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# THE COMPARISON OF FOUR TYPES OF EVERYDAY INTERDEPENDENCIES

## EXTERNALITIES IN EXCHANGE NETWORKS

Jacob Dijkstra and Marcel A.L.M. van Assen

### ABSTRACT

Actor behavior is compared theoretically and experimentally in four well-known everyday interdependence situations; (i) the market, (ii) the tragedy of the commons or resource dilemma, (iii) the public good problem, and (iv) the household. It is shown that the four situations can be studied within one general framework of exchange networks with externalities. Core theory is generalized to exchange networks with externalities and applied to derive predictions concerning differences in behavior in the four situations. The experiments corroborate the prediction that competition is most fierce in the resource dilemma, fierce in the market, and absent in the public good problem and household.

KEY WORDS • interdependence • exchange networks • externalities • social dilemmas

The focus of the present study is the theoretical and experimental comparison of actor behavior in four well-known everyday interdependence situations: (i) the market, (ii) the tragedy of the commons, also known as the resource dilemma, (iii) the public good problem, and (iv) the household. We model actor behavior in these situations as an exchange of resources, and study these four interdependence situations in the framework of a simple exchange network with externalities.

*Exchange* is typically thought of as the process through which individuals transmit and receive commodities. The significance of exchange is not limited to economic contexts (e.g., Blau 1964; Homans 1958; Lawler and Ford 1995; Molm 1997). Social interaction in general can also be perceived as exchange since 'much of what we need and value in life (e.g., goods, services, companionship, approval, status, information) can only be obtained from others. People depend on one another

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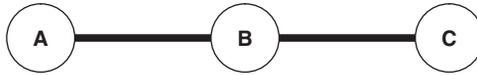


Figure 1. The Line3 network

for such valued resources, and they provide them to one another through the process of exchange' (Molm 1997: 12).

An important branch of exchange research is devoted to investigation of specific exchange situations, called *exchange networks*. The issue on which this research mainly concentrates is the effect of networks on the choice of exchange partners and the ratios of exchange (for example, see the special issue on network exchange in *Social Networks*, volume 14, and Willer 1999). In this line of research, an actor's connections in a network represent with whom the actor can exchange. If there is a connection between two actors in the network, these actors have the *possibility* to exchange, but no *obligation* to do so. If there is no link between two actors, an exchange between them is not possible. The central question is then whether and how an actor's profit or utility from exchange is influenced by that actor's position in the network.

Figure 1 contains the *Line3 exchange network*. The links in this network indicate that actors A and C can each exchange with actor B, but not with each other, whereas B can exchange with both A and C. In this article we model the four interdependence situations mentioned earlier by introducing *externalities* in exchange networks, using the one-exchange rule. This rule implies that B can exchange with either A or C, but not both.

*Externalities* of exchange are defined as *direct* (positive or negative) consequences of exchanges, for the well-being of actors who are not involved in the exchange. Externalities in the network of Figure 1 would exist if after an exchange of two actors the profit of the third actor would be affected as well. For example, if A and B exchanged with each other and C experienced an increase in profit or utility as a direct consequence of this exchange, then C would have experienced a (positive) externality of the exchange between A and B. It is important to note that the fact that C is possibly *excluded* from exchange when A and B exchange with each other is *not* interpreted as an externality. The same holds for a possible process of *competition* between A and C for access to B. Exclusion and competition are merely two forms of interdependence that can be present in an exchange network, regardless of whether externalities exist or not.<sup>1</sup>

Although exchange networks have been studied extensively, the effect of externalities on exchange in networks has been neglected in both theoretical and empirical research. The sole exception is research on collective decision making (Stokman et al. 2001; Van Assen et al. 2003). This research focuses on the fact that a bilateral exchange of two voting positions changes the expected outcome of the vote, which directly affects other political parties that are not involved in the exchange. Many real-life exchanges, other than those found in collective decision making, also have externalities for parties not involved in the exchange (examples are given below). There is no reason to suppose that exchanges with externalities are less common than exchanges without. The neglect of studying effects of externalities on exchange in networks is therefore quite remarkable.

An important cause of externalities of exchange lies in the fact that in certain social situations actors share the possession of certain resources. Exchanges of one of the actors that affect the stock of shared resources then affect all actors that share these resources. To consider the general case, assume a group of actors, of which a member engages in a bilateral exchange of resources with an actor outside the group. Then externalities of exchange can create the four interdependence situations studied in this article by systematically varying the resources group members share (see Table 1).

If actors in the group share neither the resources they transfer nor the resources they receive (upper left cell in Table 1), then the situation can be characterized as a *market*. Consider, for instance, customers buying their groceries in a supermarket; customers (group members) buying their own groceries with their own money from the supermarket (an actor from outside the group). If group members share only the resources they transfer (upper right cell), the situation can be characterized as a *resource dilemma* or *tragedy of the commons problem*, for example fishermen (group members) sharing access to fishing waters but not the revenues of selling the fish to others outside the group. The basic characteristic of *public good problems* is that actors share the resources they receive but not the ones they transfer (lower left cell), for example a person (group member) buying beer for herself and her friends (fellow group members) in a bar. Finally, in many exchanges of members of a household both resources transferred and received are shared (lower right cell). For example, the wife (group member) buys a sofa in a store (actor from outside the group) from the common family budget. Note that both sofa and budget are owned by all family members. Therefore, this fourth interdependence situation is called the *household*.

**Table 1.** A typology of four interdependence situations based on whether resources transferred and received by actors in a group are shared or not

		<i>Sharing transferred resources</i>	
		<i>No</i>	<i>Yes</i>
Sharing received resources	No	Market	Resource dilemma
	Yes	Public good	Household

It is important to remark that these four interdependence situations are defined by the resources actors share, being the fundamental characteristic distinguishing them. In some social dilemma research, resource dilemmas and public good problems are presented as equivalent with respect to payoff possibilities, and only different with respect to the framing of the experimental task. For instance, resource dilemmas and public good games are sometimes referred to as ‘take some’ (taking from a common resource) and ‘give some’ (contributing to a public good) games, respectively (e.g., Dawes 1980; Poppe and Zwikker 1996; Rutte et al. 1987; Van Dijk and Wilke 2000). As will be shown later, the interdependence situations in this article are not equivalent with respect to payoffs, i.e., are not merely reframings of one and the same situation.

Note how sharing resources in the interdependence situations causes externalities. Transmitting or receiving a shared resource directly affects the utility of all actors in the group, regardless of which group member is involved in the exchange. For example, consider the resource dilemma. A transfer of resources (catching and selling fish) of one fisherman brings about a loss to all fishermen (by increasing their marginal costs of catching fish, as additional fish are harder to catch, and ‘overfishing’ decreases the rate of reproduction of fish) since these resources are shared by all fishermen. However, since the received resources (the revenue of selling the fish) are not shared, only the fisherman making the exchange profits.

We make three comments about our classification. Firstly, note that we consider interdependence situations in which the behavior of group members is affected by actors from outside the group. In classic examples of some of these situations, e.g., the ‘tragedy of the commons’ of Hardin (1968), actors from outside the group are not present. In Hardin’s example a group of herdsmen each tries to keep as many cattle as possible on the common pasture. However, since our focus is on an exchange between a group member and an actor outside the group, the resource dilemma we studied *is* affected by the behavior of actors

outside the group that have an interest in the situation. Secondly, as was observed previously, the interaction can be understood as the actual transfer of physical goods but also as the performance of a behavior that produces value for another. Thirdly, note that the classification is exhaustive; all four possibilities of resource sharing are covered.

The focus of the present study is the theoretical and experimental comparison of the interaction between group members and actors from outside the group in the four interdependence situations: market, resource dilemma, public good problem, and household. The interaction is a bilateral transfer of resources, that is, it is conceived of as the exchange of resources. Sharing resources between members of a group induces externalities of exchange. Our research problem thus concerns the effect of externalities or type of interdependence on the ratio of resources exchanged.

The next section describes how the four interdependence situations are modeled by the Line3 exchange network with the one-exchange rule, as used in the experiments. The four experimental conditions only differ with respect to the resources shared, as explained above. In the theory section we formulate our theory and hypotheses. The theory is an adaptation of the core solution, a well-known theory in research on exchange networks (e.g., Bienenstock and Bonacich 1992). The hypotheses concern predictions of differences of exchange ratios in the four interdependence situations. The subsequent section describes the experiments, and is followed by the results section. A discussion concludes the article.

### **Sharing Resources and Externalities in the Line3 Exchange Network**

In by far the largest portion of the literature in the field of exchange network research, exchange possibilities are represented as the opportunity to divide a pool of valuable resources or 'profit points' (see, for instance, Bienenstock and Bonacich 1992; Bonacich 1998, 1995; Bonacich and Bienenstock 1995; Cook and Yamagishi 1992; Cook et al. 1983; Cook and Emerson 1978; Heckathorn 1983; Karr 2000; Lovaglia et al. 1995; Markovsky et al. 1993; Skvoretz and Burkett 1994; Skvoretz and Willer 1993; Thye et al. 1997; Willer and Skvoretz 1997). In the present article we must deviate from this practice, however, since we investigate the exchange of possibly shared resources. Therefore, instead of giving subjects the opportunity to divide a fixed number of points, we endow them with units of valuable resources that they can subsequently use in exchange.

**Table 2.** Actors, goods, endowments (E) and utilities (U) in the Line3 structure

<i>Actors</i>	<i>A</i>		<i>B</i>		<i>C</i>	
Goods	X	Y	X	Y	X	Y
E	1	0	0	48	1	0
U	24	1	48	1	24	1

The endowments used in our experiment are presented in Table 2. The first row of Table 2 indicates the three actors of the Line3 network. The second row shows there are two goods, X and Y, in the network. The third row depicts each actor's initial possession or endowment (E) of these goods. Thus, actors A and C each possess 1 unit of X and no units of Y. Actor B holds no units of X and 48 units of Y. The final row of Table 2 indicates the value or utility (U) of 1 unit of each of the goods for the actors. Thus, for actors A and C a unit of X is 24 times more valuable than a unit of Y. For actor B, a unit of X is 48 times more valuable than a unit of Y.

The endowments and utilities of Table 2 make profitable exchanges feasible between A and B, and between B and C. In return for transferring her 1 unit of X to B, actor A wants to receive at least 24 units of Y, whereas actor B is willing to transmit at most 48 units of Y. The same holds for actor C. Thus, in both exchange relations profitable exchanges are feasible in which A (C) transmits her unit of X to B and receives a number of units of Y between 24 and 48 in return. For example, assume A (C) gets 30 units of Y in return for her unit of X. The profit of actor A (C) is then  $30 - 24 = 6$ , whereas B earns  $48 - 30 = 18$ . Note how the sum of the profits of the two exchange partners in each exchange relation is 24. In Table 2, this is true for all possible exchange ratios. Also note that we only consider profits earned in exchange, i.e., we do not consider the value of the initial endowment. In the experiment reported below, this was also the case; subjects were only paid for points gained in exchange, not for the value of their initial endowment. An important feature of the endowments and utilities in Table 2 is that any exchange between A (C) and B is Pareto efficient: given any exchange ratio there is no alternative exchange ratio that yields more utility for one of the exchange partners, without decreasing the utility of the other. This is true because A and C each have only 1 unit of X and thus must transfer their entire endowment of X in any exchange.

An additional implication of the utilities depicted in Table 2 is that A and C cannot profitably exchange with each other. Thus, the network structure of Figure 1 is endogenously determined by the utilities of Table 2. An important restriction that we impose on the Line3 network, both theoretically and experimentally, is that actors are assumed to be able to complete only one exchange (this is commonly called the one-exchange rule, e.g., Willer 1999). This implies that either A or C exchanges with B, but not both.

The Line3 presented in Table 2 is employed in the experiments to characterize the four interdependence situations as follows: A and C share (i) no resources in the market, (ii) only resource X in the resource dilemma, (iii) only resource Y in the public good problem, and (iv) both resources in the household. Hence A and C constitute the group, B is the actor from outside the group, X is the resource transferred, and Y is the resource received by the group members. If A and C share X, they receive payoffs from all units of X owned by both of them.

We now show how the resource dilemma and public good problem originate from situations in which only one good is shared. Consider first the resource dilemma. An exchange of A (C) with B means C (A) incurs a loss since he loses X without receiving Y. Therefore, both A and C have an incentive to outbid the other player by demanding fewer and fewer units of Y. In fact, it is rational for A and C to accept a loss (up to the size of the externality) in their exchange with B, to prevent receiving the externality. However, in doing this, A and C create a situation that is Pareto inefficient: both players incur a loss, one through the exchange with B and the other through the externality. This situation could have been prevented, had A and C decided not to exchange with B. However, given that A (C) doesn't exchange with B, C (A) has an incentive to complete an exchange with B. Both players have a 'dominant strategy' (always underbid the other player), but in following this strategy end up in a collectively inefficient situation (both A and C incur a loss). This is the defining characteristic of the resource dilemma.

Now consider the situation in which only the good received is shared. Both A and C have an incentive to let the other player exchange with B and incur the cost of exchange, whereas they themselves profit more from the exchange. This interdependence situation deviates from the public good game most often studied in the literature, in the sense that not exchanging with B is not a 'dominant strategy': if A (C) doesn't exchange with B, C (A) should, to gain at least some points. It thus resembles a chicken game. However, the fundamental characteristic of the public good game is that it 'deals with situations in which goods and

services ... are to be realized through individual contributions, whereas consumption is not dependent on the individual contributions' (Van Dijk and Wilke 2000: 92), which is the case in our current public good game.

### Theory and Hypotheses

Many theories of exchange in networks have been developed in the last decades (e.g., for instance Bienenstock and Bonacich 1992; Braun and Gautschi 2006; Burke 1997; Cook and Emerson 1978; Cook and Yamagishi 1992; Friedkin 1992, 1995; Skvoretz and Fararo 1992; Willer 1999; Yamaguchi 1996). However, all these theories assume that exchange is without externalities. Generalizing these theories to network exchange *with externalities* is by no means straightforward. Dijkstra (2005) generalized one of these theories, core theory, to deal with externalities in exchange networks. Core theory is a solution from cooperative game theory originally introduced to the field of exchange networks by Bienenstock and Bonacich (1992). The power of the theory is that it is simple, that is, based upon a minimum number of assumptions. We will discuss both the core solution and the generalized core solution in the light of the four interdependence situations described in the previous section. Our hypotheses are derived from the generalized core theory.

#### *Original Core Theory and Generalized Core Theory*

Original core theory requires that each possible coalition of players (including 1-player 'coalitions') gets no lower payoff than the members of that coalition can guarantee by cooperating among themselves. More formally, let  $N$  be the set of players in the game. The characteristic value function  $v$  assigns a total payoff  $v(S)$  to every subset  $S \subset N$  of players, that they can realize among themselves, *despite* the actions of  $N \setminus S$ , i.e., the players not in  $S$ . Thus,  $v(S)$  represents the total payoff that a coalition  $S$  can be sure to achieve. Using the characteristic value function, one can define the core solution. Let  $\mathbf{x}$  be a payoff vector, such that  $x_i$  represents the payoff for player  $i$ . A payoff vector  $\mathbf{x}$  is in the core if it meets the following three rationality requirements:

- i)  $x_i \geq v(\{i\})$  for every  $i \in N$  (individual rationality),
- ii)  $\sum_{i \in S} x_i \geq v(S)$  for every  $S \subset N$  (coalition rationality), and
- iii)  $\sum_{i \in N} x_i = v(N)$  (group rationality).

With respect to exchange networks coalition formation is interpreted as 'agreeing to exchange'. For instance, in the Line3 market, the only interdependence situation in this article without externalities, A and B can guarantee a total payoff of 24 by exchanging with each another;  $v(AB) = 24$ . Thus, a payoff vector can only be in the core if the sum of the payoffs of A and B is at least 24. In the same vein,  $v(BC) = 24$ . To find the core however, *all* logically possible coalitions must be considered. Therefore, also the 3-player coalition between A, B and C must be taken into account. In the Line3 market this coalition can guarantee itself a total of 24 points ( $v(ABC) = 24$ ) by letting B exchange with either A or C. However, in an exchange network such as we are investigating here, coalitions of more than two players have no meaning: coalition formation is intended to mean 'agreeing to exchange' and only connected dyads can exchange. Regarding exchange networks without externalities, however, Bonacich and Bienenstock (1995) have shown that if no connected dyad receives less than it can guarantee by itself, this is also true for all other coalitions. Thus, in exchange networks without externalities, coalitions other than connected dyads can safely be disregarded when finding the core because these coalitions do not affect the core. Therefore, the original core solution makes theoretically sensible predictions in exchange networks without externalities.

In the Line3 market the only payoff vector in which the sum of payoffs of both the pair A-B and the pair B-C is 24, gives 0 to A and C and 24 to B. In terms of the inequalities of core theory, (i)  $x_A, x_B, x_C \geq 0$ , (ii)  $x_A + x_B \geq 24$ , and  $x_B + x_C \geq 24$ , and (iii)  $x_A + x_B + x_C \geq 24$  are only met if  $x_A = x_C = 0$ , and  $x_B = 24$ . Thus, in the Line3 market the core predicts that B exchanges with either A or C and gives 24 units of Y in return for 1 unit of X.

Unfortunately, in exchange networks with externalities coalitions other than dyads *cannot* be disregarded when trying to find the original core solution. Consider the Line3 household. The coalition between A and B can guarantee itself 24, that is, again,  $v(AB) = 24$ . The fact that this yields a positive externality for C is not included in the value of the coalition between A and B: the core solution only considers what each coalition can guarantee its own members. Also  $v(BC) = 24$ . However, the all-player coalition can guarantee itself a maximum total payoff of 48 ( $v(ABC) = 48$ ). This total payoff is achieved if B exchanges with either A or C and transfers 48 units of Y in return for the 1 unit of X. The payoffs of both A and C are then 24, and the payoff of B is 0. Thus, the original core solution in the Line3 household is the opposite of the core solution in the Line3 market: all the surplus of exchange goes to A and C.

Including externalities in exchange networks means the scope of core theory has to be extended. Given this extended scope the proposition of Bonacich and Bienenstock, that any payoff vector that gives each dyad at least what its members can guarantee themselves is in the core, no longer holds. For instance, consider an exchange between A and B in the household, where B transfers 36 units of Y to A, in return for the 1 unit of X. In this case all the actors get a payoff of 12, which means that the sum of the payoffs in the pair A-B as well as in the pair B-C is 24. However, the sum of all payoffs is 36, which is 12 short of what the all-player coalition can guarantee.

To summarize our reasoning: as opposed to the case of exchange without externalities, coalitions that cannot form (for instance, the all-player coalition) affect the original core solution in the case of exchange with externalities. Hence, the original core cannot be meaningfully applied to exchange with externalities, but can be applied meaningfully when externalities are not present.

Core theory can be generalized to deal with externalities simply by dropping any requirements that pertain to coalitions larger than dyads or coalitions of unconnected players. That is, coalition rationality is limited to connected dyads and group rationality is dropped. One additional assumption is required. This assumption is that if actors in a pair exchange, they exchange in a Pareto-efficient manner, i.e., they cannot make an exchange together that yields larger payoffs to both of them. Dijkstra (2005) explains why this additional assumption is needed. Note that the endowments in the Line3 network presented in Table 2 are chosen such that exchanges are necessarily Pareto efficient. Hence, the assumption concerning Pareto efficiency is not relevant in the present study since it always holds in the experiment. The three assumptions of generalized core theory can be described formally as:

- i)  $x_i \geq v(\{i\})$  for every  $i \in N$  (individual rationality),
- ii)  $\sum_{i \in S} x_i \geq v(\{i, j\})$  for every connected  $i, j \in N$  (rationality of connected dyads),
- iii)  $\sum_{i \in S} y_i \geq w(\{i, j\})$  for every connected  $i, j \in N$  (Pareto-efficiency of exchanging dyads).

In i) through iii) above,  $\mathbf{x}$  denotes the payoff vector with externalities,  $\mathbf{y}$  is the payoff vector without externalities, and  $w(\{i, j\})$  is the characteristic value of pair  $\{i, j\}$ , disregarding externalities.

The generalized core requires that no individual actor or pair of connected actors gets less than they can guarantee by themselves. Intuitively,

a payoff vector is in the generalized core when no connected dyad can successfully object to it, in the sense that through exchange the objecting actors can improve their payoffs. It is very important to note that in networks without externalities, the generalized core reduces to the original core. Therefore, generalized core theory is a true generalization of core theory to exchange situations that possibly include externalities.

Applying generalized core theory to the Line3 household we find that any exchange between B and either A or C (in which both exchange partners receive at least 0) is in the generalized core. This is true because when one of the actors A and C exchanges, the other receives the same payoff. The sum of payoffs of B and the exchanging actor is 24 by definition. Then, the sum of the payoffs of B and the actor that doesn't exchange is also 24 by definition. In terms of the inequalities of the generalized core, (i)  $x_A, x_B, x_C \geq 0$  and (ii)  $x_A + x_B \geq 24$  and  $x_B + x_C \geq 24$  are met for any exchange, as long as no actor loses. Assume A exchanges with B. Then  $x_A + x_B = y_A + y_B = 24$ , i.e., (iii) is met by definition. Since  $x_A = x_C$ , we get  $x_B + x_C = 24$ . Mutatis mutandis the same holds when B and C exchange.

### *Predictions and hypotheses concerning the exchange ratios*

The application of generalized core theory yields extreme point predictions in some interdependence situations. In these extreme predictions A and C are predicted to transfer all or half of their resources to B. However, these extreme predictions only occur after many rounds of 'playing the game' by the same subjects. For example, the Line3 market has been studied in many experiments (see Van Assen 2003, for references), and it has been found that the payoff of A and C systematically decreases over rounds. Yet, it can take many rounds for their payoff to approach the core theory's predicted payoff. In our experiments the number of rounds is limited. Moreover and importantly, we are mainly interested in the relative comparison of behavior in the four interdependence situations. Therefore we do not focus on point predictions but formulate all hypotheses in terms of comparisons of the average exchange ratios of two interdependence situations.

In the previous subsection two predictions were already derived. In the Line3 market without externalities both the generalized and original core predict that B transfers 24 units of Y. In the Line3 household the generalized core predicts that B transfers a number of units of Y from the interval [24, 48]. Hence, our first (statistical, alternative) hypothesis is:

*Hypothesis 1: On average A and C receive more in the household than in the market.*

Now consider the Line3 public good problem. If A (C) makes the exchange, C (A) profits, that is, externalities are solely positive. Therefore, each exchanging pair can guarantee a total payoff of 24, and each actor can guarantee himself at least 0. Thus, the generalized core requires that (i)  $x_A, x_B, x_C \geq 0$  and (ii)  $x_A + x_B \geq 24$ , and  $x_B + x_C \geq 24$ . Assume A exchanges with B. Then  $x_A + x_B = y_A + y_B = 24$ , i.e., (iii) is met by definition. Since A and C share Y, but not X, we have  $x_C = x_A + 24$ , and  $x_B + x_C \geq 24$  is also met by definition. Mutatis mutandis the same holds when B and C exchange. Hence, the prediction of the generalized core for the Line3 public good is identical to the one for the Line3 household: B transfers a number of units of Y from the interval [24, 48].

*Hypothesis 2: On average A and C receive the same in the household and public good problem.*

Finally, consider the Line3 resource dilemma. Again, each exchanging pair can guarantee a payoff of 24. However, not all actors can guarantee themselves 0 points, and this changes the generalized core solution. If A (C) makes the exchange, C (A) obtains a negative payoff of  $-24$ , that is, externalities are solely negative. For instance, assume B exchanges with A and transfers 36 units of Y. Both A and B then earn 12, and C earns  $-24$ . The sum of payoffs of B and C is  $12 - 24 = -12$ , which is smaller than 24. Therefore, this exchange ratio isn't in the generalized core: the pair B-C can successfully object to the payoff vector by exchanging. For instance, an exchange between B and C in which B transfers 24 units of Y yields B a payoff of 24 and C a payoff of 0. The sum of their payoffs is now 24, and the new situation is an improvement for both B and C. Given this new exchange ratio, however, A earns  $-24$ . Now the sum of payoffs of A and B is 0, which is again short of 24. Therefore, the pair A and B can raise a successful objection through an exchange in which B transfers yet fewer units of Y. The generalized core requires that (i)  $x_A, x_C \geq -24$  and  $x_B \geq 0$ , and (ii)  $x_A + x_B \geq 24$  and  $x_B + x_C \geq 24$ . Assume A exchanges with B. Then  $x_A + x_B = y_A + y_B = 24$ , i.e., (iii) is met by definition, and  $x_C = -24$ . Then,  $x_B + x_C \geq 24$  can only be met if  $x_B = 48$ , implying  $x_A = -24$ . Mutatis mutandis the same holds when B and C exchange. Thus, the only exchange ratio that is in the generalized core is the one where B transfers 0 units of Y in return for the 1 unit of X. In this case, A and C both lose 24, no matter who exchanges, and B earns 48. Note

that generalized core theory predicts that A and C are accepting *losses* in their exchange with B, something actors are never predicted to do in the case of exchanges without externalities; a principal assumption of exchange (without externalities) between rational actors is that exchange is mutually profitable. These considerations lead to Hypothesis 3.

*Hypothesis 3: On average A and C receive less in the tragedy of the commons than in the market.*

The hypotheses implicitly state that competition between group members is different in the four interdependence situations. In resource dilemmas competition is so fierce that group members are prepared to hurt themselves (lose in exchange with B) in order to prevent being hurt even more by someone else (incurring the externality). Competition is also fierce in markets. In markets group members are willing to accept a small gain in order to prevent obtaining nothing. In household and public good problems less or even no competition is predicted.

## **Experiments**

### *Subjects*

Subjects were undergraduate students from different departments of the University of South Carolina, at Columbia (SC). A total of 66 subjects participated for pay. The average earnings were approximately 15 US dollars for an experimental session that took at least 30 and at most 50 minutes.

### *Design and Procedure*

Subjects participated in groups of three individuals. The number of groups per condition was determined by an analysis of statistical power. Two groups played the Line3 market, eight groups played the Line3 household, eight groups played the Line3 public good problem and four groups played the Line3 tragedy of the commons. Each group of subjects participated in one of the four games for 10 rounds of maximally 3 minutes each. Hence a total of 220 rounds were played in all.

Subjects entered the experiment room separately. They were randomly assigned a network position (either A, B, or C), in which they remained throughout the entire experiment. Subjects were seated in

separate rooms where they could neither hear nor see any other subjects. Subjects did not meet before or during the experiment. They usually did meet after the experiment when the money was paid. However, subjects didn't know this in advance.

Upon being seated in their rooms, subjects received a written instruction explaining the experiment.<sup>2</sup> Subjects typically needed less than 10 minutes to read the instructions. After finishing reading the instructions, three practice rounds were played, using the Line3 market, i.e., the structure without externalities. After completing the practice rounds, all subjects received a written form that indicated how their monetary pay depended on their points and, in the case of externalities, the points of someone else in the game (see note 2). The experiment leader then gave each subject a 10-item quiz to establish their understanding of the game (see note 2). Subjects typically took no longer than three minutes to complete the test. The experiment leader then checked the answers on the quiz. A correct answer was worth 20 cents, so the entire quiz was worth two US dollars. Very few subjects had any wrong answers. No subject had more than one incorrect answer. In the case of a wrong answer, the experiment leader asked the subject to rethink the answer and explain it. All problems were then easily solved and all subjects were paid the two dollars for the quiz. Subjects were informed of the number of rounds to be played. The 10 experiment rounds then started.

Negotiations in the experiment were completed through computer terminals, employing the ExNet 3 software developed by Willer and associates at the University of South Carolina. Bargaining was unstructured in the sense that the order and timing of the offers were up to the subjects to decide. Subjects could make any number of offers they wished, to any subjects they were connected with in the network, within a time limit of three minutes per round. To carry out an exchange, an offer had to be accepted and the acceptance confirmed by the actor initially proposing the offer. A round ended after three minutes had elapsed or when an exchange was completed.

Subjects were endowed with the goods and utilities corresponding to their network position (see Table 2). The goods were abstractly labeled X and Y, as in Table 2. After each round of play the resources were replenished. Subjects were able to make one exchange per round only. The utilities from the final row of Table 2 were presented to the subjects as points they could earn in the game. In the externality conditions (household, public good problem, tragedy of the commons) subjects A and C were informed privately of how their payoffs depended on exchanges of the other player. Player B was ignorant of both the existence and the structure

of the externalities. Player B was kept ignorant to enable us to observe the pure effects of externalities in a given structure, without the confounding factor of another player (B) anticipating the externalities. Note that imposing B's ignorance makes the rotation of subjects across positions during the experiment impossible.

Each subject earned a fixed amount of money per point. Money per point differed per network position and per game and was private information to the subjects, i.e., subjects didn't know the pay rate of other participants. Subjects only earned money for additional points they scored through exchange or received as an externality of exchange. This was implemented in the experiment by subtracting the value of the initial resources from the points in each round. This way, subjects did not get money for the resources they started out with, but only for profits made in exchange and for externalities of exchange. The money per point was chosen in such a fashion that the expected earnings of all subjects would be 15 US dollars. Subjects that weren't expected to earn any points, such as A and C in the market, or that were expected to lose points, such as A and C in the tragedy of the commons, earned a base rate irrespective of their earnings in the game to compensate for this. This base rate was private information. At the end of the experiments actors on average gained approximately 15 US dollars, ranging from a minimum of approximately 6 dollars to a maximum of approximately 25 dollars.

## Results

### *Comparing All Four Interdependence Situations*

In total 22 groups played one game for 10 rounds, yielding a theoretical maximum of 220 exchanges. Of these 220 potential exchanges, 199 exchanges were actually completed. To account for the dependencies in the data of the same group we estimated multilevel models to test the hypotheses (e.g., Snijders and Bosker 1999), subsequently called 'mixed models'. In all the mixed models reported below only the intercept is random. All other effects are fixed.<sup>3</sup>

We first checked whether the exchange ratio was different for the four interdependence situations. We estimated two mixed models with the variable 'group' as the indicator for the second level, on all the games. The dependent variable was the number of units of Y transferred by B (Y) to either A or C. The analyses were conducted only on the 199 exchanges that actually occurred.

**Table 3.** Comparing the four interdependence situations with respect to exchange ratio – estimates for the null model (Model I) with one random intercept, and the full model (Model II) with random intercepts and fixed effect of Round for each situation; dependent variable was the number of received resources (Y)

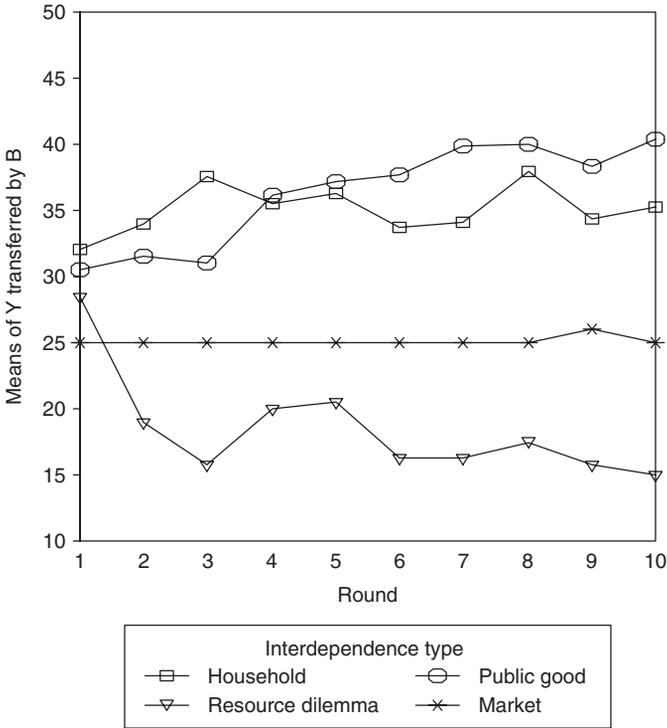
	<i>Model I</i> <i>coefficient</i>	<i>Model II</i> <i>coefficient</i>
Intercept	31.56*** (1.76)	25.13*** (3.19)
Round	0.24* (0.11)	0.04 (0.32)
Household		9.91* (3.56)
Public		11.22** (3.57)
Resource		-6.68 (3.90)
Household*Round		0.12 (0.36)
Public*Round		1.06** (0.36)
Resource*Round		-0.96* (0.39)
-2 log-likelihood	1247.51	1175.53

*Notes:* Data shown are mixed model coefficients with standard error in parentheses.

\*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$  (two-tailed tests).

The null model or Model I (see Table 3) that estimated an average exchange ratio and a common effect of Round across all four conditions yielded a fit or  $-2$  log-likelihood (LL) equal to 1247.51 and an intraclass correlation of 0.76. The intraclass correlation is a measure of the dependency of the data in the same group, and can have a value in the interval  $[0,1]$ . The value 0.76 signifies that the exchange ratio varied greatly between groups. The average exchange ratio across all groups was 31.56 (S.E. = 1.76), and the effect of Round was significant and positive ( $\chi^2_1 = 4.466$ ,  $p = 0.03$ , two-tailed). The variable Round was computed by centering the original rank numbers of the 10 rounds, i.e., Round = rank number round  $- 4.5$ . The intercept of 31.57 can then be interpreted as the average number of units of Y transferred by B in the 'average' round.

The full model or Model II estimated a random intercept and a fixed effect of Round for each interdependence situation by including a



**Figure 2.** Means of Y transferred to B across rounds in Household, Public good, Resource dilemma, and Market

dummy for three of the four situations. The Line3 market was taken to be the reference game, the other games were labeled Household, Public, and Resource. Model II was a huge improvement over Model I ( $\chi^2_6 = 71.976, p < 0.001$ ), indicating that the exchange ratio indeed differed across the four interdependence situations. The conditions also differed with respect to the effect of Round. There was no effect of Round in the market ( $F_{1, 176.99} = 0.02, p = 0.898$ ) and in the household ( $F_{1, 177.01} = 0.10, p = 0.749$ ). In the public good problem the mean number of Y transferred by B increased over rounds ( $F_{1, 177.07} = 8.56, p = 0.004$ ). In the resource dilemma the mean number of Y decreased over rounds ( $F_{1, 176.99} = 6.03, p = 0.015$ ). These trends are visualized in Figure 2, which depicts the average exchange ratios in all four interdependence situations as a function of Round. In later subsections it is verified which of the situations were different from each other by discussing separately the results corresponding to the four hypotheses.

**Table 4.** Comparing the four interdependence situations with respect to time in seconds – estimates for the null model (Model I) with one random intercept, and the full model (Model II) with random intercepts and fixed effect of Round for each situation

	<i>Model I coefficient</i>	<i>Model II coefficient</i>
Intercept	129.69*** (12.51)	114.57 (37.26)
Round	0.66 (1.30)	-2.593 (4.08)
Household		13.94 (41.65)
Public		42.74 (41.69)
Resource		-29.37 (45.55)
Household*Round		4.26 (4.58)
Public*Round		6.17 (4.64)
Resource*Round		-1.76 (4.98)
-2 log-likelihood	2196.01	2185.78

*Notes:* Data shown are mixed model coefficients with standard error in parentheses.

\*\*\* $p < 0.001$  (two-tailed test).

Core theory does not allow one to derive hypotheses concerning the time needed to reach agreement. However, since ExNet saved the time needed to reach agreement, we also tested whether the four situations were different with respect to the timing of the exchange. Timing was measured in seconds. The results of the analyses are presented in Table 4. No difference in timing was observed across the four interdependence situations ( $\chi^2_6 = 10.23$ ,  $p = 0.12$ ), and the effect of Round on timing was never significant.

#### *Comparing the Market to the Household*

Hypothesis 1 states that on average A and C receive more in the household than in the market. To test this hypothesis three mixed model analyses were run, using only the data of the household and market situations.<sup>4</sup> In the market two groups played 10 rounds each. In 18 of the 20 rounds agreement was reached. The mean Y was 25.11, with a

**Table 5.** Comparing exchange ratios of household (Game = 1) and market (Game = 0) – estimates for Model I with random intercept plus fixed effect of Game, Model II also includes Round, and Model III also includes Game\*Round

	<i>Model I coefficient</i>	<i>Model II coefficient</i>	<i>Model III coefficient</i>
Intercept	25.14*** (2.56)	25.13*** (2.55)	25.13*** (2.55)
Game	9.93** (2.86)	9.92** (2.85)	9.91** (2.85)
Round		0.13 (0.12)	0.04 (0.26)
Game*Round			0.12 (0.29)
-2 log-likelihood	503.545	502.26	502.10

*Notes:* Data shown are mixed model coefficients with standard error in parentheses.

\*\*  $p < 0.01$ , \*\*\*  $p < 0.001$  (two-tailed tests).

standard error of 0.58. Eight groups played the Line3 household. Of the eighty rounds played, 74 ended in agreement. The mean Y was 35.05, with a standard error of 5.28.

The intercept in the empty model was 33.08 (S.E. = 1.70,  $-2LL = 511.45$ ). The intra-class correlation was 0.72. In Model I we added the variable interdependence situation or 'Game' (household = 1, market = 0). In Model II we added the variable Round. In Model III we added the interaction Game\*Round to test whether the effect of Round is different across the two situations. See Table 5 for the results of the analyses.

On average A and C received 9.93 points more in the household than in the market, corroborating Hypothesis 1 ( $\chi^2_1 = 7.91$ ,  $p < 0.01$ , one-tailed). The effect of Round in Model II was not significant ( $\chi^2_1 = 1.276$ ,  $p > 0.10$ ). The effect of Game\*Round was also not significant ( $\chi^2_1 = 0.161$ ,  $p > 0.10$ ).

### *Comparing Public Good to Household*

Hypothesis 2 states that on average A and C receive the same in the household and public good problem. To test this hypothesis again three

**Table 6.** Comparing exchange ratios of household (Game = 1) and public good problem (Game = 0) – estimates for Model I with random intercept plus fixed effect of Game, Model II also includes Round, and Model III also includes Game\*Round

	<i>Model I</i> coefficient	<i>Model II</i> coefficient	<i>Model III</i> coefficient
Intercept	36.28*** (1.66)	36.32*** (1.64)	36.35*** (1.63)
Game	-1.21 (2.34)	-1.33 (2.32)	-1.30 (2.31)
Round		0.60*** (0.13)	1.10*** (0.17)
Game*Round			-0.95*** (0.24)
-2 log-likelihood	868.40	847.349	832.26

*Notes:* Data shown are mixed model coefficients with standard error in parentheses.

\*\*\*  $p < 0.001$  (two-tailed test).

mixed models were estimated (see Table 6), using only the data of the household and public good situations. In 67 of 80 rounds of the public good problem, agreement was reached, the average of  $Y$  transferred was 36.22, with a standard error of 7.49. The intercept in the empty model or average exchange ratios across all exchanges was 35.67 (S.E. = 1.179,  $-2LL = 868.66$ ), and the intra-class correlation was 0.48. The effect of Game (household = 1, public good = 0) in Model I was not significant, in agreement with our hypothesis ( $\chi_1^2 = 0.27$ ,  $p > 0.10$ ). The effect of Round in Model II was significant ( $\chi_1^2 = 21.05$ ,  $p < 0.01$ , two-tailed), as well as the interaction in Model III ( $\chi_1^2 = 15.09$ ,  $p < 0.01$ ). There is no effect of Round in the household, but a significant positive effect of Round in the public good problems ( $F_{1, 59, 14} = 33.45$ ,  $< 0.001$ ). That is, in the course of the experiment A and C gained more points in their exchange with B in the public good game. This effect can also be observed in Figure 2. Additionally, we tested whether the two interdependence situations differed in exchange ratios in only the first three and the last three rounds. No significant difference was found in either case.

We also tested two hypotheses in which we compared each of the household and public good problems to a bilateral exchange situation. It can be argued that, with respect to incentives, the household condition effectively reduces A and C to a single actor. If B were to exchange with a single actor, the only outcome to be reasonably expected would be the

**Table 7.** Comparing exchange ratios of resource dilemma (Game = 1) and market (Game = 0) – estimates for Model I with random intercept plus fixed effect of Game, Model II also includes Round, and Model III also includes Game\*Round

	<i>Model I</i> <i>coefficient</i>	<i>Model II</i> <i>coefficient</i>	<i>Model III</i> <i>coefficient</i>
Intercept	25.13*** (3.00)	25.17*** (3.00)	25.13*** (3.00)
Game	-6.68 (3.67)	-6.72 (3.67)	-6.68 (3.66)
Round		-0.60** (0.20)	0.04 (0.33)
Game*Round			-0.96* (0.40)
-2 log-likelihood	357.23	348.67	343.16

*Notes:* Data shown are mixed model coefficients with standard error in parentheses.

\*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$  (two-tailed tests).

one in which both partners earned 12 points, i.e., an exchange in which B transfers 36 units of Y in return for the unit of X.<sup>5</sup> To test this we estimated an empty mixed model to check whether the intercept was significantly different from 36. In line with our expectation, it was not ( $F_{1, 7,90} = 0.427$ ,  $p = 0.532$ ). Also, for the public good problem we found no significant deviation from 36 ( $F_{1, 7,98} = 0.022$ ,  $p = 0.886$ ).

### *Comparing Market to Resource Dilemma*

Hypothesis 3 states that on average A and C receive less in the tragedy of the commons than in the market. To test this hypothesis again three mixed models were estimated (see Table 7), using only the data of the market and the resource dilemma situations. In the resource dilemma all of the 40 possible exchanges were completed, the mean value of Y was 18.45, with a standard deviation of 7.55. Note that the mean value of Y implies a mean loss for the exchanging A or C subject of 5.55 (24 – 18.45). The mean value of Y, however, differed markedly across the four groups. In two of the groups on average the A and C subjects did not lose or hardly lost on their individual exchanges with B, indicated by average Y values of 22.5 (loss of 1.5) and 24.1 (gain of 0.1). In the other two groups, the A and C subjects did concede losses, with average values of Y of 11.3 (loss of 12.7) and 15.9 (loss of 8.1).

The average exchange ratio across all exchanges was 20.66 (S.E. = 2.147,  $-2LL = 359.881$ ), and the intra-class correlation was 0.53. The effect of Game (tragedy of the commons = 1, market = 0) was significant ( $\chi_1^2 = 2.65$ ,  $p = 0.05$ , one-tailed), corroborating Hypothesis 3. The effect of Round in Model II was negative and significant ( $\chi_1^2 = 8.57$ ,  $p = 0.003$ ). The interaction effect in Model III was also significant ( $\chi_1^2 = 5.51$ ,  $p = 0.02$ ). The effect of Round was negative in the resource dilemma ( $F_{1,36} = 11.23$ ,  $p = 0.002$ ), and there was no effect of Round in the market ( $F_{1,65.99} = 1.15$ ,  $p = 0.287$ ). See Figure 2 for a visualization of this trend.

Finally, it must be noted again that the observed differences between groups in the resource dilemma were large. In the two groups in which the A and C subjects lost in their exchanges with B, the average number of units of Y transferred by B in the first round was 29. The actor excluded from exchange then experienced the negative externality of 24. In these groups the mean number of Y then sharply dropped in round two, to a level of approximately 12, and stayed at this low level. In the two groups in which the A and C actors didn't lose or hardly lost in their exchanges with B, the mean number of Y in the first round was 28 and remained at this relatively high level during the remaining rounds, regardless of the negative externalities experienced by the excluded actor. Thus, the difference between these groups is caused by the different reactions of the A and C subjects to the externalities experienced in the first round. Moreover, regardless of whether the number of units of Y dropped in the second round, it remained relatively stable in both types of groups in the subsequent rounds of the experiment.

### *Comparing Proportions of Completed Exchanges*

Core theory predicts that all exchanges are carried out. However, different proportions of completed exchange were observed across conditions. The observed proportions were 0.84, 0.90, 0.93, 1 for the public good problem, market, household, resource dilemma, respectively. Multilevel logistic regressions were carried out to test for differences in pairs. Because the observed proportion was 1 in the resource dilemma, no multilevel logistic regression could be carried out on all four situations simultaneously, or on all pairs containing the resource dilemma. Therefore, we chose the chi-square test for independence on pairs containing the resource dilemma. This test assumes independence of observations, an assumption that is violated in the data. As a consequence of the violation of this assumption the chi-square test is too liberal, that is,

the reported  $p$ -values are too small. A safeguard is to take a smaller significance level, e.g., 0.01 instead of 0.05.

The analyses demonstrated that the difference between the following pairs of proportions of completed exchanges was at least marginally significant (lower proportion mentioned first): public good and household, (Wald  $Z = -1.676$ ,  $p = 0.10$ ), public good and resource dilemma ( $\chi_1^2 = 7.29$ ,  $p = 0.007$ ), market and resource dilemma ( $\chi_1^2 = 4.138$ ,  $p = 0.042$ ), and household and resource dilemma ( $\chi_1^2 = 3.16$ ,  $p = 0.04$ ).

## Discussion

In line with insights from social exchange theory the present article conceived of interaction as the bilateral transfer of valuable resources, or exchange. The research problem concerned the effect of externalities of exchange, or type of interdependence situation. The interdependence situations studied in this article are well-known social situations that have been frequently studied in the social sciences. The present article is the first to distinguish between these situations based on the resources shared by certain actors within the same framework of exchange networks with externalities. We argue that this approach has several important advantages. Our approach enabled us to systematically compare, both theoretically and empirically, different interdependence situations. We argue that the possibility to analyze both behavior in different interdependence situations and exchange behavior within one general system of goal-directed behavior is of central importance to sociology. We believe that the analysis of interdependence situations within the framework of exchange networks with externalities is closer to many real-life interdependence situations than the traditional analysis of these situations. Traditionally, these interdependence situations are represented by games (e.g., public good or, more generally, social dilemma) which make actors focus on their actions and the consequences of their actions for themselves and others. We believe that in real life the focus is more on the goal-directed activity or exchange of the actor, and not on the consequences of it for third parties; for example, fishermen who deplete their fishing waters are probably more focused on trading with their fish than on the structure of the resource dilemma. To conclude, we argue that the external validity of our analysis may be larger than that of the traditional analysis.

An important additional implication of studying the effect of externalities through shared resources in exchange networks is that subjects in the experiments have to be endowed with actual resources. Thus, the traditional

design in which actors negotiate over the division of a fixed pool of points is inappropriate. This is made most clear in the resource dilemma. In this dilemma we predicted and observed that the basic principle of exchange without externalities, 'actors only exchange when exchanging leads to mutually profitable outcomes', does not hold; subjects A and C consent to losses in their exchanges with B. Endowing subjects with resources facilitates these losses, since subjects have the possibility to sell their resources for a price so low they actually lose points. Dividing a fixed pool of points does not allow the incurring of a loss.

In the present article we imposed on actors the restriction that they could only exchange once every round. Given this one-exchange rule, the four interdependence situations are exhaustive: in the market no resources were shared, in the public good problem only resources received were shared, in the resource dilemma only resources transferred were shared, and in the household both resources received and resources transferred were shared. The examples of exchange with externalities offered in the present article suggest that exchanges with externalities are no less common than exchanges without externalities. Despite the empirical abundance of this phenomenon, however, externalities in exchange networks have hardly been investigated, the sole exception being research on externalities in collective decision making (Stokman et al. 2001; Van Assen et al. 2003). The current article is a start at filling this large gap in the field of exchange research.

The field of network exchange research is rife with theories (see Willer and Emanuelson 2005 for an overview). However, generalization of these theories to exchange with externalities is by no means straightforward, and presents a challenge to exchange theorists. Dijkstra (2005) modified and thereby generalized core theory such that it can be applied to exchanges both with and without externalities. Hypotheses derived from (generalized) core theory predicted varying degrees of competition between actors A and C in the different interdependence situations. Competition was predicted to be fiercest in the resource dilemma, followed by the market. No competition was predicted in the household and the public good problem. In the latter two conditions generalized core theory predicted identical exchange ratios, which were predicted to be more favorable to A and C than in the market. The least favorable exchange ratios for A and C were predicted in the resource dilemma. These effects were indeed found in the data and all hypotheses were corroborated, indicating that externalities do matter in exchange situations and have predictable effects on exchange ratios. Some issues concerning the results deserve further attention.

Contrary to the other conditions, we didn't find an effect of Round in the market. This might come as a surprise, since previous research on market-like exchange networks (networks with one seller and multiple buyers) demonstrated that the demand of the buyers decreases in Round (e.g., Skvoretz and Zhang 1997). The absence of an effect of Round is probably due to the fact that the three practice rounds subjects played before the actual experiment were played in the market condition. These practice rounds might thus have provided an anchor for the actual experiment. In the market experiment the conditions didn't change with respect to this anchor situation, leading to outcomes that were stable across rounds. In the other situations, conditions did change with respect to the anchor situation, leading to gradually changing exchange ratios over time. This possible anchoring effect does not confound our results. On the contrary, despite the possible anchor we did observe the predicted differences between the conditions after ten rounds.

With respect to the resource dilemma, we observed a remarkable difference between groups of subjects. In two of the four groups the A and C subjects on average didn't lose in their exchanges with B, whereas A and C subjects in the other two groups did. Loss aversion cannot explain this result, since completing an exchange with B that implies a loss to A (C) prevents an even larger loss for the exchanging actor. An explanation could be based on perceptions of fairness. Subjects in the two groups might consider it fair that a central player such as B harvests the entire surplus of exchange due to her network position, but consider it unfair if more than the exchange surplus is appropriated by B. In any case the results reveal that not only the structure of the resource dilemma determines the results, but also the characteristics of the actors involved in the dilemma. We expect that the possible effect of actor characteristics is overruled by the effect of structure, when the resource dilemma involves more than two peripheral actors like A and C; cooperation (not exchanging with B or transferring only a small amount of resources to B) among actors is only possible if all of them are prepared to cooperate.

Although we formulated no hypotheses concerning the proportions of completed exchanges in the different conditions, we did find some interesting results. The proportions observed seem to mirror the amount of competition between subjects A and C. Proportions were highest in the resource dilemma and lowest in the public good problem. The proportion of completed exchanges in the household was in between these two extremes. This is an indication that externalities also influence the rate of agreement in exchange networks: when externalities enhance competition,

they seem to increase actors' willingness to reach agreement, whereas externalities that attenuate competition have the opposite effect.

In this article we focused on one particular outcome of exchange in networks, namely the exchange ratio. Another important outcome of exchange networks not investigated in the present article is the exchange pattern, i.e., the pattern of who exchanges with whom. In a future article experiments will be reported that investigate the effects of externalities on both the exchange ratio and partner selection in exchange networks. Like the hypotheses concerning the exchange ratio, the hypotheses concerning partner selection will be derived from generalized core theory.

The results predicted for and observed in the laboratory experiments reported in the present article have implications for real-life exchanges. Whenever externalities exist, it is insufficient to know only actors' resource endowments and utilities, together with the network structure, to make sensible predictions concerning the outcomes of the exchange process. One needs to know the size and sign of the externalities as well, as they may crucially influence the outcomes. Thus, in for instance collective decision-making situations such as parliaments and labor-management negotiations, the exchanges of two parties may well have profound effects for other parties involved in the decision process. As this article indicates, the structure of these externalities might dramatically alter the outcome with respect to a situation without externalities.

An important question concerns the ecological validity of our conclusions regarding actor behavior in the four interdependence situations. First of all, we only considered very simple situations involving only three actors. Secondly, we only considered behavior in the four situations under the one-exchange rule. Discarding the one-exchange rule in the Line3 network does not change the predictions of behavior in the household and the public good interdependence situations, but it eliminates the advantage of the B actor in the market and changes the resource dilemma into a prisoner's dilemma game.

Discarding the one-exchange rule allows the study of other dilemmas. For example, it transforms the resource dilemma into a prisoner's dilemma; the dominant strategy of both A and C is to exchange with B, but if both A and C exchange with B, both A and C end up with a negative payoff. The Pareto efficient outcome results when both A and C do not exchange with B. This example shows that also prisoner's dilemmas can be conceived of as exchanges with externalities. A future article will investigate the difference in outcomes between 'regular' prisoner's dilemmas and two experiments we conducted in which prisoner's dilemmas were embedded in exchange networks.

To conclude, we have studied only one of many instances of each of four interdependence situations. However, our study shows that all these situations can be fruitfully studied in the same general framework of exchange networks with externalities, and that generalized core theory could provide accurate relative predictions of actor behavior in the instances examined.

### NOTES

1. If one defines externalities such that exclusion and interdependence are included in the definition, the definition becomes meaningless because all possible effects of an exchange are then by definition externality effects. Our definition allows one to distinguish the effects of exclusion and competition and the direct effects of exchange, i.e., the mere addition or subtraction of payoff as a result of the exchange.
2. The instruction and test can be obtained from the first author.
3. For example, if one wants to estimate and test the multilevel model with only variable Round as predictor, then the following equation is estimated:  $Y_{ij} = \gamma_{00} + \gamma_{10}\text{Round} + U_{0j} + e_{ij}$ . The random variables  $U_{0j}$  and  $e_{ij}$  are assumed to be normally distributed with mean zero. Their variances are parameters and are estimated in the multilevel model.  $U_{0j}$  is the group-dependent deviation,  $e_{ij}$  is the observation-dependent deviation of the prediction. The equation can be expanded by including other predictors, like Game and  $\text{Game}^*\text{Round}$ .
4. The parameter estimates obtained by running an analysis separately on two games are identical to those obtained when analyzing the four games altogether (presented in Table 3). However, the standard errors of these estimates differ. Consequently, to test for differences between the games an analysis is required that only compares the two games.
5. In fact, this would be the predicted outcome of classic theories of bilateral monopoly such as the Nash bargaining solution (Nash 1950) and the Raiffa-Kalai-Smorodinsky solution (Kalai and Smorodinsky 1975).

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