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EXTERNALITIES IN EXCHANGE NETWORKS

AN ADAPTATION OF EXISTING THEORIES OF EXCHANGE NETWORKS

Jacob Dijkstra

ABSTRACT

The present paper extends the focus of network exchange research to *externalities* in exchange networks. Externalities of exchange are defined as direct effects on an actor's utility, of an exchange in which this actor is not involved. Existing theories in the field of network exchange do not inform us on how externalities are predicted to affect behavior in exchange networks. Three prominent theories in the field, core theory, power dependence theory and exchange resistance theory, are extended to exchange networks with externalities, allowing three main conclusions about the expected effects of externalities in exchange networks: externalities (i) change actors' payoffs, (ii) change the exchange pattern, and (iii) change the power distribution across actors. The investigated theories yield predictions concerning the occurrence and magnitude of these effects. A method is proposed to separate the effect of (i) the network, (ii) the externalities, and (iii) the interaction between network and externalities.

KEY WORDS • core • exchange networks • exchange resistance • externalities • power dependence

In the social sciences a fair amount of research is devoted to exchange networks. The issue on which this research has mainly concentrated 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. Generally, exchange possibilities are represented as the opportunity of two actors to divide a pool of valuable resources or 'profit points', usually of size 24.

Sociologists such as Granovetter (1985) have recognized the importance of this *social embeddedness* for social theory. Access constraints, and thereby network structures, can arise because of a variety of reasons, such as *personal*, *cultural*, or *social* differentiation (Braun 1993). Instances of personal access constraints are difference in physical location or incompatible preferences. Differences in, for instance, ethnicity or ideological commitments can cause cultural barriers to arise, while, for example, different positions in a hierarchy may cause social access constraints. Kranton and Minehart (2001) define a network connection as anything that makes a particular bilateral exchange possible or adds value to such an exchange. Customized equipment for instance can form a connection between two firms. But also relations with extended family members or personal connections between managers can form links that facilitate business transactions (for instance Stokman et al. 1987).

One of the simplest examples of an exchange network, for obvious reasons sometimes called Line3, is presented in Figure 1a. In the Line3 network, the actors in positions A and C do not have the possibility to exchange with each other since they are not connected. B can negotiate and (possibly) exchange with both A and C. If actors fail to reach agreement, neither gets any points. In most studies actors are limited to making only one exchange. The reasons for this limiting seem to be mostly based on arguments of tractability (see, for instance, Willer 1999 for exchange networks where the one-exchange rule is relaxed). Theories in the field of exchange network research seek to predict who exchanges with whom and what will be the payoff for each of the actors.

In the current paper I will extend the basic framework (one exchange per actor, and exchange represented as the opportunity to divide a pool of 24 points) by introducing *externalities*. I start from the basic framework so as to focus exclusively on the effects of externalities, leaving the effects of externalities in other frameworks (such as networks in which actors can complete more than one exchange) for future research.

As I will show below, externalities occur in many real-life exchange situations, and affect the outcomes of exchange. The aim of the present paper is to analyze existing theories in the field with the objective to extend them to exchange with externalities. I define externalities as they are commonly defined in economics. In the words of Mas-Colell, Whinston, and Green (1996: 350) economic situations *without* externalities are situations in which an actor's preferences or utilities are defined

Figure 1a. The Line3 exchange network

Figure 1b. The Line4 network without externalities

Figure 1c. The Line4 network with externalities of -8 between A and C

Figure 1d. The Line4 network with externalities of y_A and y_C between A and C

Figure 1e. The Line4 network with externalities of -24 between A and C, and between B and D

solely over the set of goods that she might herself decide to consume. An *externality* is defined to be present whenever the well-being of an actor is *directly* affected by the actions of another actor (p. 352).

In the context of exchange networks, externalities of exchange are defined as direct consequences (positive or negative) of exchanges for the well-being of actors who are not involved in the exchange. Externalities in the Line3 network of Figure 1a would exist if after an exchange of two actors the profit of the third actor is directly affected as well. For example, if A and B obtain 16 and 8 points in their exchange with each other respectively, and C obtains 4 points as a direct consequence of this exchange, then C experiences *positive* externalities of the exchange between A and B, equal to 4. If, for example, 4 points are subtracted from C's profits after the exchange between A and B, C is experiencing *negative* externalities of 4. It is important to note that if C's profit is unaffected, i.e., no points are *directly* added or subtracted due to the exchange between A and B, there are *no* externalities. Thus, according to the definition of externalities I employ, the *exclusion* of C when A and B exchange is *not* an externality effect of the exchange between A and B. Also a possible outbidding process of A and C to be able to exchange with B is not connected to externalities. Exclusion and the outbidding process are merely two instances of *interdependence* that are present in exchange networks, whether there are externalities of exchange or not. If we were to include exclusion and outbidding in the definition of externalities, virtually any interdependency in an exchange network would be an externality and the concept would lose its usefulness.

There exists a considerable amount of research on the concept of externalities. However, existing models that explicitly allow for externalities (see for instance the generalization of the Shapley value by Myerson 1976) assume that all actors in the economy can exchange with each other. The problem studied in the present paper deviates from this by focusing on externalities in exchange *networks*, in which interaction possibilities are limited by network connections.

Many instances of strategic interaction commonly studied in the social sciences can be conceptualized as exchange problems with externalities. Resource dilemmas for instance, can be analyzed as a network of exchange relations in which a number of players use a common resource as a source of supply of exchangeable commodities. Think for instance of fishermen sharing waters. By all using the same waters to their own benefit, the fishermen deplete the resource, thereby ending up in a Pareto inefficient equilibrium. The externality consists of the fact that by catching fish from the common waters, a fisherman increases the

marginal cost of catching fish for other fishermen: it becomes harder to catch fish now, and an excess of fishing lowers the reproduction rate of fish, decreasing the number of fish in the water in the future. A social dilemma exists because whether or not other fishermen abstain from catching fish, it is always best for any individual fisherman to catch fish. Since this holds for all fishermen, they deplete the water of fish.

In the fishermen example above, fishermen experience negative externalities from other fishermen *catching* fish, not from exchanging them. However, assuming fishermen catch fish to sell them, the benefit of analyzing such a situation as an exchange network with externalities, is that it allows one to investigate the interaction between the externality structure (multiple fishermen fishing from the same lake) and the relations in the exchange network (between fishermen and retailers or consumers of fish). What are the effects of the externalities on other players in the network that are not subject to externalities themselves (such as consumers, or retailers of fish)? How do the externalities affect the exchange ratios in the network (e.g. the price of fish) or the partner choice? For instance, in the buyer–seller network of fishermen and consumers, less fish on the market may lead to a strong increase in price. This may on the one hand appear to ‘solve’ the dilemma for the fishermen, provided the price increases sufficiently, but on the other hand most likely increases the rate of resource depletion. What are the effects of the network structure on how players in the resource dilemma play the game? For instance, what if one fisherman has exclusive access to a (group of) consumer(s), for example due to international trade policies? As an example consider Figure 1b, and let B and D be fishermen and A and C be consumers. Fisherman D has no access to consumer A. Will fisherman B now try to monopolize buyer C, thereby pushing D out of the market and thus preventing any negative externalities caused by D? Answers to questions like these become feasible only when the externality structure and the larger social structure surrounding it, are studied in concert.

The societal relevance of studying externalities of exchange follows from the abundance of examples of exchanges with externalities in real life. Some exchanges with externalities that most of us are familiar with and experience on a daily basis, are exchanges of and between members of a household. The father’s purchases in the supermarket (the exchange of money for products) are experienced as externalities by the other members of the household: less money to spend on other products or activities, and the possibility to consume the products bought by the father. Note that for convenience I conceive of the supermarket here as

a unitary actor. In reality, the father exchanges with a supermarket employee, who himself has an exchange relation with the management of the supermarket (exchanging labor for a wage). Note also that in particular the children in the household experience externalities all the time, since they commonly do not have their own budget, or have a very limited one. Thus, the children have no network connection to the supermarket, but are connected to their parents. Exchanges between parents and children are now most likely influenced by the externalities the children experience from exchanges between parents and supermarket.

Another example is collective decision making. In a division in Parliament for instance, two political parties may agree to exchange their voting positions concerning two issues that have to be decided upon (see for instance Udehn 1996, Thomson et al. 2006, and Dijkstra et al. 2008). Since this 'logrolling' changes the eventual outcome of the vote, the exchange directly affects other political parties that are not involved in the agreement: in other words, the political parties that do not exchange experience externalities. Since the exchange may shift the outcome of the division either toward or away from the position of a particular party not involved in the exchange, the externality may be evaluated positively or negatively by that party (Stokman et al. 2001; van Assen et al. 2003). In collective decision making, networks can arise from ideological barriers or similarities, but also from preferences or positions: in the example above, if two parties agree on what should be the outcome of one of the two issues, they simply cannot exchange.

A crucial insight that is gleaned from thinking about examples of externalities of exchange is that these externalities arise when certain actors *share resources* that are exchanged. Thus, the fishermen experience externalities because they share access to the fishing grounds; household members experience externalities because they share the available household commodities; political parties experience externalities because they share the power to shift the outcome of decision making in a certain direction. The important point is that actors that share a resource cannot use it in exchange with each other, since both actors already 'own' it. Thus, an externality relation between two actors is logically distinct from an exchange relation.

Since many resources are shared, exchanges with externalities can be expected to be no less common in real-life than exchanges without externalities. However, research on effects of externalities on exchange networks has been scarce. More specifically, existing theories in the field of network exchange do not inform us on how externalities are predicted to affect actors' behavior in exchange networks. The present paper aims

to meet this challenge, by analyzing three prominent theories from the field of network exchange research, and indicating how they can be extended and applied to the problem of externalities. My aim is to adapt and apply each of the theories, while not changing their basic assumptions. That is, modifications or extensions of the theories in order to apply them to exchange with externalities do not affect the theories' predictions regarding exchange *without* externalities. In the words of Lakatos and Musgrave (1970: 116), our purpose is to devise theories with 'excess empirical content'.

In the next section I discuss the core solution, originally introduced to the field of network exchange by Bienenstock and Bonacich (1992). I show how the core solution can be fruitfully adapted to the problem of externalities in exchange networks. Moreover, in making this adaptation, we find that the core of an exchange network *without* externalities, is always a subset of the newly defined core in the *same* network, with *positive* externalities. An advantage of the core solution is that it is based on a minimal number of simple assumptions about individual actors and coalitions. More specifically, in my adaptation of the core to the problem of externalities we will see that we only have to make rather straightforward assumptions about individuals and connected dyads. A drawback of the core, however, is that in small, not fully connected networks it does not generally yield 'point predictions', i.e. exact ratios of exchange, but mostly specifies an interval wherein the exchange ratio is predicted to lie. Two prominent exchange theories that mend this drawback at the cost of the loss of at least part of the simplicity advantage are exchange resistance theory (for instance Willer 1999) and power dependence theory (for instance Cook and Yamagishi 1992). By making some additional assumptions about individual actors, and defining a condition under which exchange is predicted to occur (equiresistance and equidependence, respectively) these theories manage to predict an exact ratio of exchange in many but not all networks. Section 2 is devoted to the investigation of power dependence theory under the condition of externalities in exchange networks, and section 3 scrutinizes exchange resistance theory. In sections 2 and 3 we find that these solutions too, can be fruitfully extended to exchange networks with externalities.

A means is introduced that enables one to decompose an actor's payoff into a part attributable to the network, a part attributable to the externalities, and a part attributable to the interaction between network and externalities. This method therefore explicates what the predicted effect of externalities is, and is able to theoretically separate its effect from the effect of the network. Section 4 concludes the paper and indicates directions for future research.

Throughout the paper I will illustrate the application of the theories using 4 numeric examples. These examples are no more than illustrations. They have been chosen to investigate the behavior of the examined theories under different externality conditions, and are not derived from real-life exchange situations. The theories however are generally applicable to exchange networks of various shapes.

1. The core solution

Exchange without externalities

The core solution was originally introduced to the field of network exchange by Bienenstock and Bonacich (1992). Based on the assumption that exchanges can be represented as the opportunity to divide a fixed pool of resources, Bienenstock and Bonacich (1992) have shown that exchange networks can be conceptualized as cooperative games with transferable utilities. Such a game is described by the *characteristic value function* (see, for instance, Friedman 1986).

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 guarantee itself; the coalition can be sure to achieve at least this payoff. According to the assumption of transferable utility, this total payoff can be divided among the members of S in any conceivable way.

Using the characteristic value function, one can define the core solution. Let (x) be a payoff vector, such that x_i represents the payoff for player i . A payoff vector (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).

In words: the core consists of the set of payoff vectors such that no coalition (including one-person coalitions) receives less than it can guarantee itself.

In exchange networks, coalition formation is understood to mean 'reaching agreement to exchange' in connected pairs. Thus, the problem

Table 1. The characteristic value function of the Line4 (Figure 1b) without externalities

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$v(\{A\}) = v(\{B\}) = v(\{C\}) = v(\{D\}) = 0$
$v(\{AB\}) = v(\{CD\}) = v(\{BC\}) = 24$
$v(\{AC\}) = v(\{AD\}) = v(\{BD\}) = 0$
$v(\{ABC\}) = v(\{ABD\}) = v(\{ACD\}) = v(\{BCD\}) = 24$
$v(\{ABCD\}) = 48$

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with the conceptualization of exchange networks as cooperative games in characteristic function form, is that in exchange networks no coalitions S can form other than individuals and connected dyads. Therefore, rationality requirements that pertain to coalitions larger than dyads, or to coalitions of unconnected players, have no meaning: the coalitions cannot form and therefore cannot change the payoff vector.¹ However, if we restrict all actors in the network to at most one exchange then, as is shown by Bonacich and Bienenstock (1995), Proposition 1 holds:

Proposition 1:

If coalitional rationality holds for every dyad it also holds for any larger coalition.

We discuss an example to clarify the point. Consider the Line4 network in Figure 1b. For each subset of players, find the maximum number of exchanges that can be completed between members of this subset, given the exchange network. Then multiply this number by 24, the value of each of the exchanges. For instance, the coalition between players A, B, and C has a characteristic value of 24, since only one exchange can be completed between members of this coalition. The characteristic value function of the Line4 is depicted in Table 1, where coalitions are enclosed in curly brackets. According to Proposition 1, if we find a feasible payoff vector that satisfies the rationality requirements of individuals and two-person coalitions, this payoff vector also satisfies all other rationality requirements. Such a payoff vector is, for instance, $(x) = (12, 12, 12, 12)$. The reader can easily verify that exchange outcomes in which A divides 24 points with B, and C divides 24 points with D, and in which the sum of payoffs for B and C is at least 24, satisfy the rationality requirements for individuals and two-person coalitions *and* are in the core, i.e. satisfy all other rationality requirements.

Table 2. The characteristic value function of the Line4 (Figure 1c) with negative externalities of -8 between A and C

$v(\{A\}) = v(\{C\}) = -8$
$v(\{B\}) = v(\{D\}) = 0$
$v(\{AB\}) = v(\{CD\}) = 16$
$v(\{BC\}) = 24$
$v(\{AC\}) = 0$
$v(\{AD\}) = -8$
$v(\{BD\}) = 0$
$v(\{ABC\}) = v(\{ACD\}) = 16$
$v(\{ABD\}) = v(\{BCD\}) = 24$
$v(\{ABCD\}) = 32$

Exchange with externalities

The previous analysis and proposition pertain to exchange networks as they have been studied in the literature thus far, i.e. without externalities. If we want to study externalities and apply the core solution, the first question arising is how to incorporate externalities in the characteristic value function. An initial candidate answer readily presents itself: strictly adhere to the definition of a coalition's characteristic value as the maximum value a coalition can guarantee itself, despite the actions of others. We'll check the implications of this answer by introducing externalities in the Line4 network of Figure 1b. Assume negative externalities exist between A and C. More specifically, say that whenever C exchanges, A gets a payoff of -8 , additional to any payoffs A receives in her own exchanges. Assume that, *mutatis mutandis*, the same holds for C. This situation is depicted in Figure 1c. The arrow in this figure that points from C to A, indicates the externality for A, if C exchanges. Similarly, the arrow from A to C indicates the externality for C, if A exchanges.² Note that these arrows do not indicate a direct transfer of resources, but an externality. In keeping with the definition of characteristic value above, I compute the characteristic value function for this game in Table 2.

The characteristic value description of a game requires that the value of a coalition can be divided among its members in any possible way, i.e., it requires that utilities be transferable. For this requirement to be met in exchange networks with externalities, we have to make two extra assumptions:

Transferable utility assumption 1

In each exchange relationship there exists a commodity X in which both actors' utility functions are separably linear (see, for example, Friedman

1986). For instance, if x_i , y_i , and z_i are amounts of goods X, Y and Z respectively, held by actor i , each actor i 's utility function is of the form $u_i(x_i, y_i, z_i) = cx_i + w_i(y_i, z_i)$, where c is a constant equal for both actors and $w_i(\cdot)$ is a function.

Transferable utility assumption 2

Each actor i has a sufficient amount of this commodity X to compensate any externality. For instance, if in the example above A experiences an externality of -8 and exchanges with B, actor B has enough of X to compensate A, i.e. to 'take over the loss' of A. If A were to experience a (positive) externality of say $e > 0$, then the two transferable utility assumptions mean that A has enough of commodity X to transfer the entire benefit of e to B.³

The characteristic value of the individual players A and C has dropped from 0 to -8 : neither of them alone can prevent the other from exchanging, and the maximum each can *guarantee* herself is thus -8 . If A and C were to form a coalition, they would not be able to complete an exchange with each other (given the network structure), but they could agree not to exchange at all and thus guarantee a total payoff of 0.⁴ Hence, the value of the coalition between A and C is 0. Note how the characteristic values of the coalitions between A and B and between C and D have fallen from 24 to 16; they can split 24 points among themselves, but they cannot prevent the negative externality for C or A, respectively. Finally, we observe that the characteristic value of the coalition of all players has dropped from 48 to 32: two exchanges can be completed in which a total of 48 points is divided, but two members of the coalition (A and C) each experience an externality of -8 .

Now that we have incorporated externalities in the characteristic value function, let us try to find a payoff vector (x) , that lies in the core. To that end we introduce a vector (y) , that gives the payoffs for the players, *without* externalities. The vector (y) thus simply gives the division of the 24 points for each *exchanging* pair. In line with Proposition 1, we start by looking at individual actors and two-person coalitions. Assume $(y) = (12, 12, 20, 4)$. With the assumed externalities this gives rise to the payoff vector $(x) = (4, 12, 12, 4)$. This vector meets all rationality requirements for individual actors and two-person coalitions. According to Proposition 1, this vector should then meet all the remaining rationality requirements and consequently be in the core. However, $(x) = (4, 12, 12, 4)$ fails to meet the rationality requirement of for instance the triad $\{ABC\}$. The value of this coalition is 24, as can be read from Table 2. However, under $(x) = (4, 12, 12, 4)$, this coalition

Table 3. The characteristic value function of the Line4 (Figure 1c), with positive variable externalities between A and C

$$\begin{aligned} v(\{A\}) &= v(\{B\}) = v(\{C\}) = v(\{D\}) = 0 \\ v(\{AB\}) &= v(\{BC\}) = v(\{CD\}) = 24 \end{aligned}$$

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gets a sum of merely 20. Hence, we find that Proposition 1 fails to hold generally, when externalities are involved (a similar example could be constructed with positive externalities).⁵

In exchange networks with externalities, coalitions between more than 2 players, and coalitions between unconnected players cannot be disregarded when determining the core. However, these coalitions are precluded by the rules of network exchange, since coalition formation is interpreted as exchange, and exchange is only allowed between two connected actors. For exchange networks with externalities, we thus cannot apply the traditional core, and are left with only two sensible rationality requirements:

- (i) $x_i \geq v(\{i\})$ for every $i \in N$ (individual rationality), and
- (ii) $\sum_{i \in S} x_i \geq v(\{i, j\})$ for every connected $i, j \in N$ (rationality of connected dyads).

This gives rise to a first attempt to define a ‘generalized core solution’: a payoff vector (x) is in the generalized core whenever it meets the two rationality requirements mentioned above. Note how, according to Proposition 1, the generalized core is identical to the traditional core in exchange networks without externalities.

The generalized core as formulated above has a serious drawback. To demonstrate this we consider an example. In the example of Figure 1c, we considered ‘constant’ externalities: the size of the externality depends only upon whether or not a certain actor exchanges, and not on the payoff this actor receives in this exchange. Nothing in the definition of externalities, however, precludes ‘variable’ externalities, i.e. externalities that depend on the payoff of some other actor. Consider again the network of Figure 1b, and assume that variable, positive externalities exist between A and C. More specifically, assume that A gets the same payoff as C, in addition to any payoffs A receives in her own exchanges. Assume that, *mutatis mutandis*, the same holds for C.⁶ Thus, A and C now possibly gain from two sources: receipts from their own respective

exchanges, and the gains the other player earns in her exchange. This situation is depicted in Figure 1d, where y_A and y_C indicate the shares of the resource pool A and C appropriate in their own exchanges, respectively. I then compute the characteristic value function in Table 3. Since coalitions of unconnected players and coalitions larger than two players cannot form, I omit them.

Note how the characteristic values of A and C are 0: alone they cannot guarantee that the other player will exchange (in which case they would receive the positive externality), and thus all they can guarantee themselves is 0. The same holds for the two-person coalitions: A and B cannot assure by themselves that C and D will conclude an exchange nor that C will receive a strictly positive payoff in such an exchange. Hence, the maximum A and B can *guarantee* themselves is 24. Now, consider the vector $(y) = (10, 10, 12, 12)$, that registers the players' payoffs without externalities. With externalities this gives rise to the payoff vector $(x) = (22, 10, 22, 12)$. The vector (x) easily meets the two rationality requirements of the generalized core solution. However, vector (y) has an undesirable feature in the light of rationality: players A and B each receive ten points in their exchange, and thus leave four of the twenty-four points 'on the table', or 'undivided'. In other words: A and B exchange in a Pareto *inefficient* manner. Such inefficient exchanges are thus not precluded by the two rationality requirements stated above. Since Pareto efficiency at the dyadic level is a basic requirement that any rational choice theory should satisfy, I add this requirement to the two rationality requirements of the generalized core. Thus, assuming that transferable utility assumptions 1 and 2 are met, the generalized core is finally defined as the set of payoff vectors (x) such that,

- (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), where $w(\{i, j\})$ is the characteristic value of pair $\{i, j\}$ without externalities.

Firstly, note how requirement (ii) pertains to all connected dyads whereas requirement (iii) pertains to *exchanging* dyads only. Thus, for all connected dyads, we require that they receive at least their characteristic value (requirement (ii)). For exchanging dyads we pose the additional

requirement that they maximize their payoffs, regardless of what other players do, i.e. regardless of any externalities (requirement (iii)). Secondly, note how in an exchange network without externalities, the characteristic value of a connected pair is by definition equal to the size of the pool of points to be divided, guaranteeing all exchanges to be efficient. Thus, the generalized core in networks without externalities still equals the traditional core. Note that like the core, the generalized core does not necessarily exist nor is it necessarily unique when it exists.

It is instructive to investigate the behavior of the generalized core in exchange networks with externalities. Shapley and Shubik (1969) have shown that if the core of an economy is non-empty, it is also non-empty when positive externalities are added. A similar proposition can be proved for the generalized core in exchange networks.

Proposition 2:

The (generalized) core without externalities is a subset of the generalized core with positive externalities.

The proof of Proposition 2 can be found in the Appendix. This proposition implies that if the core without externalities is non-empty, the generalized core with positive externalities is also non-empty and includes the core without externalities. The intuition behind Proposition 2 is that positive externalities don't change the characteristic values of connected dyads. To illustrate the proposition I refer once again to the example of Figure 1d. Take the payoff vector $(y) = (10, 14, 14, 10)$. This vector is in the (generalized) core without externalities. With externalities between A and C according to Figure 1d, $(y) = (10, 14, 14, 10)$ implies a payoff vector with externalities of $(x) = (24, 14, 24, 10)$, which is in the generalized core of this network (see Table 3 for characteristic values). The generalized core in the network with externalities is strictly larger than the core without externalities because there are positive externalities. Consider, for instance, the vector $(y) = (24, 0, 0, 24)$, which is *not* in the core without externalities. With the positive externalities of Figure 1d, $(y) = (24, 0, 0, 24)$ implies $(x) = (24, 0, 24, 24)$, which *is* in the generalized core with externalities.

A straightforward but important corollary of the proposition above is that any 'exchange pattern' that can occur in the core without externalities can occur in the generalized core with positive externalities. In other words, if in a network without externalities, there exists a payoff vector in the core such that two actors exchange with each other, there exists a

Table 4. The characteristic value function of the Line4 (Figure 1e), with negative externalities between A and C and between B and D

$v(\{A\}) = v(\{B\}) = v(\{C\}) = v(\{D\}) = -24$
$v(\{AB\}) = v(\{CD\}) = -24$
$v(\{BC\}) = 24$

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payoff vector in the generalized core of the same network with positive externalities, such that the same two actors exchange with each other. Loosely speaking, according to the generalized core, positive externalities cannot ‘force’ the exchange pattern to change.

To round up the examples of Figures 1c and 1d, we give them the entire generalized cores. In the generalized core of Figure 1c, A exchanges with B, and C exchanges with D. Moreover, the sum of the pool shares that B and C receive is at least 32, i.e. $y_B + y_C \geq 32$. In the generalized core of Figure 1d, two exchange patterns are feasible. Either B exchanges with C, in which case C should receive the entire resource pool ($y_C = 24$), or B exchanges with A, and C exchanges with D. In this last exchange pattern, any division of the resource pools is admissible.

Contrary to positive externalities, negative externalities *do* sometimes change the feasible exchange pattern in the generalized core. This is the case because, contrary to positive externalities, *negative* externalities change the characteristic value of individual actors and dyads. Once more consider the Line4 network of Figure 1b. Assume negative externalities exist between both A and C, and B and D. More specifically, assume that whenever A exchanges, C loses 24 points, additional to any points C might gain in exchanges she herself completes, and that A similarly loses 24 points whenever C exchanges. Assume that, *mutatis mutandis*, the same externality relation exists between B and D. This situation is depicted in Figure 1e. The characteristic value function is shown in Table 4.

Consider the vector $(y) = (0, 12, 12, 0)$, which implies B and C exchange with each other and split the 24 points evenly. The vector $(y) = (0, 12, 12, 0)$ implies the payoff vector $(x) = (-24, 12, 12, -24)$, which meets the rationality requirements of the generalized core. However, $(y) = (0, 12, 12, 0)$ is not in the core without externalities. In other words, the large negative externalities induce B and C to exchange with each other, a situation inadmissible in the core without externalities, but rational in the generalized core with externalities. Moreover, the original exchange pattern in the core without externalities, i.e. A exchanging with B and C

with D, *cannot* occur in the generalized core with externalities. The generalized core in this example consists of all exchanges between B and C. A general relationship between the generalized core in networks without externalities and in networks with negative externalities, such as we found for positive externalities in the previous proposition, was not found. More specifically, as illustrated by the most recent example, the generalized core of an exchange network with negative externalities is not necessarily a subset of the generalized core without externalities.

2. Power dependence theory

Exchange without externalities

Power dependence theory was conceived by Emerson (1962, 1964) as a general theory of power relations ‘in an effort to resolve some of the ambiguities surrounding “power”, “authority”, “legitimacy”, and power “structures”’ (Emerson 1962: 31). After its first formulations, the theory was applied to predict exchange ratios in exchange networks (for instance, Cook and Emerson 1978; Cook et al. 1983; Cook and Yamagishi 1992). Central in the theory is the concept of *dependence*. In exchange networks, Cook and Yamagishi (1992) define the dependence of actor *i* on actor *j* (D_{ij}), as the amount of extra profit *i* gets in the *i*–*j* exchange over *i*’s best available alternative. This best alternative of *i* is referred to as *i*’s *conflict payoff* in the remainder of the text. Denoting *i*’s payoff in exchange with *j* as y_{ij} , and *i*’s conflict payoff as y_{ij}^{con} , we can write $D_{ij} = y_{ij} - y_{ij}^{con}$. Power dependence theory claims that actors will agree at the point where their mutual dependences are equal, i.e., where $D_{ij} = D_{ji}$. Moreover, in exchange networks, power dependence theory predicts that mutual dependences will be equal, *throughout the network* (Cook and Yamagishi 1992). That is, $D_{ij} = D_{ji}$ for each pair of connected actors *i* and *j*.^{7,8}

To illustrate how this *equidependence* principle operates in exchange networks without externalities, we again consider the Line4 network of Figure 1b. Assume that A exchanges with B and C with D. Then we know that $y_{BA} = 24 - y_{AB}$ and $y_{DC} = 24 - y_{CD}$.⁹ The expressions for the conflict payoffs, dependences and the equidependence principle for these relations, are given in Table 5. The conflict payoffs for actors A and D are 0: neither has an alternative exchange partner to respectively B and C. Actors B and C however, have each other as alternatives. B will then have to offer C at least y_{CD} , i.e., the payoff of

C in the exchange with D. Therefore, the value of the conflict payoff for B, in her exchange with A, is $24 - y_{CD}$. A similar reasoning holds for actor C. Setting the dependences within the A–B and C–D relations equal to each other, yields equations (1) and (2) in Table 5. Solving for y_{AB} and y_{CD} yields $y_{AB} = 8$ and $y_{CD} = 16$, which implies $y_{BA} = 16$ and $y_{DC} = 8$. It now remains to check the B–C relationship. According to the computations above, both B and C can earn 16 in their best alternatives to each other. Thus, $y_{BC}^{con} = y_{CB}^{con} = 16$. This means that the sum of the conflict payoffs of actors B and C exceeds 24, the amount to be divided by B and C, if they were to exchange with each other. Cook and Yamagishi (1992) dub this a *latent relation*. They state that ‘the maximum profit an actor can obtain in a latent relation is the profit-overlap minus the best alternative of his exchange partner’ (p. 252). Therefore, in our example we get $y_{BC} = y_{CB} = 24 - 16 = 8$. Now we are ready to determine the actors’ dependence. We find $D_{BC} = D_{CB} = 8 - 16 = -8$. Thus we find that given the payoffs computed before, the mutual dependences of B and C are equal. Moreover, they are negative, indicating that both can earn larger profits in their best alternatives.

Exchange with externalities

Introducing externalities in exchange networks, means that an actor’s payoff is not merely a function of the share of the resource pool she appropriates for herself, but also of the actions of some other actor(s), distant in the network. In power dependence theory externalities can influence both an actor’s conflict payoff and/or her actual payoff. To illustrate how externalities are incorporated in power dependence theory we once again consider the example of the Line4 network of Figure 1c, with the negative externalities of -8 between A and C. Assume again that A exchanges with B and C exchanges with D. Actors A and C will now get a total payoff consisting of the share of the pool they appropriate in their exchanges with B and D, respectively, and the externality of -8 . Thus, $x_A = y_{AB} - 8$ and $x_C = y_{CD} - 8$, where y indicates payoffs without externalities and x indicates payoffs with externalities.¹⁰ For B and D we have $x_B = 24 - y_{AB}$ and $x_D = 24 - y_{CD}$. The expressions for the conflict payoffs, dependences and the equidependence principle for the A–B and C–D relations are given in Table 6.

The conflict payoff for A is set at -8 ; A has no alternative exchange partners and we assume that if A fails to exchange with B, B will

Table 5. Dependences and equidependence for the A–B and C–D relations in the Line4 network without externalities (Figure 1b)

<i>Relation</i>	<i>Conflict Payoff</i>	<i>Dependence</i>	<i>Equidependence</i>
A–B	$y_{AB}^{con} = 0$	$D_{AB} = y_{AB} - 0$	$y_{AB} = y_{CD} - y_{AB}$ (1)
	$y_{BA}^{con} = 24 - y_{CD}$	$D_{BA} = (24 - y_{AB}) - (24 - y_{CD})$	
C–D	$y_{CD}^{con} = 24 - y_{BA} = 24 - (24 - y_{AB}) = y_{AB}$	$D_{CD} = y_{CD} - y_{AB}$	$y_{CD} - y_{AB} = 24 - y_{CD}$ (2)
	$y_{DC}^{con} = 0$	$D_{DC} = y_{DC} - 0 = 24 - y_{CD}$	

Table 6. Dependences and equidependence for the A–B and C–D relations in the Line4 network, with externalities of –8 between A and C (Figure 1c)

<i>Relation</i>	<i>Conflict Payoff</i>	<i>Dependence</i>	<i>Equidependence</i>
A–B	$x_{AB}^{con} = -8$	$D_{AB} = y_{AB}$	$y_{AB} = y_{CD} - y_{AB} - 8$ (3)
	$x_{BA}^{con} = 24 - x_{CD} = 24 - (y_{CD} - 8)$	$D_{BA} = (24 - y_{AB}) - (32 - y_{CD})$	
C–D	$x_{CD}^{con} = 24 - y_{BA} = 24 - (24 - y_{AB}) = y_{AB}$	$D_{CD} = y_{CD} - 8 - y_{AB}$	$y_{CD} - 8 - y_{AB} = 24 - y_{CD}$ (4)
	$x_{DC}^{con} = 0$	$D_{DC} = y_{DC} - 0 = 24 - y_{CD}$	

exchange with C. In that case A will get a negative payoff of 8. A will also receive this negative externality when exchanging with B, since *we assume then C will exchange with D.* Note how the italicized text above amounts to making a ‘worst case scenario’ assumption with respect to the conflict payoff of A: whether or not A exchanges, we assume that in the rest of the network the worst possible scenario unfolds regarding externalities. I will return to this point when summarizing the analysis of power dependence theory.

In the current example, the negative externality ‘cancels out’ in the dependence of A on B, as can be seen by comparing Tables 5 and 6. In both tables, A’s dependence on B consists of the share of the resource pool A appropriates in exchange with B. This makes perfect sense: since A cannot avoid the negative externality, it shouldn’t influence her negotiation behavior. The same is not true for C, however. C *can* avoid the negative externality by exchanging with B, thereby precluding an exchange of A. Therefore, we read from Table 6 that C’s conflict payoff consists simply of $24 - y_{BA}$: the externality of -8 is not included. The conflict payoff of actor B with respect to actor A is also affected by the externality, in the following way. B has to offer C at least the payoff C earns in exchange with D, i.e. $x_C = y_{CD} - 8$. In this payoff the externality is included, which implies that B’s conflict payoff in the relation with A becomes $24 - (y_{CD} - 8)$. Setting the mutual dependences in the A–B and C–D relations equal to each other yields equations (3) and (4), respectively. Solving for y_{AB} and y_{CD} yields $y_{AB} = 5 \frac{1}{3}$ and $y_{CD} = 18 \frac{2}{3}$, which implies $y_{BA} = 18 \frac{2}{3}$ and $y_{DC} = 5 \frac{1}{3}$. These are the shares of the resource pools the actors get in their exchanges, i.e. the payoffs *without* externalities. Adding the externalities we have $x_A = -2 \frac{2}{3}$, $x_B = 18 \frac{2}{3}$, $x_C = 10 \frac{2}{3}$, and $x_D = 5 \frac{1}{3}$. At these payoffs, the mutual dependences are equal in all relations and the B–C relation is again latent.

Comparing this outcome to the outcome for the Line4 network without externalities, shows how the externalities and the network interact to influence the actors’ payoff throughout the network. We already observed how the negative externality doesn’t influence the dependence of A upon B, since A cannot avoid the negative externality. However, since C *can* avoid the negative externality through exchange with B, C’s dependence on B is enhanced. B’s dependence on C is not affected, and thus B’s negotiation position vis-à-vis C is strengthened. Moreover, since C is more dependent on B and is thus a more ‘willing’ alternative for B, B’s dependence on A is lowered. This strengthens B’s negotiation position vis-à-vis A. Thus, the negative externalities between A and C have given B a better negotiation position, which is reflected in the

larger payoff B receives in exchange. The payoff of actor D is also affected. Since C experiences a negative externality of -8 when exchanging with D, but not when exchanging with B, the relative value of the C–D relationship for actor C is lowered, i.e. C's dependence on D becomes smaller. This is reflected in the lower payoff of actor D (and the larger share of the pool C appropriates in the C–D exchange).

So, externalities do not only affect the payoffs of the actors that are subject to its condition, but also the payoffs of other actors through connections in the network. The same conclusion can be drawn from the generalized core from the previous section. However, because we now have a point prediction, the effects of the network, of externalities *per se*, and of the interaction between the network and externalities can be theoretically decomposed by comparing the same network with and without externalities.

We can write an actor's payoff as the sum of three variables: $O_i = O_{iN} + O_{iE} + O_{iExN}$. The network effect (O_{iN}) is the prediction in the network without externalities. The externalities effect (O_{iE}) is the direct impact of the externalities on an actor's payoff, for instance the deduction of 8 in the previous example. The remainder of the payoff is interpreted as the interaction between network shape and externalities. I have made this decomposition of payoffs for the example above in Table 7. Thus we see that additional to the direct effect on the payoffs of A and C, externalities interact with the network to produce an additional change in the payoffs of $2\frac{2}{3}$. Since the externalities render C more eager to exchange with B, and make the relationship with D less valuable to C, this interaction effect is positive for the structurally advantaged positions B and C. For the structurally disadvantaged A and D, the interaction effect is negative.

As we discussed in the previous section, externalities can be variable. In the previous section we discussed the example of Figure 1d. These variable externalities pose no special challenge to the application of power dependence theory I have just illustrated. Instead of including an externality of -8 in the payoff functions of A and C, the externalities for A and C now become y_C and y_A , respectively. Computing the point of equidependence for this situation yields $y_A = y_B = y_C = y_D = 12$, which implies $x_A = x_C = 24$ and $y_B = y_D = 12$. I decompose these payoffs in Table 8. In this table we see that the interaction effect has an absolute value of 4 for all actors. For the peripherals this effect is positive, for the central actors it is negative. Thus, we see that the interaction between externalities and network structure can benefit structurally disadvantaged actors, like A and D, and hurt structurally advantaged actors.

The example of Figure 1e demonstrates how externalities are predicted by the generalized core to change the exchange pattern, i.e. the pattern of

Table 7. Decomposition of payoffs in Line4 network with externalities of -8 between A and C (Figure 1c), according to the equidependence principle

Actor	Decomposition $O_i = O_{iN} + O_{iE} + O_{iE \times N}$
A	$O_A = 8 - 8 - 2^2/3 = -2^2/3$
B	$O_B = 16 + 0 + 2^2/3 = 18^2/3$
C	$O_C = 16 - 8 + 2^2/3 = 10^2/3$
D	$O_D = 8 + 0 - 2^2/3 = 5^1/3$

who exchanges with whom. Assuming that A exchanges with B and C exchanges with D we determine the equidependence solution for this example. This yields $y_A = y_D = -8$ and $y_B = y_C = 32$, which implies $x_A = x_D = -32$ and $x_B = x_C = 8$. This result has two problems. Firstly, both A and D get less in total than their conflict payoffs (-24). Secondly, and related to the first point, the mutual dependences *within* the exchanging pairs are negative (-8), signaling that both players in each pair can get a larger payoff in their best alternative. For B and C, their best alternative is exchanging with each other, and for A and D it is not exchanging at all. Now assume an exchange between B and C. We then get $x_A = x_D = -24$ (by definition) and $y_B = y_C = x_B = x_C = 12$. This solution solves the problem of A and D getting less than their conflict payoffs. Moreover, the conflict payoffs for B and C are 0: if B wanted to exchange with A, B had to offer A a total payoff of at least -24. This implies that B would have to offer A at least a share of the pool of size 0, giving B a share of 24. With externalities subtracted this would yield a total payoff of -24 for A and 0 for B. The same holds for C and D. Thus, the second problem is also solved: the mutual dependences of B and C are positive (12). The equidependence principle therefore predicts an equal exchange between B and C, and thus a change in exchange pattern.

There is at least one theoretical issue still to be resolved, concerning the application of externalities to power dependence theory, as illustrated above. To determine the effect of externalities on the conflict payoffs and the actual payoffs of an actor, assumptions have to be made on what happens in the rest of the network. In the Line4 examples in this paper we assumed for instance that if A and B failed to reach agreement,

Table 8. Decomposition of payoffs in Line4 network with externalities of y_C and y_A , respectively, between A and C (Figure 1d)

Actor	Decomposition $O_i = O_{iN} + O_{iE} + O_{iE \times N}$
A	$O_A = 8 + 12 + 4 = 24$
B	$O_B = 16 + 0 - 4 = 12$
C	$O_C = 16 + 12 - 4 = 24$
D	$O_D = 8 + 0 + 4 = 12$

B would exchange with C. The externality that C caused for A (either, -8 , y_C , or -24 , in our examples) was then taken as A's conflict payoff. However, power dependence theory as such offers no guidance in the determination of 'what happens in the rest of the network'. It is an important question however, since the externality effects an actor experiences will generally differ, depending on what happens in distant parts of the network. A solution is to opt for the 'worst case scenario'. For instance, if an actor experiences positive externalities from another actor, but can't be sure this other actor exchanges, one chooses not to include the positive externalities in the first actor's payoffs. Note how the generalized core solution *does* itself offer an answer to this problem: an actor's characteristic value is the value an actor can maximally *guarantee* herself, i.e. the worst case scenario.

3. Exchange resistance theory

Exchange without externalities

Heckathorn (1978; 1980; 1983) developed a theory of the bargaining process in bilateral bargaining situations, in which the concept of *resistance* was introduced. In this theory, an actor i 's resistance R_{ij} to an outcome y_{ij} is defined as

$$R_{ij} = \frac{y_{ij}^{\max} - y_{ij}}{y_{ij}^{\max} - y_{ij}^{\text{con}}},$$

in which $y_{ij}^{\max}$ is the maximum profit actor i can obtain in exchange with actor j . The theory claims that actors i and j agree at the point where their resistances are equal, i.e. where $R_{ij} = R_{ji}$. This point is called the point of *equiresistance*. The resistance concept was subsequently introduced to

network exchange by Willer and Anderson (1981). Through time, many different variations of applications of the equiresistance principle to exchange networks have sprung up (see Willer 1999, for an overview). To make the discussion in the current section comparable to the one in the previous, we choose simply to replace the equidependence principle from that section with the equiresistance principle. That is, we determine the exchange-resistance solution for a network, by requiring that mutual resistances in all relations in the network be equal. More formally, we require that $R_{ij} = R_{ji}$, for each connected pair of players i and j . The same approach was taken by van Assen (2003).

To illustrate how this equiresistance principle operates in exchange networks without externalities, we once more consider the Line4 network of Figure 1b. Assume that A exchanges with B and C with D. The expressions for the conflict payoffs, maxima, resistances and the equiresistance principle for these relations are given in Table 9. The maxima for all the actors in the network are 24: the size of the pool to be divided.¹¹ The determination of the conflict payoffs is identical to Table 5 in the previous section. Computing the actors' resistances and setting them equal within the A–B and C–D relationships yields equations (5) and (6). Solving for y_{AB} and y_{CD} yields $y_{AB} = 9.17$ and $y_{CD} = 14.83$, respectively.¹² This implies $y_{BA} = 14.83$ and $y_{DC} = 9.17$. It remains to check the B–C relationship. According to the computations above, both B and C can earn 14.83 in their best alternatives to each other. Thus, $Y_{BC}^{con} = Y_{CB}^{con} = 14.83$. This means that the sum of the conflict payoffs of actors B and C exceeds 24, the amount to be divided by B and C, if they were to exchange with each other. Similar to the previous section, and again following Cook and Yamagishi (1992), we dub this a *latent relation*. As in the previous section, I assert that in a latent relation the payoff of an actor is the size of the resource pool minus the partner's best alternative, which yields $y_{BC} = y_{CB} = 24 - 14.83 = 9.17$. Moreover, we take the same approach with respect to the maximum payoffs, i.e., the maximum payoff of an actor in a latent relation is the size of the resource pool minus the conflict payoff of the partner in the latent relation. This amounts to simply setting an actor's maximum payoff in a latent relation equal to her payoff in that relation, thereby setting the resistance in a latent relation equal to 0, by definition. Thus, with the payoffs calculated above, we have equal mutual resistances throughout the network. Comparing with the previous section, we see that the equiresistance principle allocates the peripherals A and D a larger payoff than does the equidependence principle.

Table 9. Resistances and equireistance for the A-B and C-D relations in the Line4 network without externalities (Figure 1b)

<i>Relation</i>	<i>Conflict Payoff</i>	<i>Maximum</i>	<i>Resistance</i>	<i>Equireistance</i>
A-B	$y_{AB}^{con} = 0$	$y_{AB}^{max} = 24$	$R_{AB} = \frac{24 - y_{AB}}{24}$	$\frac{24 - y_{AB}}{24} = \frac{y_A}{y_C} \quad (5)$
	$y_{BA}^{con} = 24 - y_{CD}$	$y_{BA}^{max} = 24$	$R_{BA} = \frac{24 - (24 - y_{AB})}{24 - (24 - y_{CD})} = \frac{y_{AB}}{y_{CD}}$	
	$y_{CD}^{con} = 24 - y_{BA} = y_{AB}$	$y_{CD}^{max} = 24$	$R_{CD} = \frac{24 - y_{CD}}{24 - y_{AB}}$	
C-D	$y_{DC}^{con} = 0$	$y_{DC}^{max} = 24$	$R_{DC} = \frac{24 - (24 - y_{CD})}{24} = \frac{y_{CD}}{24}$	$\frac{24 - y_{CD}}{24 - y_{AB}} = \frac{y_{CD}}{24} \quad (6)$

Externalities in exchange networks

Compared to the equidependence principle, the equiresistance principle has one additional parameter: the maximum payoff. We adapt the maximum payoff to the situation of externalities by defining it as the size of the resource pool plus the externalities, *given the exchange pattern under consideration*. Note how the size of the resource pool is fixed, but how externalities might be variable, possibly rendering the maximum payoff variable.

To illustrate how externalities are incorporated in exchange resistance theory we reconsider the example of Figure 1c, with the negative externalities of -8 between A and C. Assume again that A exchanges with B and C exchanges with D. We then get the same payoffs for A and C as in the previous section, i.e. $x_A = y_{AB} = -8$ and $x_C = y_{CD} = -8$. Moreover, the maxima for these actors are $y_{AB}^{\max} = y_{CD}^{\max} = 24 - 8 = 16$: the size of the resource pool plus the externalities, given the exchange pattern. For B and D we have $x_B = 24 - y_{AB}$, $x_D = 24 - y_{CD}$ and $y_{BA}^{\max} = y_{CD}^{\max} = 24$. The expressions for the conflict payoffs, maxima, resistances and the equiresistance principle for these relations are given in Table 10. The computations of the conflict payoffs are identical to the ones in the previous section.

Note how the resistance of actor A is not affected: the externality cannot be avoided, i.e. it results in the subtraction of 8 from all parameters in the resistance equation. As in the previous section, the conflict payoff of actor C is not affected by the externality, since C can avoid it by exchanging with B. However, since C's maximum payoff and payoff in the exchange with D are changing, C's resistance is modified. The resistance of B is changed via the conflict payoff, just as in the previous section on the equidependence principle. The resistance of D is unaffected by the externality. Computing the actors' resistances and setting them equal within the A–B and C–D relationships yields equations (7) and (8). Solving for y_{AB} and y_{CD} yields $y_{AB} = 6.70$ and $y_{CD} = 17.30$, which implies $y_{BA} = 17.30$ and $y_{DC} = 6.70$. With externalities we get: $x_A = -1.3$, $x_B = 17.3$, $x_C = 9.3$ and $x_D = 6.7$. The B–C relation is again latent, since the sum of their total payoffs exceeds 24.

Given the predictions of the equiresistance principle for the Line4 network with and without externalities, we can again decompose the actors' payoffs, by writing them as the sum of the network effect, the externalities effect and the interaction between network and externalities. This is done in Table 11. Comparison of Tables 7 and 11 shows that the equidependence and equiresistance principles differ with respect to

Table 10. Resistances and equireistance for the A–B and C–D relations in the Line4 network, with externalities of –8 between A and C (Figure 1c)

<i>Relation</i>	<i>Conflict Payoff</i>	<i>Maximum</i>	<i>Resistance</i>	<i>Equireistance</i>
A–B	$x_{AB}^{con} = -8$	$x_{AB}^{max} = 16$	$R_{AB} = \frac{16 - (y_{AB} - 8)}{16 - (-8)} = \frac{24 - y_{AB}}{24}$	$\frac{24 - y_{AB}}{24} = \frac{y_{AB}}{y_{CD} - 8} \quad (7)$
	$x_{BA}^{con} = 24 - x_{CD} = 32 - y_{CD}$	$x_{BA}^{max} = 24$	$R_{BA} = \frac{24 - (24 - y_{AB})}{24 - (32 - y_{CD})} = \frac{y_{AB}}{y_{CD} - 8}$	
	$x_{CD}^{con} = 24 - x_{BA} = y_{AB}$	$x_{CD}^{max} = 16$	$R_{CD} = \frac{16 - (y_{CD} - 8)}{16 - y_{AB}} = \frac{24 - y_{CD}}{16 - y_{AB}}$	
C–D	$y_{DC}^{con} = 0$	$x_{DC}^{max} = 24$	$R_{DC} = \frac{24 - (24 - y_{CD})}{24} = \frac{y_{CD}}{24}$	$\frac{24 - y_{CD}}{16 - y_{AB}} = \frac{y_{CD}}{24} \quad (8)$

Table 11. Decomposition of payoffs in Line4 network with externalities of -8 between A and C, according to the equiresistance principle (Figure 1c)

<i>Actor</i>	<i>Decomposition $O_i = O_{iN} + O_{iE} + O_{iE \times N}$</i>
A	$O_A = 9.17 - 8 - 2.47 = -1.3$
B	$O_B = 14.83 + 0 + 2.47 = 17.3$
C	$O_C = 14.83 - 8 + 2.47 = 9.3$
D	$O_D = 9.17 + 0 + 2.47 = 6.7$

their predictions, in both the network *with* and *without* externalities. Moreover, the tables show that the predictions are qualitatively the same, in the sense that they predict a negative interaction effect for the peripheral A and D, and a positive interaction effect of the same magnitude, for the central B and C.

Variable externalities pose no special challenge to the application of the equiresistance principle I have just illustrated. Computing the point of equiresistance for the example of Figure 1d yields $y_A = y_B = y_C = y_D = 12$, which implies $x_A = x_C = 24$ and $x_B = x_D = 12$, which is identical to the prediction of power dependence theory.

Like power dependence theory, exchange resistance theory also predicts changes in the exchange pattern in the example of Figure 1e. Assuming an exchange between B and C, both get a payoff of 12, whereas A and D get a payoff of -24 . This is again the same prediction as the one made by the equidependence principle.

Thus, we see that the equiresistance principle can be equally well adapted to the case of externalities, as the equidependence principle. The unresolved issue of what happens in the rest of the network also exists when considering the equidependence principle. Like power dependence theory, exchange resistance theory offers no guidance in this matter. Choosing the worst case scenario is again a possible solution.

4. Discussion

Caused by the fact that actors share resources, exchanges with externalities are abundant in real life and occur in a wide variety of contexts, such as households, resource dilemmas and collective decision making problems. This paper offers the first theoretical study of externalities in exchange networks. The combined study of exchange networks and

externalities, offers the opportunity of investigating interactions between externalities and the social structure in which they occur.

The analyses from this paper allow three main conclusions about the theoretically expected effects of externalities in exchange networks. Externalities (i) change actors' payoffs, (ii) change the exchange pattern (who exchanges with whom) and (iii) change the relative power distribution across actors, with respect to exchange networks without externalities. Furthermore, I have shown that three prominent theories from the field can be fruitfully adapted to the problem of externalities, and yield predictions concerning the occurrence and magnitude of these effects. These theories have been adapted in such a way, that their predictions for networks without externalities are unaltered, extending the empirical content of these theories.

In addition, some general properties of these theories were investigated.

For core theory, the general proposition was established that the core of a network without externalities, is a subset of the generalized core of the same network with positive externalities. With respect to power dependence and exchange resistance theory, it was shown that their point predictions enable one to theoretically separate the pure effect of the externalities from the effect of the interaction between network and externalities.

The insights gained in this paper have real-world implications. Consider for instance collective decision-making situations. This paper shows that the effects of a process of logrolling on the well-being of third parties depends critically on the interaction between the shape of the policy network and the externalities. Actors that possess a seemingly powerful position in the network might experience a marked decrease in their well-being because of the interaction between network and externalities. Alternatively, the interaction between network shape and externalities might increase their power. Thus, it is insufficient to know only the shape of the policy network and the feasible exchanges in it. This paper argues that externalities play a significant role in determining the eventual outcome, and might even lead to the neglect of exchange relations that would have been used had no externalities existed.

In the examples discussed in this paper, the equidependence and equiresistance principles made qualitatively identical predictions, regarding the effects of externalities. Future research should be aimed at finding networks and externality situations, for which these theories make quantitatively and possibly qualitatively different predictions, concerning the effects of externalities.

One might suggest that core theory has two problems: (i) the (generalized) core doesn't necessarily exist, and (ii) when it does exist, the

solution is not necessarily unique. However, I argue that instead of problems, these are mere characteristics of the (generalized) core solution. The (generalized) core embodies a list of rationality requirements that the solution vector (if any) should meet. If such a vector doesn't exist, but if nonetheless these rationality requirements are thought of as a good model of what is going on in (network) exchange, the outcomes in empirical networks that have no core should be unstable. Bonacich and Bienenstock (1995) indeed find that coreless networks without externalities are unstable. Moreover, it is scientifically unsound to *a priori* demand that a theory always yield a unique prediction in terms of an exact exchange ratio. Such a requirement presupposes that an equilibrium of some kind always exists. This is a statement, however, that should follow from theory, not precede it.

Similarly, the predictions of the equidependence and equiresistance principles: (i) do not always exist, and (ii) when they do exist they are not necessarily unique. Moreover, when using the equidependence and equiresistance principles, one has to make assumptions regarding 'what happens in the rest of the network', to determine the externalities an actor experiences. Neither theoretical principle itself offers a solution to this problem, and it thus remains an unresolved issue. It is, of course, possible to compute *several* solutions, under different assumptions on what happens in the rest of the network, and compare these solutions to outcomes in (experimental) data.

Appendix: proof of proposition 2

Proposition. The (generalized) core without externalities is a subset of the generalized core with positive externalities.

Proof. I prove this proposition by showing that introducing positive externalities in a network doesn't change the characteristic value of individual actors and dyads.

Let i and j be two actors in a network, and let i experience positive externalities from an exchange of j . 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 . Since i experiences the externality only 'with the help of j ', $v(\{i\})$ doesn't change. Let i be capable of exchanging with another actor k . Since i experiences the externality only when j exchanges, and

since $j \in \{i, k\}$, $v(\{i, k\})$ doesn't change. It remains to show that $v(\{i, j\})$ doesn't change. Assume i and j are unconnected. Then $v(\{i, j\})$ remains 0. Now assume i and j are connected. Actor i cannot experience an externality from actor j that springs from an exchange between i and j , since externalities by definition are direct consequences of an exchange experienced by actors not involved in the exchange. Therefore, externalities for i can only be caused by an exchange of j with an actor other than i , which implies $v(\{i, j\})$ doesn't change. Note that only coalitions need to be considered having 1 or 2 actors.

Now assume (y) is a payoff vector *without* externalities, i.e. (y) reflects how actors in the network split the characteristic values of their (two-person) coalitions. Let (x) be the payoff vector *with* positive externalities, that results from (y) . Since the characteristic values of individual actors and dyads don't change because of positive externalities, and $(x) \geq (y)$, any payoff vector (y) that is in the core without externalities is in the generalized core with positive externalities. This completes the proof.

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NOTES

- 1 One could, of course, take another conception of exchange networks, in which coalitions larger than dyads *are* possible. See Simpson and Macy (2001) for an investigation in this direction.
- 2 As an empirical illustration of this kind of externality, think for instance of A and C as two political parties, that have identical points of view regarding two issues, but have opposite priorities concerning them. The negative externality is then caused by the fact that if A reaches a compromise with party B, A gives up her position on the issue that is most important to C. Thus, C thereby loses an ally (A) on an important issue, decreasing the probability of a positive result on this issue for party C. *Mutatis mutandis*, the same holds for A, with the exception that C can not only negotiate with B, but also with party D.
- 3 Dijkstra and van Assen (2006; 2008) report experiments in which these two assumptions are met. Alternatively, one could abstain from assuming transferable utilities and employ the non-transferable utility core solution (see, for instance, Shubik (1982), Friedman (1986), Myerson (1993)). I have chosen to stick with transferable utilities because this solution is most well-known in exchange theory.
- 4 Note how this amounts to stretching the definition of coalition formation in exchange networks. Before, it meant reaching an agreement to exchange between

two connected actors. For the purpose of this example it now also includes the possibility to reach an agreement to abstain from exchange, between unconnected actors. This stretching of the definition of coalition formation becomes unnecessary when we next consider the generalized core, which takes into account only coalitions between connected actors.

- 5 The core of the game of Table 2 actually contains only 1 payoff vector, namely $(y) = (8, 16, 16, 8)$, which implies $(x) = (0, 16, 8, 8)$. If the negative externality becomes larger than -8 , the core is empty.
- 6 As an empirical illustration of this kind of externality, again think of A and C as two political parties that have identical points of view regarding two issues. Moreover, assume they have identical priorities concerning them. The positive, variable externality is then caused by the fact that if A reaches a compromise with party B, C experiences the same increase in utility. *Mutatis mutandis*, the same holds for A, with the exception that C can not only negotiate with B, but also with party D. Thus, since A and C hold the same positions on the issues, and since the issues have the same relative weight to them, an ally for one, is an ally for the other.
- 7 Cook and Yamagishi (1992) introduce an algorithm to compute the point of equidependence throughout the network. I will not use that algorithm here, but use the method of solving systems of simultaneous equations instead. When there is more than one solution, the algorithm of Cook and Yamagishi gives the 12–12 resource split as the solution. When using simultaneous equations, all solutions are found.
- 8 Note how this requirement *does not* imply that the dependences of all actors in the entire network are equal.
- 9 Note how this amounts to assuming Pareto efficiency.
- 10 Note how I drop the second subscript of x_{ij} , because the payoff of actor i is now a function of more than her gains in her exchange relationship with j .
- 11 Alternatively, one could interpret an actor's maximum payoff as the size of the resource pool minus the conflict payoff of the actor's partner. Van Assen (2003) has shown that with this interpretation, the equireistance principle reduces to the equidependence principle.
- 12 There exists a second solution, namely $y_{AB} = 62.83$ and $y_{CD} = -38.84$. However, we dismiss this solution, since actor A gets more than her maximum payoff and actor C gets less than her conflict payoff.

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