyers punish deviations of the seller². This equilibrium, as we will show in this paper, also holds regardless of the link costs. We thus investigate whether players engage in coordination, and if so, who facilitates the coordination and whether coordination is affected by the link costs.

There exist two strands of experimental literature related to this paper. The first is the study of anti-coordination in the finitely repeated games of chicken, battle of the sexes, entry, and congestion. Similar to our study, in these games agents can engage in the “opposite” actions and take turns to maximize their joint payoffs while also maintaining equality. Such anti-

² For the sake of simplicity, in the rest of this paper, we will mostly stick to the expressions “coordinating on one link” for both buyer anti-coordination and seller coordination behaviour, “buyer coordination” to refer to the buyer anti-coordination, and “seller coordination” to refer to the seller coordination.

coordination behaviour did not receive substantial attention in the experimental literature, and the evidence for anti-coordination is mixed³. Rapoport, Guyer and Gordon (1976) studied a variant of the chicken game in a repeated setting and found anti-coordination to be prevalent. Similarly, Arifovic, McKelvey, and Pevnitskaya (2006) showed that players anti-coordinated in the repeated battle of the sexes games. Helbing, Schönhof and Holyst (2005) studied what they called the 2-persons congestion game. In this game choosing the Pareto dominating action yielded zero payoff for both players whereas alternating their actions maximized their long-run payoff. They found that the players often learned to alternate their actions in the repeated game. There was no conclusive evidence for alternation behaviour in repeated market entry games (see Erev and Haruvy, 2009 for an overview; Kaplan and Ruffle 2008). Unlike the aforementioned studies that exclusively studied anti-coordination, in our setting both coordination and anti-coordination is possible. The buyers can anti-coordinate and take turns on the non-competitive network, but taking turns on the non-competitive network can also be facilitated by the seller. Moreover, the network formation game makes it possible for us to study the anti-coordination behaviour of players also when a weakly dominating strategy exists in the one-shot game. The existence of a weakly dominating strategy might make anti-coordination more difficult to achieve.

The second strand of related experimental literature focuses on network formation and examines whether behaviour in link formation games is in line with the predictions of various theoretical models (See Berninghaus, Ehrhart, and Ott 2006; Berninghaus, Ehrhart, Ott, and Vogt 2007; Callander and Plott, 2005; Deck and Johnson, 2004; Falk and Kosfeld, 2003; Goeree, Riedl, and Ule, 2008). In most of these papers the focus was on whether certain network structures such as “stars” and “cycles”, which were predicted to be formed by the considered theoretical model, emerged in the laboratory. Attaining those structures posed a coordination problem for the players involved. In all these studies, being linked almost always led to higher payoffs than not being linked. The coordination results of these studies were mixed. Coordination on a star structure mostly failed if players were homogenous as in Goeree et al (2008) or if the player who

³ Anti-coordination behaviour received little attention also in the theoretical network literature. There exist two theoretical papers that investigate anti-coordination in networks by Bramoullé (2007), and Bramoullé, Lopez-Pintado, Goyal, and Vega-Redondo (2004).

paid for the link was not the sole beneficiary of the link as in Falk and Kosfeld (2003). However, players mostly formed the star structures in the continuous time setting of Berninghaus et al (2006, 2007), and with heterogeneous agents of Goeree et al (2008). Also, in both Falk and Kosfeld (2003), and Callander and Plott (2005) coordination on the cycle network occurred in the majority of the cases. Different from these network formation studies, in our game, not all the players have similar incentives for forming a certain network. Whereas the seller is better off in a competitive network, the buyers are better off by anti-coordinating on the non-competitive network. Moreover in a repeated setting, the buyers can induce the seller to coordinate on forming the non-competitive network by punishing deviations.

In this paper, we first show that formation of the non-competitive network with alternating buyers constitutes an equilibrium of the finitely repeated game, and such a formation can be facilitated either by buyer anti-coordination, or seller coordination behaviour. Our experimental results show that the link costs do not significantly affect the seller or the buyers' link offers, and there exist both buyer and seller coordination in both cost treatments. The coordination behaviour is further reflected at the group level results that show that regardless of the link costs, the majority of the groups play similar to coordination equilibria. Among the coordinating groups, some engage in the buyer coordination, some in the seller coordination, and some in both. Interestingly and contrary to what one might expect, the number of coordinating groups does not increase with the link costs.

The remainder of this paper is organized as follows. The next section presents the game along with the hypotheses that are derived from the equilibrium analysis. Section 3 outlines the experimental design and procedure. Section 4 presents the experimental results and tests of the various hypotheses. Section 5 discusses and concludes.

2. The Game

The game involves one seller and two buyers. The players simultaneously offer links to each other. The two buyers cannot form a link with each other. Links can be considered as necessary connections for trade to take place. Since trade requires the consent of both players, a link is formed when both players offer it. After the simultaneous link offer stage, the payoffs are realised according to the link or links that are formed, and the next period starts. We investigate

two cases with different link costs. In the first case, links are costless; in the second, there are link costs. The cost of a link can be thought of as a necessary investment for trade to take place. The cost of a link is the same for both sellers and buyers. Costs are incurred once a link is formed, not when a link is offered. The link offers of the players are made common knowledge at the end of the link formation.

There are 16 different networks that can be formed considering the link offers of the seller and the buyers. We categorize these 16 networks according to the number of links formed, and for simplicity call them the no-link networks, 1-link networks, and the 2-link network. In the no-link networks no player has a link. Nine networks are categorized as no-link networks. In the 1-link networks one buyer maintains a link with the seller. Six networks are categorized as 1-link networks. In the 2-link network both buyers have a link with the seller. The 16 networks are depicted in the Appendix A in Figure A.1.

The payoffs of the players depend on the number of links that are formed, and their role. If no links are formed, each player receives a payoff of zero regardless of the link costs. The pie is fixed at 240 points. In a competitive network, the whole surplus goes to the seller. In a non-competitive network, the linked buyer earns a positive profit albeit less than the seller. There are two different levels of link costs; in the first the link costs are zero, and in the second each link costs 40 points for both parties involved in the link. The latter level of costs is chosen such that it is high enough to have an effect on the behaviour of the players, but low enough to make sure that the buyers are willing to form a link with the seller. The payoffs of players in the 1-link and 2-link networks if the link costs are 0, and 40 are illustrated in Figure 1, and Figure 2, respectively. Note that in the figures unreciprocated link offers are omitted.



Figure 1. Payoffs if link costs are 0.

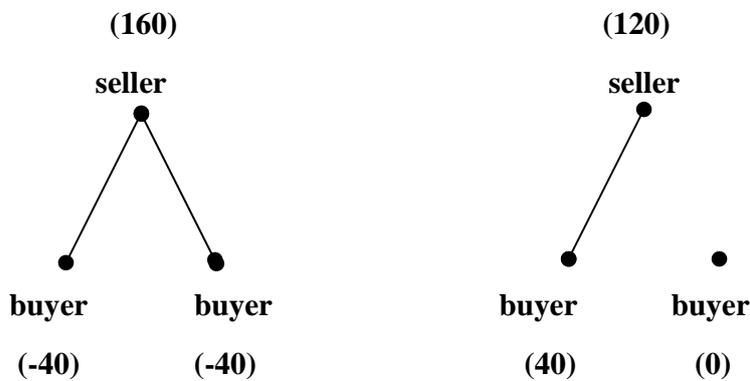


Figure 2. Payoffs if link costs are 40.

The Nash equilibrium (NE) of the one-shot game in pure strategies depends on the cost of a link. If the links are costless, the following six networks are NE: the no-link network in which no player offers a link, the two 1-link networks in which the seller offers two links, the two 1-link networks in which the seller offers one link, and the unlinked buyer does not offer a link, and the 2-link network. The no-link network without link offers is a NE because neither the seller nor the buyers are better off by unilaterally offering a link. In the 1-link and 2-link Nash equilibrium networks, no player has an incentive to unilaterally break a link. In the 1-link networks, the unlinked buyer is not better off by offering a link, and the seller is indifferent between offering and not offering a link to the unlinked buyer. Notice that in the one-shot game, offering two links (one link) is a weakly dominating strategy for the seller (buyers); hence an equilibrium refinement such as trembling hand perfection would prescribe the 2-link network as the unique equilibrium in pure strategies.

If the link costs are 40, five networks are NE. The no-link network with no link offers, the two 1-link networks in which the seller offers two links, and the two 1-link networks in which the seller offers one link and the unlinked buyer does not offer a link are NE in pure strategies. Note that these five networks are also NE if the links are costless and an explanation on why the networks are NE is therefore omitted. Unlike the cost-0 case, the 2-link network is not a NE because a buyer has an incentive to unilaterally delete the link with the seller, which improves her payoffs from -40 to 0 . In the one-shot game, offering two links is a weakly dominating strategy for the

seller if the link costs are 40, so the only trembling hand perfect equilibria in pure strategies are the two 1-link networks in which the seller offers two links.

The repeated game admits multiple pure strategy NE as well as multiple subgame perfect Nash equilibria (SPE). Assuming that the players do not discount the future⁴, any combination of the NE of the one-shot game throughout the experiment is a SPE equilibrium of the repeated game⁵. Additionally, strategies that do not constitute a NE in the stage game might be supportable as a SPE of the repeated game. First, we rule out the possibility of such equilibria concerning the no-link networks for both cost cases and the 2-link network in the cost-40 case.

Proposition 1. Regardless of the link costs, strategies leading to the repeated formation of no-link networks in which there is at least one link offer cannot be supported as a SPE of the repeated game. Additionally, strategies leading to the repeated formation of 2-link networks can also not be supported as a SPE of the repeated game if the link costs are 40.

Proof. In the eight no-link networks with at least one link offer, all players earn their minmax payoff⁶, that is, for each player, who best responds to the actions of others' strategies, it is the case that any combination of actions by other players cannot lower her payoff. Since there is at least one link offer by one player in these no-link networks, there exists a one period profitable deviation for at least one player. The player who is offered a link is better off by deviating and forming a link with that player. Such a deviation cannot be punished because players cannot be made worse off than their minmax payoff. Likewise, if link costs are 40, in the 2-link network, both buyers prefer to deviate by not forming a link and such a deviation cannot be punished. ■

In this paper we focus our analysis on three types of play: repeated play of the undominated strategies of the one-stage game and the two repeated game strategies that require coordinating

⁴ The design of the experiment implicitly assumes that players do not discount the future such that the payoffs of the players are constant across periods.

⁵ To characterize all the SPE of the repeated game is beyond the scope of this paper. For a detailed exposition of the Nash and SPE equilibria of repeated games see Vega-Redondo (2003; Chapter 8).

⁶ Formally, the minmax payoff is defined as the $\min_{a_{-i} \in \times A_{j \neq i}} \max_{a_i \in A_i} g_i(a_i, a_{-i})$ where $a_i \in A_i$ is player i 's pure action, $a_{-i} \in \times A_{j \neq i}$ is any combination of pure actions of players other than i , and g_i is player i 's payoff function.

on the formation of a 1-link network in each period. All three strategies can be supported as a SPE of the repeated game regardless of the link costs.

As the experimental literature points out, players generally avoid playing dominated strategies⁷. Hence, first, we investigate the repeated play of the undominated strategies in this game. In the one-shot game, it is a weakly dominating strategy for the seller to offer two links regardless of the link costs. For the buyers, it is a weakly dominating strategy to offer a link only if the link costs are 0. There does not exist a weakly dominating strategy for the buyers if the link costs are 40. So, the repeated play of the undominated strategies predicts a 2-link network to be formed in every period if the link costs are 0. If the link costs are 40, however, the repeated formation of 2-link networks cannot be supported as an equilibrium.

The growing social preference literature has shown that inequality aversion is not uncommon among players. So, we analyzed the two repeated game strategies that yield less unequal payoffs for the buyers compared to the undominated strategy play but require coordination among the players. These two strategies result in the formation of a 1-link network in each period with an alternating buyer so that not only the total payoff of the buyers is maximal but also the buyers' earnings are the same. Hence each buyer has an incentive to sustain these strategies. These two strategies differ in who coordinates the formation of the 1-link network; in the first it is the buyers (buyer coordination) and in the second it is the seller (seller coordination) who alternates the link offer. In the buyer coordination strategy, the seller offers two links every period, and buyers alternate in forming a link with the seller by taking turns in offering a link. In the seller coordination strategy, the buyers offer a link each to the seller every period, and the seller offers a link to one buyer in an alternating fashion. Next, we show that these two repeated game strategies do indeed constitute an equilibrium.

⁷ For example, in the dominance solvable beauty contest games of Nagel (1995), few subjects chose the weakly dominated strategies. Similar results were found in the two-iteration dominance-solvable symmetric normal-form games of Stahl and Wilson (1994, 1995), and in the two- and three- iteration dominance solvable games of Costa-Gomes, Crawford, and Broseta (2001). Notice that in the network formation game considered in this paper, there is only one step of iteration needed for playing the undominated strategy.

Proposition 2. Buyer Coordination: Regardless of the link costs, in the repeated game, the following strategies can be supported as a SPE: the seller offers two links in every period, and the buyers alternate in offering a link to the seller.

Proof: We know that playing a stage-game Nash equilibrium in each period is a repeated game SPE. So, the 1-link network in which the seller offers two links, and the buyers offer a link in alternating periods is also a SPE of the repeated game regardless of the link costs⁸. ■

Proposition 3. Seller Coordination: Regardless of the link costs, until the last three periods of the repeated game the following strategies can be supported as a SPE: buyers offer a link each in every period, and the seller alternates in offering a link to the buyers.

Proof: Assume that both buyers offer a link to the seller every period. Without loss of generality assume also that the seller offers a link to buyer 1 at odd numbered periods, and to buyer 2 at even numbered periods. Now, if the seller and buyer 2 stick to the equilibrium play in every period, buyer 1 does not deviate in an odd numbered period because she is worse off by deviating (the opportunity of getting a positive payoff from a link is lost). The same argument holds for buyer 2 in even numbered periods. Buyer 1 (2) does not deviate in even (odd) numbered periods, because she is not better off by deviating⁹. However, the seller has an incentive to deviate in every period because if she offers two links she earns more; i.e. 240 instead of 160 in cost-0 case, and 160 instead of 120 in the cost-40 case. So, to prevent the seller from offering two links at any period a punishment strategy is necessary.

If the seller deviates from equilibrium play and offers two links in a period, then both buyers offer no link for at least one period as a punishment (seller punishment hereafter). Notice that

⁸ Notice that in the buyer coordination equilibrium, it is assumed that both the seller and the buyers stick to the equilibrium play if they are indifferent. For example, in the cost-0 case if the seller offers two links in every period, and buyer 1 offers a link in the odd-numbered periods, then it is also a SPE that buyer 2 offers a link in all periods. To rule out such costless deviations from equilibrium play, punishment is needed: It can be shown that the buyer coordination equilibrium can be sustained as a strict equilibrium via appropriate punishment structures.

⁹ As in the buyer coordination equilibrium, SPE assumes that if the players are indifferent between two actions, then they stick to the equilibrium play. The following punishment structure rules out such indifference: if, say, buyer 1 deviates in an even numbered period, then the seller offers two links for two consecutive periods, and buyer 2 offers a link whereas buyer 1 does not offer a link. Any deviation by buyer 1 from the punishment repeats the punishment.

with this punishment structure the seller is strictly worse off by deviating: she earns 240 (160) in the deviation period and zero for the punishment period instead of earning 160×2 (120×2) for two periods if the link costs are 0 (40). Now, a buyer prefers to deviate and form a link with the seller instead of punishing the seller. So, the following is necessary to sustain the punishment of the seller (buyer punishment hereafter). If buyer 1 deviates from not offering a link during the seller punishment phase, then buyer 2 offers a link to the seller for *at least* two consecutive periods, the seller offers two links in these two periods. Buyer 1 does not offer a link in these two periods. Any deviation by buyer 1 in the buyer punishment phase repeats the punishment. So, assume buyer 1 deviates in the seller punishment period, then she earns 80 (40) in the deviation period and zero in the next two periods if the link costs are 0 (40). If buyer 1 does not deviate from the seller punishment, then she earns zero for one period, and 80 (40) in total in the next two periods if the link costs are 0 (40). So buyer 1 is not better off by deviating from punishing the seller. Buyer 2, on the other hand, is strictly better off by punishing buyer 1; buyer 2 earns 80×2 (40×2) if she punishes buyer 1, and 80 (40) if she does not punish buyer 1 if the link costs are 0 (40). The seller is indifferent between punishing and not punishing buyer 1, and earns 160×2 (120×2) if the link costs are 0 (40). So, a minimum of three periods are necessary to sustain the equilibrium. In the last three periods of the game any one-stage Nash equilibrium can be played. ■

To sum up, the repeated play of all one-stage Nash equilibrium networks can be supported as a repeated game SPE. Finally, there exist networks whose repeated play cannot be supported as a SPE of the repeated game. We focus on two coordination equilibria that provide both buyers with a positive and equal payoff. First is the buyer coordination equilibrium in which a 1-link network is formed every period, the seller offers two links every period, and the buyers alternate their link offers. Second is the seller coordination equilibrium in which the buyers always offer two links and the seller alternates her link offer every period.

Hypotheses

We formulate the theoretical predictions into five hypotheses. The first and the second hypotheses are based on the play of undominated strategies of the stage game. The third hypothesis is on the link formation in a coordination equilibrium. The fourth and the fifth

hypotheses are on the buyers' and seller's link offers assuming the buyer and the seller coordination, respectively.

Link Formation in Undominated Strategies of the One-Shot Game

1. *The 2-link network is formed less often if the link costs are 40 than if the link costs are 0.*

If both the seller and the buyers play the weakly dominating strategies of the one-shot game, then a 2-link network is formed at all periods if the link costs are 0. If the seller plays the weakly dominating strategy of the one-shot game, i.e., offers two links, then in equilibrium a 1-link network is formed at all periods if the link costs are 40.

Link Offers in Undominated Strategies of the One-Shot Game

- 2.1. *Link costs do not affect the seller's link offer.*

Offering two links is a weakly dominating strategy for the seller in the one-shot game irrespective of the link costs.

- 2.2. *The buyers are less likely to offer a link if the link costs are 40 than if the link costs are 0.*

Offering a link is a weakly dominating strategy for both buyers in the one-shot game if the link costs are 0 but not if the link costs are 40.

Link Formation in a Coordination Equilibrium

3. *Regardless of the cost treatment, the conditional probability that a link is formed with buyer 1 (2) given that a link is formed with buyer 2 (1) is smaller than the marginal probability that a link is formed with buyer 1 (2).*

In a buyer or seller coordination equilibrium one link is formed with alternating buyers in each period. So, the probability of having a 1-link network is not independent of the probability of buyer 1 or buyer 2 having a link. If we define \Pr_{Buyer1}^{link} as the probability that buyer 1 forms a link, and $\Pr_{Buyer1|Buyer2}^{link}$ as the probability that buyer 1 forms a link given that buyer 2 forms a link, then by dependence of the link formation the following holds in a coordination equilibrium:

$$\Pr_{Buyer1}^{link} > \Pr_{Buyer1}^{link} |_{Buyer2} \text{ and } \Pr_{Buyer2}^{link} > \Pr_{Buyer2}^{link} |_{Buyer1} .$$

Link Offers in a Buyer Coordination

4. *Regardless of the cost treatment, the conditional probability that buyer 1 (2) offers a link given that buyer 2 (1) offers a link is smaller than the marginal probability that buyer 1 (2) offers a link.*

In a buyer coordination equilibrium, the buyers alternate on offering a link to the seller, and the seller offers two links regardless of the link costs. So, the link offer decisions of the buyers are not independent of each other. If we define $\Pr_{Buyer1}^{link\ offer}$ as buyer 1's probability of offering a link, and $\Pr_{Buyer1}^{link\ offer} |_{Buyer2}$ as the probability that buyer 1 offers a link given that buyer 2 offers a link, then by dependence of the link offers the following holds in a buyer coordination:

$$\Pr_{Buyer1}^{link\ offer} > \Pr_{Buyer1}^{link\ offer} |_{Buyer2} \text{ and } \Pr_{Buyer2}^{link\ offer} > \Pr_{Buyer2}^{link\ offer} |_{Buyer1} .$$

Link Offers in a Seller Coordination

5. *Regardless of the cost treatment, the conditional probability that the seller offers a link to buyer 1 (2) given that she offers a link to buyer 2 (1) is smaller than the marginal probability the seller offers a link to buyer 1(2).*

In a seller coordination equilibrium, the seller offers one link to the buyers in an alternating fashion, and the buyers offer two links regardless of the link costs. So, the seller's link offer decision to a particular buyer is not independent of her link offer decision to the other buyer. If we define $\Pr_{Seller1}^{link\ offer}$ as the seller's probability of offering a link to buyer 1, and $\Pr_{Seller1}^{link\ offer} |_{Seller2}$ as the seller's probability of offering a link to buyer 1 given that she offers a link to buyer 2, then the dependence of the link offers of the seller implies the following in a seller coordination:

$$\Pr_{Seller1}^{link\ offer} > \Pr_{Seller1}^{link\ offer} |_{Seller2} \text{ and } \Pr_{Seller2}^{link\ offer} > \Pr_{Seller2}^{link\ offer} |_{Seller1} .$$

Notice that the hypotheses are not mutually exclusive. The undominated strategy play predicts the formation of the 1-link network if the link costs are 40 but does not prescribe which 1-link network is formed. Also, the last two hypotheses can be confirmed for the same group if both the buyers and the seller coordinate on forming one link.

3. Experimental Design

The experiments were conducted at the CentERlab in Tilburg University, the Netherlands. A total of 63 subjects participated in 4 sessions, and each subject participated only once. Subjects were recruited through email lists of students interested in participating in experiments. There were in total 30 subjects (10 groups) in 2 sessions in the cost-0 treatment, and 33 subjects (11 groups) in 2 sessions in the cost-40 treatment. Subjects were at tables separated by partitions, such that they could not see other participants' screens but could see the experimenters in front of the room. Sessions lasted between 45 and 75 minutes, and average earnings were approximately 10.78 (9.54) Euros including a show-up fee of 5 Euros in the cost-0 (40) treatment.

First, written instructions were given to the participants and read out loud by the experimenter. A copy of the instructions is included in Appendix B. It was explained in the instructions that each group consisted of 3 players who were randomly selected at the beginning of the experiment and that the group composition stayed the same throughout the experiment. Subjects had no way of knowing which of the other participants were in their group during the experiment. In the instructions and the experiment, the sellers were denoted as Player 1, and one buyer was denoted as Player 2, and the other buyer as Player 3. Player roles remained fixed throughout the experiment. The game was explained as consisting of two parts: the first being about offering links to other players and the second about sharing an amount of points. Subjects were informed that the task would be repeated for 30 periods and that their final earnings comprised of the total points they earned in the experiment converted at a rate of 0.25 (0.35) Eurocents per point in the cost-0 (40) treatment plus the show up fee. In the cost-40 treatment, it was emphasized that offering a link is not costly, but that if a link is formed players who have the link each pay 40 points. After the instructions were finished, subjects played one practice period in order to familiarize them with the procedure and the screens. Subjects' understanding of the task was then assessed by asking them 3 questions to answer at their own pace. Their answers were

checked one by one and when necessary the task and the payoff structure were explained again privately.

The experiment was programmed and conducted with the software z-Tree (Fischbacher 2007).¹⁰ Each period started with a screen with the three boxes with labels 1, 2, and 3, representing the players of the group. An example of the subject screen is contained in the instructions of the experiment in Appendix B. A player's own box was always presented on top of the screen. Players simultaneously decided with whom to link, and they offered a link by clicking on the box of another player. Buyers could not link to each other. Subjects saw an arrow pointing to the other player's box when they clicked, and it was possible to undo the link offer by clicking again. When the players moved to the next screen¹¹, a line between two players on the screen informed them about the links that formed. If a link was offered unilaterally this was indicated with an arrow pointing to the other player. The players were informed about their own payoff in that period, the group members' payoffs in that period, and their own cumulative payoffs. In the cost-40 treatment, their total payoff was the amount of points from the link formation minus the link costs. Note that players could earn negative payoffs in this treatment in which case the money was deducted from their show-up fee. Nevertheless, the point to money conversion rate and the show-up fee were chosen such that even in the case of maximum losses in every period the subjects would not need to pay money to the experimenters. All groups in a session started each period at the same time. Thus it was not possible to identify one's group members at any point of the experiment. At the end of the experiment participants were paid privately and separately in an adjacent room.

4. Results

This section has two subsections. The first subsection illustrates the link formation and link offer results of the experiment in the order of the hypotheses. In this subsection, first the averages¹²

¹⁰ The program of the experiment is available from the author upon request.

¹¹ The subjects moved to the next phase of the experiment when all group members pressed the "Press to move" button. Also, each screen had a binding time limit of 180 seconds in the first 5 periods, and 60 seconds in the later periods.

¹² Throughout the results section, we will focus on the average number of links and average number of link offers.

are reported along with the relevant tests. Then, the independence of the link formations and the link offers are investigated using an exact test which will be described in detail. The second subsection investigates the link offer behaviour at the group level using the test results on the independence of link offers.

Throughout the results section, unless otherwise stated, a group of one seller and two buyers interacting over 30 periods is treated as one independent observation. There are 10 independent observations in the cost-0 treatment and 11 in the cost-40 treatment. The p -values reported for between-treatment comparisons are based on the Mann-Whitney test; p -values reported for within-treatment comparisons are based on the Wilcoxon matched-pairs signed-ranks test. We use a one-tailed (two-tailed) test when the hypothesis is (is not) directional. Conclusions are based on the 10 percent α -level.

4.1. Link Formation Results

Result 1. The 2-link network was formed significantly less often if the link costs were 40 than if the link costs were 0.

Table 1 shows the frequencies of the number of links, and the average number of links per treatment. The ‘0 links’ column shows that there were few periods with no links. The average frequency of one links was not significantly lower in the cost-0 treatment than in the cost-40; in the cost-0 treatment 1-link networks were formed in 62% of the periods, and in the cost-40 treatment in 70% of the periods. The frequency of the two links was significantly lower in the cost-40 treatment (21%) than in the cost-0 treatment (34%). The number of links was significantly lower in the cost-40 treatment (1.13) than in the cost-0 treatment (1.31). To sum up, in line with the undominated strategy equilibrium predictions, the 2-link network was formed less often in the cost-40 treatment than in the cost-0 treatment.

The results on formed links were further reflected in the average payoffs of the seller and the buyers. Whereas the average gross seller payoff was significantly lower in the cost-40 treatment

For the sake of simplicity and readability, the words “average number of” are dropped from the description of the results wherever the meaning is obvious. For example, instead of buyers’ (seller’s) average number of link offers, buyers’ (seller’s) link offers is used. Likewise, differences in link offers refers to differences in the average number of link offers.

due to the formation of fewer 2-link networks, the average payoff of the buyers was not significantly higher if the link costs were 40. Table C.1 in the Appendix C presents the average payoffs of the seller and the buyers in both cost treatments as well as the one-tailed exact p -values¹³.

Table 1. Average frequency and number of links^a

	0 links	1 link	2 links	Average number of links
Cost-0	3.7 (4.0)	62.0 (25.4)	34.3 (27.7)	1.31 (0.30)
Cost-40	8.2 (9.2)	70.3 (25.6)	21.5 (23.9)	1.13 (0.26)
p	.338 ^c	.228 ^b	.095 ^b	.063 ^b

^aStandard deviations are in parentheses. ^b 1-tailed exact test ^c 2-tailed exact test

Result 2.1. The seller's link offers were not significantly different between the cost treatments.

Table 2 shows the average number of link offers per period as a function of link costs and player roles. The second column of the table is the average number of links the seller offered to each buyer per period. The third column states the average number of links each buyer offered to the seller. The sellers offered on average 0.77 links per buyer in the cost-0 treatment, and 0.71 links in the cost-40 treatment. The difference in the average link offers of the sellers between the cost treatments was not significant.

Table 2 Average number of link offers^a

	Seller	Buyers
Cost-0	0.77 (0.15)	0.77 (0.16)
Cost-40	0.71 (0.18)	0.74 (0.16)
p	.415 ^c	.308 ^b

^aStandard deviations are in parentheses. ^b 1-tailed exact test ^c 2-tailed exact test

¹³ Assuming undominated strategy play of the one-shot game, the seller's payoff is lower if the link costs are 40, but the average buyer payoff is higher if the link costs are 40.

Result 2.2. The buyers' link offers were not significantly lower in the cost-40 treatment than in the cost-0 treatment.

As shown in the third column of Table 2, the buyers' average number of link offers was 0.77 in the cost-0 treatment, and 0.74 in the cost-40 treatment. So, the buyers' link offers were not significantly lower in the cost-40 treatment than in the cost-0 treatment.

To conclude, the result of the seller's and the buyers' link offers were not completely in line with the predictions based on the undominated strategies of the one-shot game. Although there was no significant difference in the seller's link offers across the cost treatments, the seller's link offers were less than two links in both treatments. Also, the buyers' link offers were not significantly lower in the cost-40 treatment.

The link offers of the seller and the buyers averaged over segments of three periods are illustrated in Figure 3, and Figure 4, respectively. As shown in Figure 3, the link offer of the seller averaged over three periods varied between 0.70 and 0.83 in the cost-0 treatment, and between 0.67 and 0.76 in the cost-40 treatment. Although the link offer of the seller was lower in the cost-40 treatment than in the cost-0 treatment in all segments but one, the differences between the cost treatments were not statistically significant except in the fourth segment. Similarly, the averaged link offer of the buyers was not significantly higher in the cost-0 treatment than in the cost-40 treatment. As depicted in Figure 4, in the cost-0 treatment the link offer of the buyers was between 0.73 and 0.85, and in the cost-40 treatment the average was between 0.62 and 0.79. Also, in both cost treatments the link offer of the buyers seemed to have a downward trend with increasing periods.

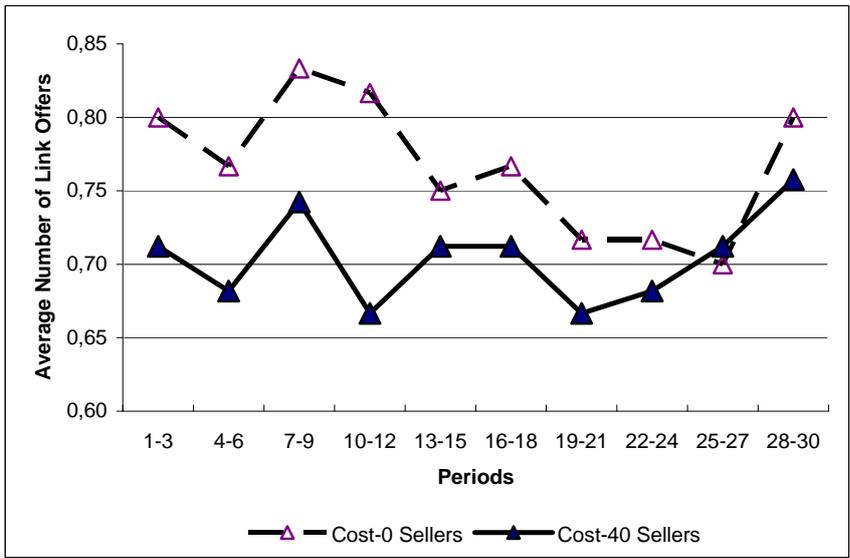


Figure 3. Average Number of Link Offers of the Seller

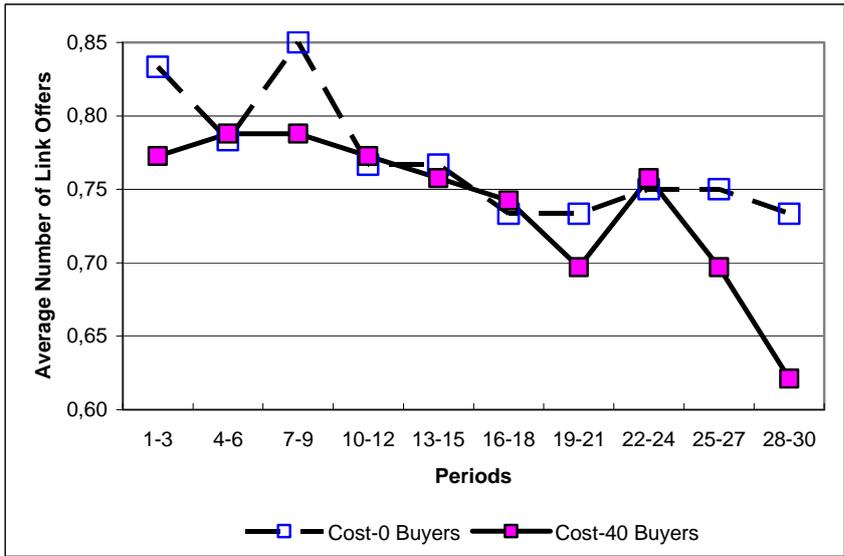


Figure 4. Average Number of Link Offers of the Buyers

Result 3. *Regardless of the cost treatment, the conditional probability that a link was formed with buyer 1 (2) given that a link was formed with buyer 2 (1) was significantly smaller than the marginal probability that a link was formed with buyer 1 (2).*

Table 3 illustrates the average number of periods buyer 1 and buyer 2 formed a link with the seller, and the expected number of periods in parentheses. The frequencies in the cells were

calculated by averaging the corresponding cell frequencies of all groups in a treatment. The expected frequencies of the cells corresponding to the empty network, given the marginal frequencies of Table 3, were 3.61 and 5.62 for the cost-0 and cost-40 treatment respectively. These numbers exceeded the observed frequencies by 2.51 (3.61–1.10) and 3.16 (5.62–2.46) in the cost-0 and cost-40 treatment, respectively, which were in line with our hypothesis that the conditional probability of having a link is larger if the other buyer does not have a link. To test the hypothesis statistically we must take into account that Table 3 is the result of combining frequency distributions of groups that have substantial differences in their marginal frequencies. We first describe the logic of the test.

Table 3 Observed and expected number of links^{a,b}

		Buyer 2	
		No link	Link
		Cost-0	
Buyer 1	No Link	1.10 (3.61)	9.40 (6.90)
	Link	9.20 (3.70)	10.30 (12.81)
		Cost-40	
Buyer 1	No Link	2.46 (5.61)	9.73 (6.57)
	Link	11.36 (8.21)	6.46 (9.61)

$p: < .001$ ^b

$p: < .001$ ^b

^aExpected number of periods are in parentheses. ^b 1-tailed exact test

To test the null hypothesis of the independence of link formation across all groups within a treatment, we used the p -values of an independence test for each group. Let X_j denote the random variable corresponding to both buyers having a link with the seller, and x_j the observed value of that random variable for group $j=1, \dots, J$. Also, let the observed frequencies of no (one) link for buyer 1 and buyer 2 be denoted as r_{1j} and c_{1j} (r_{2j} and c_{2j}), respectively. The probability that X_j is at most x_j for group j given r_{1j} , r_{2j} , c_{1j} , and c_{2j} , $\Pr(X_j \leq x_j | r_{1j}, r_{2j}, c_{1j}, c_{2j})$ or $\Pr(X_j \leq x_j)$ for short, is also the p -value of the independence test of link formation at the group level. Note that, the smaller the x_j , the more evidence there is for dependence in the form of coordination on forming

the 1-link network. This probability has a hypergeometric distribution and equals the one-tailed p -value of the Fischer exact test. Under the null hypothesis of independence, the probability that the p -value equals $\Pr(X_j \leq x_j)$ is equal to $\Pr(X_j \leq x_j) - \Pr(X_j \leq x_j - 1)$. An overview of the p -values from the independence tests at the group level is provided in the Appendix C Table C.2.

Assuming the independence of link formation across all groups within a treatment, $\Pr(X_1 \leq x_1 \cap X_2 \leq x_2 \cap \dots \cap X_J \leq x_J) = \prod_{j=1}^J \Pr(X_j \leq x_j)$. This product can be calculated for all possible value

combinations of (X_1, X_2, \dots, X_J) . Under the null hypothesis the probability of the value of the product $\prod_{j=1}^J \Pr(X_j \leq x_j)$ equals $\prod_{j=1}^J [\Pr(X_j \leq x_j) - \Pr(X_j \leq x_j - 1)]$. Lower values of the product

$\prod_{j=1}^J \Pr(X_j \leq x_j)$ correspond to more negative dependence. The one-tailed p -value of the test of

independence of link formation across all groups is then the cumulative probability that the value of product $\prod_{j=1}^J \Pr(X_j \leq x_j)$ is smaller or equal to the value of this product observed across the groups. This probability can either be found by computing all such products or by simulation. We found the p -values by simulation after calculating the value of the product in 100,000 draws from the joint hypergeometric distributions.

Applying the test to the link distributions of the groups resulted in a p -value smaller than .001 for both cost treatments. Thus, in both treatments there was evidence for coordination behaviour and the proportion of periods in which a 1-link network was formed was higher than the expected proportion of periods under the independence assumption.

Result 4. Regardless of the link costs, the probability that buyer 1 (2) offers a link given that buyer 2 (1) offers a link was significantly smaller than the probability that buyer 1 (2) offers a link.

Table 4 illustrates the average, and expected number of periods buyer 1 and buyer 2 offered a link to the seller. The expected frequencies exceeded the observed frequencies corresponding to the empty network by 1.35 (1.55–0.20) and 0.91 (2.00–1.09) for the cost-0 and cost-40 treatment

respectively. This was in line with our hypothesis that the conditional probability of a buyer offering a link is larger conditional on the other buyer not offering a link. Applying the same test as in Result 3, we rejected the null hypothesis of independence with p -values smaller than .001 for both cost treatments. Thus, in both cost treatments there was evidence for buyer coordination.

Table 4 Observed and expected number of periods of buyer link offers^a

		Buyer 2	
		No link Offer	Link Offer
		Cost-0	
Buyer 1	No Link Offer	0.20 (1.55)	5.70 (4.35)
	Link Offer	7.70 (6.35)	16.40 (17.75)
		Cost-40	
Buyer 1	No Link Offer	1.09 (2.00)	5.64 (4.73)
	Link Offer	7.82 (6.91)	15.46 (16.36)

$p: <.001$ ^b

$p: <.001$ ^b

^aExpected number of periods are in parentheses. ^b 1-tailed exact test.

Result 5. In both cost treatments, the probability that the seller offers a link to buyer 1 (2) given that the seller offers a link to buyer 2 (1) was significantly smaller than the probability the seller offers a link to buyer 1(2).

Table 5 shows the average and expected number of periods the seller offered a link to buyer 1 and buyer 2. The expected frequencies were 1.63 (1.63–0.00) and 2.48 (2.57–0.09) larger than the observed frequencies in the cells corresponding to the empty network for the cost-0 and cost-40 treatment, respectively. The p -values of the test of independence were smaller than .001 in both cost treatments, and the null hypotheses of independence were rejected. Thus, in both cost treatments there was evidence for seller coordination.

Table 5 Observed and expected number of periods of seller's link offers^a

		Buyer 2	
		No link Offer	Link Offer
		Cost-0	
To Buyer 1	No Link Offer	0.00 (1.63)	7.50 (5.88)
	Link Offer	6.50 (4.88)	16.00 (17.63)
		Cost-40	
To Buyer 1	No Link Offer	0.09 (2.57)	7.55 (5.07)
	Link Offer	10.00 (7.52)	12.36 (14.84)

$p: < .001$ ^b

$p: < .001$ ^b

^a Standard deviations are in parentheses. ^b 1-tailed exact test

4.3. Link Formation Results at the Group Level

Results 3 to 5 provide evidence at the aggregate level for the coordination of link formation, link offers of the buyers and link offers of the seller in both cost treatments. Next, we categorize the groups in each treatment with respect to the coordination strategies they used¹⁴.

To categorize the groups according to their strategies, we mainly relied on the test results of the independence of the buyers' link offers (as in Result 4) and the independence of the seller's link offers (as in Result 5). To be precise, if the test results of the independence test for the buyers' (seller's) link offers was significant, then that group was classified as playing the buyer (seller) coordination if it also satisfied the following conditions. For the buyer coordination, the difference between the following two numbers was not higher than 10: the number of periods buyer 1 offered a link to the seller and buyer 2 did not offer a link, and the number of periods

¹⁴ We also ran logistic regressions for each treatment on a buyer's probability of offering a link to the seller, and the seller's probability of offering a link to a buyer to test the predictions of the buyer coordination equilibrium and the seller coordination equilibrium. The results support both buyer and seller coordination equilibrium in the cost-0 treatment, but not in cost-40 treatment. One of the most important reasons for the lack of support for coordination equilibria in the cost-40 treatment is the diversity of strategies employed in this treatment. The regression results are included in Appendix Tables C3, and C4.

buyer 2 offered a link to the seller and buyer 1 did not. Similarly, for the seller coordination, the difference between the following two numbers was not higher than 10: the number of periods the seller offered a link only to buyer 2, and the number of periods the seller offered a link only to buyer 1. The rationale for the additional conditions was to prevent wrongly specifying the groups in which there was coordination on forming one link with the *same* buyer in most of the cases. This situation is referred to as ‘one buyer only’. In such a situation the link offers of the buyers might significantly depend on each other (likewise for the seller), hence leading to a significant p -value in the test for independence. However, since in this paper coordination is defined as forming one link that maximizes the payoff of each buyer in a repeated setting while maintaining equality, the aforementioned situations were not classified as coordination¹⁵.

A group was said to play *similar* to buyer (seller) coordination equilibrium if there was no significant p -value for the independence of the buyers’ (seller’s) link offers, but a 1-link network was formed in majority of the periods, and the above condition for the buyers (seller) held. An overview of the independence test results for each group is included in the Appendix C Table C.2. In this table, the groups are arranged according to the order of their mention in this section. All reported p -values in this section are one-tailed.

In the cost-0 treatment 7 out of 10 groups engaged in coordination. Among these seven groups there was one group with both buyer and seller coordination, three groups played the buyer coordination, and the other three groups played the seller coordination. The remaining three groups of the cost-0 treatment played similar to the undominated strategy of the one-shot game, i.e., these groups formed two links in most periods. The categories of strategies in both cost treatments along with the number of groups playing those strategies are summarized in Table 6.

¹⁵ Limiting the maximum difference between link offers to 10 periods or using a similar rule does not affect the categorization of the groups dramatically. For the differences between link offers between 10 and 25, the categorization would be the same as in this paper. Dropping these conditions altogether would lead to a change in the categorization of only one group. Making the conditions stricter would, however, lead some groups to be dropped from the coordination category depending on how small the chosen number is. Choosing another rule such as limiting the difference between the formed links of buyer 1 and buyer 2 to 10 would lead to the same categorization as in this paper. Nonetheless, there is a need to define a coordination index or heuristic that would lead to consistent and meaningful categorizations. The author of this paper is not aware of any such index that is applicable to this analysis.

Table 6 Number of groups playing different strategies

	Cost-0	Cost-40
Buyer & Seller Coordination	1	2
Buyer Coordination	3	1
Seller Coordination	3	1
<i>Similar</i> to Coordination	-	2
One Buyer only	-	3
(Un)dominated Strategy	3	2
Total	10	11

In the first group of the cost-0 treatment, both buyer and seller coordination strategy play was observed; the buyers offered in total one link in 21 periods and the seller offered in total one link in 24 periods. 1-link networks were formed with each buyer for 13 periods.

There was buyer coordination equilibrium in three groups (2 to 4); the buyers offered in total one link in 25, 23, and 24 periods, and the seller offered two links in 13, 19, and 16 periods. In these groups, a 1-link network was formed in 25, 22, and 24 periods with the buyers having roughly the same number of 1-link networks.

In the three groups with seller coordination equilibrium (groups 5 to 7), the buyers offered two links in 15, 30, and 24 periods, the seller offered one link in 27, 18, and 19 periods, and a 1-link network was formed in 26, 18, and 19 periods, respectively. In these three groups there was one buyer who always offered a link. Note that in none of these groups there was evidence for punishment after the formation of two links.

Finally, the repeated play of the undominated strategy equilibrium of the one-shot game was observed in three groups. In these three groups, the sellers offered two links in 30, 30, and 20 periods, both buyers offered a link in 22, 25, and 22 periods, and as a result, two links were

formed in 22, 25, and 16 periods respectively. Also, in all the three groups there was evidence of an attempted buyer coordination that failed such that one buyer alternated between offering and not offering a link at the beginning of the game, but the other buyer did not reciprocate. Notice that such repeated play is also a SPE of the game.

In the cost-40 treatment, 4 out of 11 groups played the coordination equilibria, and two other groups played similar to the coordination equilibria. Among the four coordinating groups, in two groups both buyer and seller coordination were observed, in one group there was buyer coordination, and one group played the seller equilibrium. In the two groups that played similar to the coordination equilibria, one group's play was similar to the buyer equilibrium, and the other group's play was similar to the seller equilibrium.

In the remaining five groups of the cost-40 treatment, two types of play other than coordination were observed. In three groups a 1-link network was observed almost exclusively with the same buyer, and in two groups there was "dominated strategy" play, leading to the formation of 2-link networks in the majority of the periods. Notice that such a strategy was dominated for the buyers in the cost-40 treatment.

In the groups in which both the buyers and the seller coordinated, the buyers offered one link in total in 22, and 26 periods, and the sellers offered one link in 28, and 25 periods. In these two groups a 1-link network was formed with alternating buyers in 30, and 28 periods respectively. In the group with buyer coordination the buyers offered one link in total in 21 periods, the seller offered two links in 20 periods, and a 1-link network was formed in 18 periods. In the group with seller coordination the buyers offered two links in 21 periods, the seller offered one link in 17 periods, and a 1-link network was formed in 16 periods. In this group the seller also formed two links in some periods without being punished afterwards.

Two groups are considered as playing similar to the coordination equilibria. In the group that played similar to the buyer coordination equilibrium, the buyers offered one link in total in 17 periods, and the seller offered two links in 30 periods. A 1-link network was formed in 17 periods. In this group the buyers seemed to learn to alternate their link offers over time albeit not totally successfully. In the group that played similar to the seller coordination, the buyers offered two links in 19 periods and the seller offered one link in 16 periods. In this group, 1-link

networks were formed in 18 periods. However, there was not enough power to reject the independence hypothesis for the seller's link offer decisions.

In the cost-40 treatment, different from the cost-0 treatment, there were groups in which in almost all periods a 1-link network was formed with the same buyer. In three groups, the buyers offered two links in 6, 24, and 28 periods, and the sellers of these groups offered a link to the *same* buyer in almost all periods (27, 29 and 27 periods respectively). In the first group both buyers offered two links in six out of the first nine periods, and after the ninth period one buyer did not offer a link whereas in the latter two groups buyers offered two links in most periods. Although in the last group the independence test showed a significant effect for the seller's link offers (p-value: .007), the coordination condition was not satisfied for the seller, i.e., the seller offered one link to buyer 1 in 27 periods, one link to buyer 2 in 2 periods and the difference between the two was more than 10. Notice that the strategies of the players in these three groups constitute a SPE of the repeated game provided that deviations are punished¹⁶. Also, in all groups the seller offered two links in the last period which might imply that the sellers played equilibrium strategies until the last period in which a deviation could not be punished.

The last two groups' play was similar to the undominated strategy play of the one-shot game in the cost-0 treatment. In these two groups the seller offered two links in 22, and 26 periods, and the buyers offered two links in 22, and 24 periods respectively. As a result two links were formed in 15, and 22 periods, respectively which led to substantial losses for both buyers. Although given that the seller offered two links, and one buyer always offered a link, the other buyer was better off by not offering a link, both buyers did not deviate from offering a link in the majority of the periods. As in the groups that played the undominated strategy in the cost-0 treatment, in these two groups one buyer tried to coordinate at the beginning of the game, but the other buyer did not reciprocate and kept on offering a link to the seller in every period. Note that such buyer behaviour was not only contrary to the repeated SPE predictions, but also to the

¹⁶ It can be shown that it is a SPE of the repeated game that both buyers always offer a link, and the seller always offers a link to the same buyer. If the seller deviates and offers two links, then both buyers punish the seller for at least one period by not offering a link.

predictions of the inequality aversion models such as Fehr and Schmidt (1999), Bolton and Ockenfels (2000), and a preference for efficiency¹⁷.

To sum up, in the cost-0 treatment, seven out of 10 groups engaged in some sort of coordination behaviour. In the other three groups, the undominated strategy play was prevalent. In the cost-40 treatment, four out of 11 groups played coordination equilibria. In two other groups the strategies were similar to coordination play. In three groups players coordinated on forming one link with the same buyer only. Finally, there were two groups who played contrary to the theoretical predictions. So, in both cost treatments the majority of the groups played similar to the coordination predictions using the buyer or the seller coordination strategies or both. Remarkably, and contrary to what one might expect, the number of coordinating groups did not increase with link costs.

5. Discussion and Conclusion

In this paper we examined the impact of the link costs on network formation. Particularly, we addressed the questions of whether the players coordinated on forming the non-competitive networks, who facilitated the coordination, and whether link costs affected the coordination behaviour.

To investigate these questions we implemented a finitely repeated game between one seller and two potential buyers. The seller decided whether to form one or two links with the buyers and the buyers simultaneously decided whether to form a link with the seller. If a competitive network was formed in which the seller was linked to both buyers, then the seller earned the entire surplus. In a one link network the surplus was shared between the seller and the linked buyer. We studied the repeated game subgame perfect equilibria with and without link costs. If the players used undominated strategies of the one-shot game, the presence of link costs was predicted to reduce the occurrence of competitive networks. We have shown that, regardless of the link costs, the formation of one link with alternating buyers in which the buyers anti-coordinate their actions and take-turns was a repeated game subgame perfect equilibrium.

¹⁷ Assuming that the seller always offers two links, and one of the buyers always offers one link as was the case in these three groups, then according to these models the other buyer is better off by not offering a link regardless of the inequality aversion parameter values.

Moreover, coordination on forming one link that is facilitated by the seller could also be supported as a subgame perfect equilibrium. We thus investigated whether coordinated existed, and if so who facilitated the coordination.

We found that with link costs, a competitive network in which the seller was linked to both buyers was less likely to be formed. Although the average number of links was significantly lower with link costs, the seller's or the buyers' link offers were not significantly different across the cost treatments. Thus, both the seller and the buyers coordinated their link offers if the link costs were positive so as to form the competitive network less often. Moreover, sellers did not employ the weakly dominating strategy (of the one-shot game) of offering two links regardless of the link costs.

We found strong evidence for coordination on forming one link in both cost treatments. The test results on both treatments showed highly significant dependence of i) the link formation of one buyer on the link formation of the other buyer, ii) a buyer's link offer on the link offer of the other buyer, and iii) the seller's link offer to one buyer on the seller's link offer decision on the other buyer.

The analysis at the group level showed that if the links were costless, seven out of 10 groups engaged in some sort of coordination behaviour. If the link costs were positive, four out of 11 groups played coordination equilibria, and two other groups played *similar* to coordination equilibria. Among the coordinating groups, some engaged in the buyer coordination, some in the seller coordination, and some in both. So, in both cost treatments the majority of the groups played similar to the coordination equilibria. Notably, and contrary to what one might expect, the number of coordinating groups did not increase with the link costs.

Our group level results pointed to two types of play that deserves special attention. First, if the links were costly, there were three groups in which one link was formed with the same buyer in almost all periods. In these three groups, the seller facilitated the formation of one link networks but did not "coordinate". So, clearly, the sellers of these groups did not care about the payoff inequality across the buyers. The second type of play that deserves special attention is the dominated strategy play: If the links were costly in two groups two links were formed in most periods causing the buyers to earn negative payoffs. Such buyer behaviour cannot be explained

by the profit maximizing rational agents even if inequality aversion or preference for efficiency is taken into consideration. Thus, these buyers might have social preferences that cannot be captured with the inequality aversion models .

Our findings on anti-coordinating on a mutually beneficial outcome by alternating, i.e., buyer coordination, was in line with the findings of the repeated chicken and battle of the sexes games investigated by Rapoport, Guyer and Gordon (1976) and Arifovic et al. (2006) respectively. Different from these studies, however, in our game anti-coordination involved more than two players. Also, a third party who had a weakly dominating strategy in the one-shot game could also coordinate on the mutually beneficial outcome of the other two players. We found evidence for both coordination and anti-coordination behaviour in a 3-player game with a rich setting. For future research, it would be interesting to study (anti-) coordination behaviour in network formation games of more than three players.

In sum, the present paper shows that in markets that require connections to be established between transacting agents, coordinating on the non-competitive outcome which maximizes the long-run payoffs of the long side of the market is common. Moreover, coordination does not only arise from the behaviour of the long side of the market, but from the short side as well.

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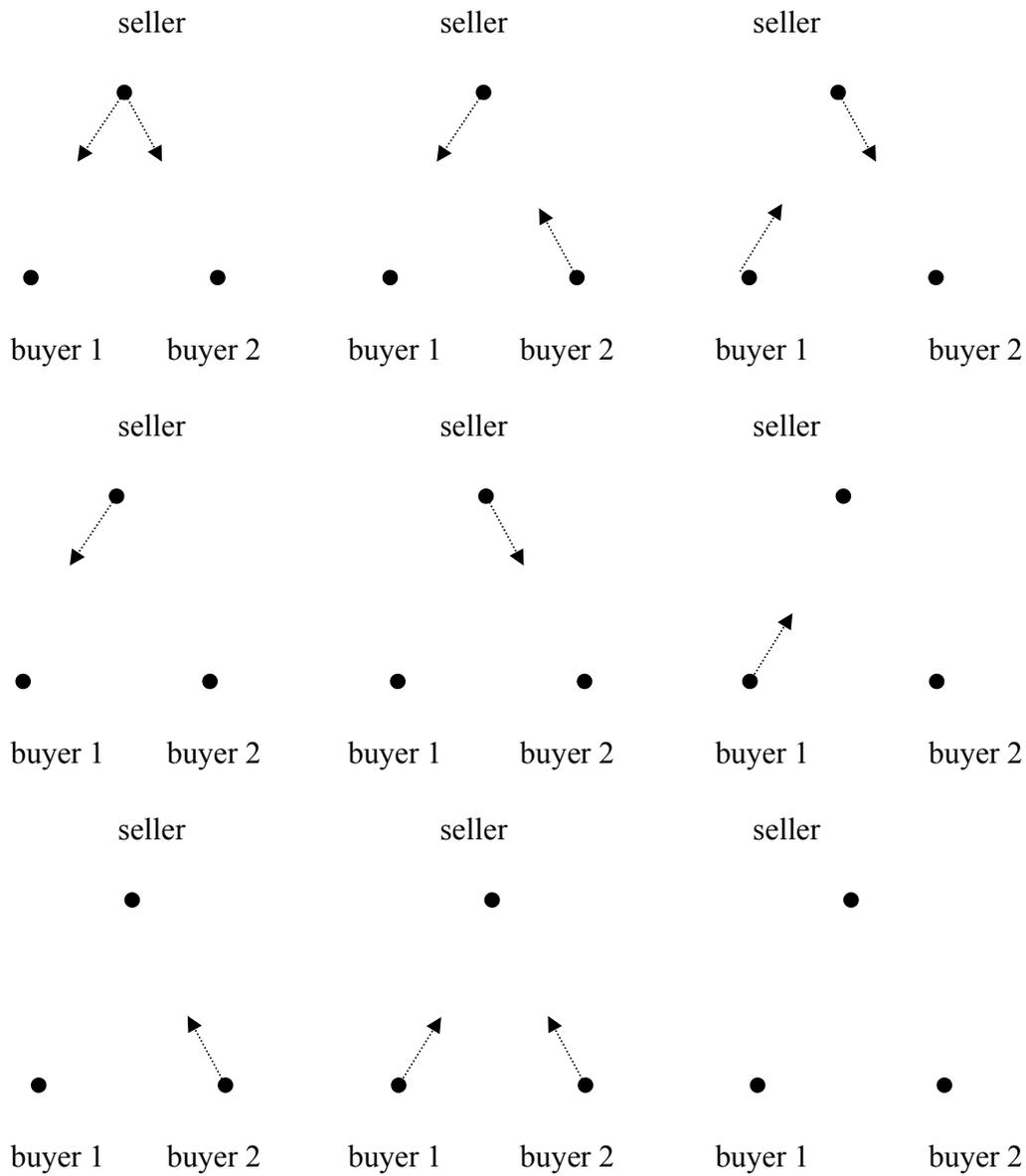
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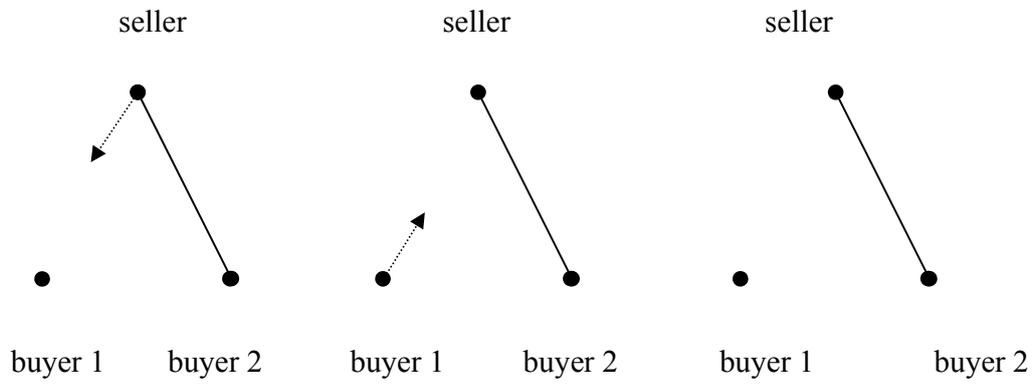
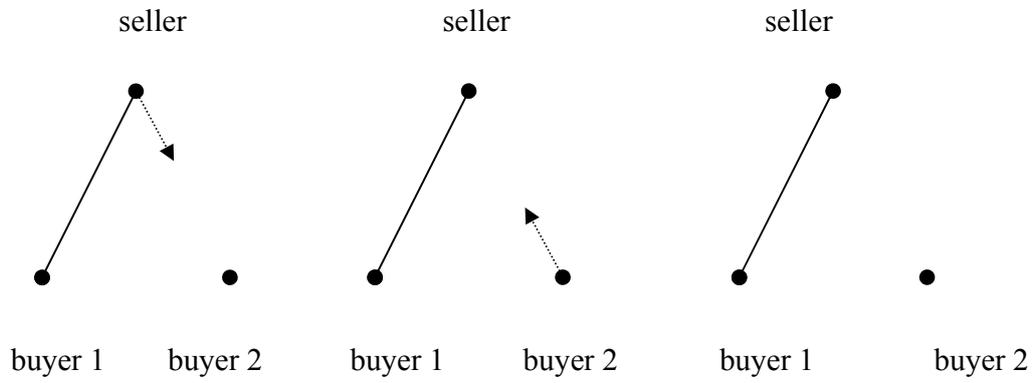
Appendix A. List of Networks

Figure A.1. Networks according to the number of links

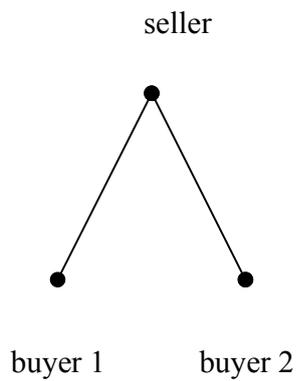
No-Link Networks:



1-Link Networks:



2-Link Network:



Note. An arrow indicates a link offer. A line indicates a formed link.

Not For Publication

Appendix B. Experimental Instructions for the Cost-40 Treatment

Introduction

Welcome to this experiment on decision making. We will first go through the instructions together. Then there will be a practice period. After the practice period the experiment will start. Talking is strictly forbidden during the experiment. If you have a question, please raise your hand and I will come to your table to answer your question.

The experiment will last about 1 hour. If you follow the instructions carefully you can earn a considerable amount of money. During the experiment your earnings will be denoted in points. After the experiment your earnings will be converted into money at a rate of 1 point is 0.35 Eurocents. In addition, you will receive a show-up fee of 5 Euros. Your earnings will be paid to you, privately and in cash, immediately after the experiment.

Instructions for the experiment

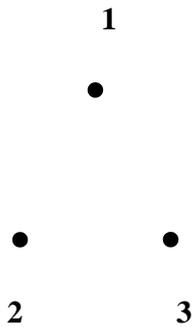
In this experiment, you are in a group of 3 persons. Each person has her or his own number; 1, 2, or 3. Your number is randomly determined at the beginning of the practice period and it stays the same throughout the whole experiment. Also, the composition of your group remains the same throughout the experiment. You will not know who is in your group. You and your group members are referred to as player 1, player 2 and player 3.

Your group faces the same task for 30 periods. In each period, you make a decision about whether to offer links to other players in your group or not.

A link is formed between two players if both of them offer a link to each other. Player 1 can have two links; player 2 and 3 can have only one. Hence player 2 and player 3 each have to decide whether they want to offer a link to player 1. Player 1 has to decide whether to offer a link to player 2 and whether to offer a link to player 3. Offering a link is not costly. However, each player has to pay 40 points for each link that he has formed.

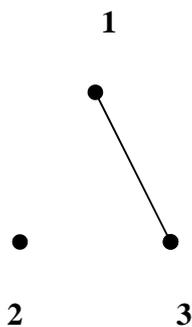
Depending on the links that form, a maximum of 240 points is shared among the players that form a link with each other. There are 4 different types of situations that can arise from the players' decisions to offer links to other players. The earnings of the players differ across these four situations.

SITUATION A:



In Situation A there are no links. This occurs when player 1 and player 3 do not both offer a link to each other, and player 1 and player 2 do not both offer a link to each other. No points are shared among the three players. And since no links have formed, no player pays any linking costs. Hence players 1, 2, and 3 earn $0 - 0 = 0$ points.

SITUATION B:

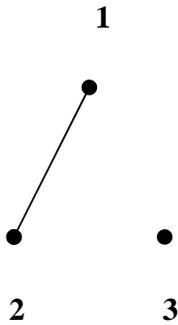


In Situation B there is only one link, namely between player 1 and player 3. This occurs when both player 1 and player 3 offer a link to each other, while player 1 and player 2 do not both offer a link to each other.

The 240 points are shared among player 1 and player 3 in the following way; Player 1 gets 160 points and player 3 gets 80 points. Both player 1 and player 3 pay 40 points for their link. Hence

player 1 earns in total $160 - 40 = 120$ points, Player 3 earns in total $80 - 40 = 40$ points. Player 2 earns in total 0 points.

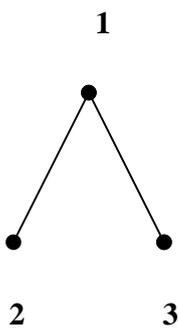
SITUATION C:



In Situation C there is only one link, namely between player 1 and player 2. This occurs when both player 1 and player 2 offer a link to each other, while player 1 and player 3 do not both offer a link to each other.

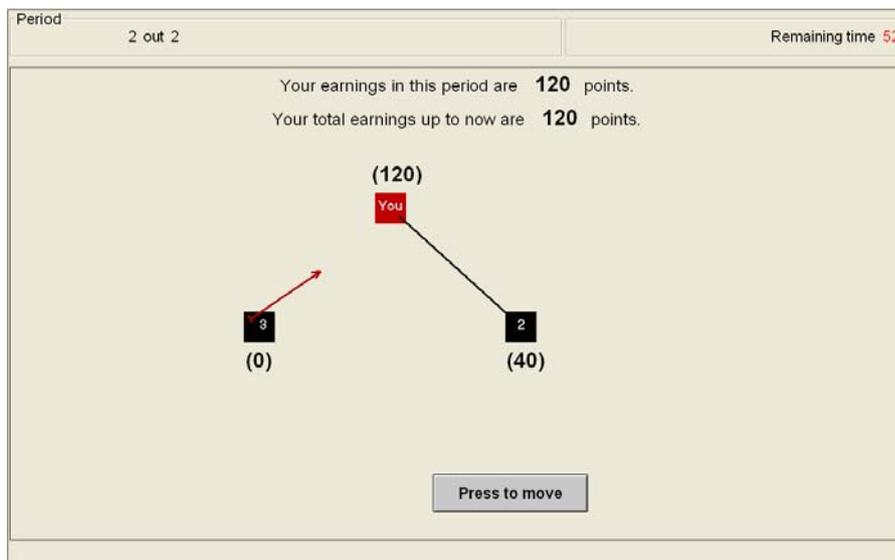
The 240 points are shared among player 1 and player 2 in the following way; Player 1 gets 160 points and player 2 gets 80 points. Both player 1 and player 2 pay 40 points for their link. Hence player 1 earns in total $160 - 40 = 120$ points, Player 2 earns in total $80 - 40 = 40$ points. Player 3 earns in total 0 points.

SITUATION D:



In Situation D there are two links: a link between player 1 and player 3, and a link between player 1 and player 2. This occurs when both player 1 and player 2 offer a link to each other and also both player 1 and player 3 offer a link to each other.

The 240 points are shared among the three players in the following way. Player 1 gets 240 points; player 2 and player 3 get 0 points. Player 1 pays 80 points for two links; and player 2, and player 3 each pay 40 points. Hence, player 1 earns in total $240 - 80 = 160$ points. Player 2 and player 3 each earn in total $0 - 40 = -40$ points.



The figure above illustrates how the results of the first part of the period are displayed to you on the computer screen. A black line indicates that both players offered a link to each other. A red arrow indicates that one player offered a link but the other player did not offer a link to that one player. So, in this example the black line indicates that player 1 (which is "You" in this case) and player 2 offered a link to each other and as a result a link is formed between them.

In this situation (which corresponds to situation C above), player 1 gets 160 points from one link and pays 40 points for the link. So, player 1 earns in total 120 points. Player 2 gets 80 points from the link and pays 40 points for the link. So, player 2 earns in total 40 points. The red arrow indicates that player 3 offered a link to player 1 while player 1 did not offer a link to player 3. Therefore no link is formed between player 1 and player 3. Player 3 does not pay for offering a link. Player 3 earns in total 0 points. Notice that for each player the total earnings for the period are indicated in parentheses.

To summarize:

You will be in a group of 3 persons. Each person will have her or his own number; 1, 2, or 3. Your number will be randomly determined at the beginning of the practice period and it will stay the same throughout the experiment. Also, the composition of your group will remain the same throughout the experiment. You will not know who is in your group.

There will be 30 periods in the experiment. In every period you will decide with whom to link. The important points of the experiment are the following:

- A link is formed between two players if both of them offer a link to each other.
- Player 2 and player 3 cannot form a link with each other.
- Offering a link is not costly but if a link is formed, then players who have the link each pay 40 points for the link.
- If there is at least one link, the three players share 240 points among them.
- The earnings of players in each period are equal to the earnings from a link or links minus the cost of having a link/s.
- In each period you will be informed about all the decisions made by your group members. At the end of each period, you will be informed about your and other players' earnings.
- Your total earnings will be the sum of all points you earn over all periods. For each point you earn in the experiment, you will get 0.35 Eurocents.

Appendix C. Tables

Table C.1 The average gross payoff of the seller and the buyers^{a, b}

	Seller	Buyers
Cost-0	181.60 (26.71)	24.80 (10.14)
Cost-40	164.12 (24.27)	28.12 (10.23)
<i>p</i>	.041	.228

^a Standard deviations are in parentheses. ^b One-tailed exact *p*-values.

Table C.2 The one-tailed p -values of the independence tests per group^a

	Group	Buyer Link Offer	Seller Link Offer	Formed Links
Cost-0	1	.004	<.001	<.001
	2	.001	-	.005
	3	<.001	-	<.001
	4	<.001	-	.001
	5	-	<.001	<.001
	6	-	.022	.022
	7	-	.016	.069
	8	-	-	-
	9	-	-	-
	10	-	-	-
Cost-40	1	.003	<.001	<.001
	2	<.001	<.001	<.001
	3	.071	-	.340
	4	-	.035	.412
	5	.290	-	.290
	6	-	-	.231
	7	-	-	-
	8	-	-	-
	9	-	.007	.131
	10	-	-	-
	11	-	-	-

^a “-” indicates that there was not enough power to reject the independence hypothesis.

Note. The lack of power occurred for some combinations of marginal probabilities, for instance, if one of the marginal probabilities was very high.

Table C.3 A buyer's probability of offering a link to the seller^{a,b, c, d}

	<i>Cost-0</i>		<i>Cost-40</i>		<i>Buyer</i>	<i>Seller</i>
	Coeff.	<i>p</i>	Coeff.	<i>p</i>	<i>Eq</i>	<i>Eq</i>
Period	0.062 (0.325)	.848 ^c	-0.379 (0.164)	.021 ^c		
Own Link _{t-1}	-1.322 (0.694)	.029 ^b	0.106 (0.625)	.568 ^b	-	
Other Link _{t-1}	2.146 (1.126)	.029 ^b	0.884 (0.731)	.114 ^b	+	
Two Links _{t-1}	0.627 (0.880)	.762 ^b	0.824 (0.514)	.946 ^b		-
Period × Own Link _{t-1}	-0.454 (0.375)	.225 ^c	0.354 (0.179)	.048 ^c		
Period × Other Link _{t-1}	0.214 (0.482)	.657 ^c	0.003 (0.243)	.991 ^c		
Period × Two Links _{t-1}	0.271 (0.346)	.435 ^c	0.502 (0.207)	.016 ^c		
Constant	1.251 (0.778)	.108 ^c	0.604 (0.476)	.205 ^c		

^a Robust standard errors at the group level between parentheses.

^b One-tailed *p*-values. ^c Two-tailed *p*-values.

^d The variable Own Link denotes the 1-link network in which the buyer forms a link, Other Link denotes a 1-link network in which the other buyer is linked, and Two Links denote a two link network. Period was grouped into 6 segments and centered, i.e for the periods 1-5, 6-10, ..., 25-30 the values of the variable period were -2.5, -1.5, ..., 2.5 respectively.

Table C.4 Seller's probability of offering a link to a buyer^{a, b, c}

	<i>Cost-0</i>		<i>Cost-40</i>		<i>Seller Eq</i>
	Coefficient	<i>p</i>	Coefficient	<i>p</i>	
Period	-0.040 (0.209)	.848 ^c	0.187 (0.126)	.139 ^c	
Own Link _{t-1}	-0.796 (0.671)	.118 ^b	-0.518 (0.725)	.238 ^b	-
Other Link _{t-1}	1.980 (0.674)	.002 ^b	-0.967 (0.626)	.938 ^b	+
Two Links _{t-1}	1.128 (0.812)	.165 ^c	0.448 (0.439)	.307 ^c	
Period × Own Link _{t-1}	-0.093 (0.250)	.712 ^c	-0.151 (0.110)	.171 ^c	
Period × Other Link _{t-1}	0.037 (0.232)	.872 ^c	-0.172 (0.145)	.237 ^c	
Period × Two Links _{t-1}	0.125 (0.258)	.627 ^c	-0.061 (0.249)	.808 ^c	
Constant	0.746 (0.506)	.140 ^c	1.344 (0.256)	<.001 ^c	

^a Robust standard errors at the group level between parentheses.

^b One-tailed *p*-values. ^c Two-tailed *p*-values.

^d The variables Own Link, Other Link, Two Links, and Period are as in Table C.3.