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Unequally Valued Exchange Relations*

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Network exchange theory has focused on a simple type of exchange structure in which all the exchange relations are equally valuable. In this paper we relax the usual constraint of uniform relations and evaluate the applicability of current theoretical approaches to structures of unequally valued exchange relations. For this evaluation we draw on experiments that entail three variants of mixed relations in four networks. We examine the fit of theoretical predictions and outcomes with respect to the probabilities of exchange transactions and their payoffs.

How does a structure of exchange relations affect the development of inequalities of power? In the research on this question, an exchange structure is conceptualized as a configuration of opportunities to engage in social exchange, in which power is manifested by inequalities in the ratio of benefits received by actors from their exchanges. To date, a very simple type of homogeneous exchange structure has been examined, in which all of the exchange relations are equally valuable (Bienenstock and Bonacich 1992; Friedkin 1995; Markovsky et al. 1993; Yamagishi and Cook 1992).

Although some of the current theories of network exchange allow the particular value of an exchange relation to enter into the determination of power inequalities, homogeneous networks have been addressed because an exchange structure has been conceptualized as a pattern of opportunities for exchange transactions. Hence, to disentangle the effects of an exchange structure from the effects of the values of exchange relations, researchers have examined homogeneously valued networks. This emphasis on homogeneous exchange structure also may be a product, in part, of the early interest in the application to exchange structures of standard graph-analytic measures of point-centrality (Cook et al. 1983); because most of these measures were not designed to handle valued networks, homogeneous networks may have become a focus of empirical work by default.

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We propose a different conceptualization of exchange structure. An exchange structure is a pattern of relations describing opportunities for exchange transactions, in which each transaction has a particular value. In line with this view, previous work on network exchange concentrated on a special case of exchange structure in order to address hypotheses about certain types of structural effects on the probability of exchange transactions and power development. Presumably the same exchange process is at work in heterogeneously valued networks as in homogeneously valued networks. Hence a general theory of the exchange process should predict patterns of exchange transactions and power inequalities in any exchange network, regardless of the values of the exchange relations.

The scope of applicability of network exchange theory is a concern when it limits, rather than encourages, an understanding of social exchange phenomena. A theory of restricted scope may be preferred to a less accurate but more general theory if the former deals with the great majority of exchange structures that arise in natural groups. Heterogeneously valued networks, however, are ubiquitous outside the laboratory; hence, restricting tests of social exchange theories to homogeneously valued networks seems hard to justify, and the development of exchange theory strictly with regard to such networks appears unduly restrictive. In this paper we relax the usual constraint of uniform relations and evaluate the applicability of current theoretical approaches to structures of unequally valued exchange relations.

The probability of exchange transactions and power inequalities depends not only on the configuration of exchange opportunities, but also on the values of the exchange relations. Consider the hypothetical situation illustrated in Figure 1, involving two sellers and three buyers of automobiles. Bob (B) and Ethel (E) each own a car that they are willing to sell for a minimum of $3,000. Andy (A), Charlie (C), and David (D) are the buyers; each can purchase only one automobile. Andy and Charlie are not interested in Ethel's car, and both are willing to pay up to $4,000 for Bob's car. David is willing to spend up to $4,000 for either Bob's or Ethel's car. Each possible transaction has a potential profit of $1,000, the difference between the minimum acceptable offer to the seller and the maximum acceptable offer from the buyer.

This potential profit can be split in any way between the buyer and the seller. For example, if Andy buys Bob's car for $3,700, Andy has paid $300 less than the value of the car to him, and Bob has received $700 more than the value of the car to him. As we shall see, all theories that make predictions about trading patterns suggest that Bob will sell his car to Andy or Charlie (not to David) at a price close to $4,000 and that Ethel will sell her car to David with no power advantage to either David or Ethel. This prediction, however, would have to be modified greatly if (for instance) David was willing to spend up to $4,500 for Bob's car and could outbid Andy and Charlie. The general point is that both trading patterns and power differences are affected by variations in the value of relations.

EXISTING APPROACHES

Three current approaches to the account of trading patterns and power differences in exchange networks are sensitive to changes in the values of relationships: the core game-theoretic model (Bienenstock and Bonacich 1992), the expected-value model (Friedkin 1995), and the power-dependence model (Yamagishi and Cook 1992). These models predict that, when the structure of exchange opportunities is held constant, the trading pattern and the power distribution among actors will change when the values of the exchange relationships are changed in various ways. In this section we discuss each of these theoretical approaches.[1]

The Game-Theoretic Core Model

Bienenstock and Bonacich (1992, 1993) have used the core model to predict power in exchange networks. The core is a fundamental game-theoretic solution concept for cooperative games, with a scope much greater than that of exchange networks. The model is based on the concept of a characteristic function, which is considered to be the "cornerstone of the theory of cooperative n-person games" (Shubik 1982:128).

Consider a set of players N playing a cooperative game. A characteristic function v assigns to every subset of players S a total payoff $v(S)$ that they can guarantee them-

[1] We do not include approaches that are based on the graph-theoretic power index (GPI) (Lovaglia et al. 1995; Markovsky et al. 1993; Markovsky, Willer, and Patton 1988) because these approaches do not predict a change in the trading pattern and power distribution among actors in an exchange structure when the values of the exchange relationships are changed. Consider a simple triangle in which the A-B and B-C exchange relations have equal values (24 points) and the A-C relation has a considerably lower value (2 points). The GPI values of three actors are equal; so are their probabilities of inclusion under the weak-power probability model. It is obvious, however, that B occupies the most powerful position and that exchange ratios will favor that actor. The various models related to the GPI approach were not designed to handle networks with heterogeneous values and should not be applied to such networks.

This conclusion also holds for a closely related version of these approaches, exchange/resistance theory (Skvoretz and Willer 1993), which employs estimates of the probability of inclusion to make predictions about the distribution of resources in an exchange transaction. Depending on the network, Skvoretz and Willer (p. 817) base these estimates on relative GPI scores or on the probability model of the weak-power approach. With such bases for estimating the probability of inclusion, the relative power of actors in the exchange network is not affected by the values of the relations in the exchange structure. Although exchange/resistance theory currently does not deal with the contributions of unequally valued relations to power development, future versions might be extended to address such relations.

selves regardless of the other players' actions (Kahan and Rapoport 1984:26-27). In network games the characteristic value for any subset of players is their maximum total payoff if the network consists only of the connections among these players. For example, in the network portrayed in Figure 1, $v(\{A,B,C,D\})$ = $1,000 because B can conclude an agreement with only one other position; $v(\{A,B,D,E\})$ = $2,000 because this set could guarantee itself $2,000 in profit if A were to exchange with B, and E with D.

Each game-theoretic solution is based on conceptions of rationality. Three kinds of rationality are commonly distinguished in the coalition literature: individual rationality, coalition rationality, and group rationality (Rapoport 1970:88-90). *Individual rationality* is the assumption that no individual in a coalition will accept less than a player can earn alone. Let x_i be a prospective payoff for player *i*. A payoff vector $x = (x_1, x_2, \ldots, x_n)$ is individually rational if

$$x_i \geq v(\{x_i\}) \text{ for every } i \in N. \quad (1)$$

In other words, no individual can be made to accept less than he or she can be guaranteed through his own actions.

Coalition rationality is the same assumption with respect to coalitions. If *S* is a coalition, then

$$\sum_{i \in S} x_i \geq v(S) \text{ for every } S \subset N. \quad (2)$$

That is, no set of actors will accept less in total than they can earn together in a coalition.

Finally, group rationality is the assumption that the set of all actors, the grand coalition, will maximize their total reward:

$$\sum_{i \in N} x_i = v(N). \quad (3)$$

The core is the set of all payoffs satisfying individual, coalition, and group rationality. Intuitively the core is "the set of all outcomes that leaves no coalition in a position to improve that payoff to all its members" (Shubik 1982:147).

There exist networks and sets of values for which no outcome satisfies all the constraints of the core in Equations 1, 2, and 3; in such cases, the core is "empty." When this happens, no outcome is stable because some pairs of players always will be better off leaving their current partners (if they have any) and trading instead with each other. Bonacich and Bienenstock (1994) have shown that usually, in these circumstances, no single trading pattern is able to establish itself; the trading patterns may change from game to game. In most games with cores, on the other hand, a single trading pattern can succeed in establishing itself in a group so that the pattern does not change from game to game.

The Power-Dependence Model

Yamagishi and Cook (1992) propose that exchanges occur on terms in which both participants profit equally in comparison to their best alternatives. At this equilibrium point all trading partners are equally dependent on one another. Yamagishi and Cook provide an algorithm for finding the equilibrium state of an exchange system; we find, however, that we can replace their algorithm with a direct solution that is based on an existing game-theoretic solution concept: the kernel. The kernel duplicates power-dependence predictions in those situations in which power-dependence makes a prediction, and it extends the scope of power-dependence to situations that are not covered by Yamagishi and Cook's (1992) approach.

The proposed extension of the power-dependence model does no violence to Yamagishi and Cook's original model. The power-dependence model consists of equations that imply a distribution of power within an exchange pattern: Equations 1 through 4 in Yamagishi and Cook (1992) and an additional equation (6) in their paper that implies particular exchange patterns. We use the first set of equations (1-4 in their paper) to infer the distribution of power within all possible exchange patterns, thus extending their model. Their equations 1 though 4 are identical to the definition of the game-theoretic kernel (Shubik 1982:343). Hence we suggest that the power-dependence model might be represented by the kernel because of the close formal relationship between the two and the greater generality of the latter. We will present predictions for the extended model while indicating those instances in which Cook and Yamagishi have made no prediction.

The kernel can be found as a solution to a set of simultaneous linear equations. To illustrate the kernel, consider again the situation described by Figure 1. Suppose that Andy buys Bob's car and David buys Ethel's car. As a result of these transactions, the actors' profits are the quantities x_A, x_B, x_C, x_D, and x_E. It is assumed that all actors have considered the maximum additional profit they could make (or lose) if they were to transact with their best alternative. Andy has no alternative; thus he is certain to lose x_A. If Bob were to trade with his best alternative, Charlie, he could earn an additional 1,000 - x_B - x_C, the difference between the value of this transaction and what its members are earning under the current trading pattern. If David were to trade with his best alternative, Bob, he could earn at best an additional 1,000 - x_B - x_D. Ethel has no alternative, so she would certainly lose x_E. Equating each transacting pair's potential profit outside their relationships, and taking into account the fact that Charlie makes no profit (x_C = 0), we arrive at the following equations:

$$x_C = 0 \quad (4)$$

$$1{,}000 - x_B - x_D = 0 - x_E \quad (5)$$

$$1{,}000 - x_B - x_C = 0 - x_A \quad (6)$$

$$x_A + x_B = 1{,}000 \quad (7)$$

$$x_D + x_E = 1{,}000 \quad (8)$$

Equation (4) states that Charlie receives no profit because he is left out of any exchange. Equation (5) equates the potential profits or losses for David and Ethel if they were to cease exchanging with one another and instead choose their best alternatives. Equation (6) equates the potential profits for Andy and Bob. Equations (7) and (8) are true when Andy trades with Bob and David with Ethel. The solution to these equations is that Bob receives all the profit in his exchange with Andy (B = 1,000) and that David and Ethel profit equally (D = E = 500).

The power-dependence model predicts exchange outcomes when there is no core.

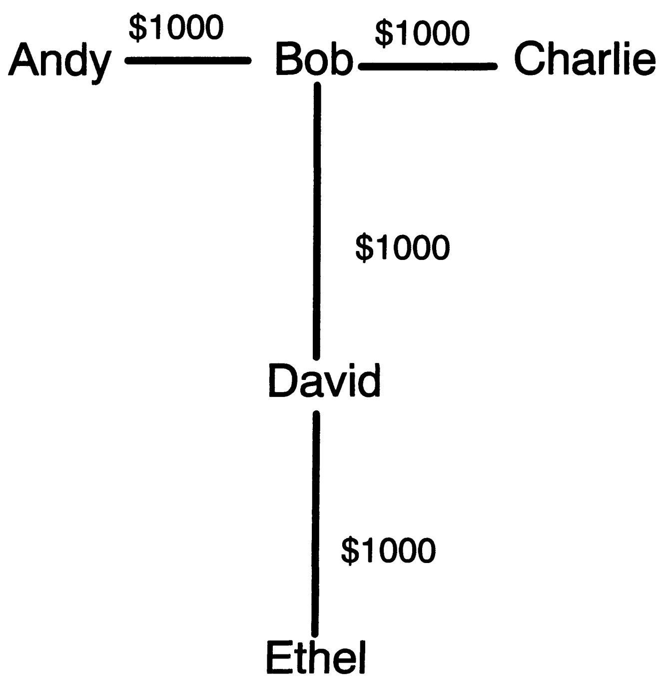

Figure 1. Values of Exchange Relations: A Hypothetical Situation

The power-dependence solution to an exchange network, however, is always within the core for any trading pattern predicted by the core (proof is available on request). This is true, surprisingly, despite the great difference in motivations behind the two approaches. The power-dependence approach equates dependencies between exchanging pairs. The core focuses on the total rewards available to pairs that could trade with each other but do not. Moreover, Equation 6 in Yamagishi and Cook (1992), which states that positions will not trade with each other if they can earn more from alternative trading partners, always implies the same trading patterns as those predicted by the core (proof is available on request).

The Expected-Value Model

The expected-value model (Friedkin 1993, 1995) describes an iterative process of social exchange in which probabilities of exchange affect actors' bargaining positions and payoffs, these payoffs affect the probabilities of future exchange transactions, and so on.

$$V_t = f(p_t) \quad (9)$$

$$p_{t+1} = g(V_t) \quad (10)$$

for $t = 1, 2, \ldots$, where p_t is a Kx1 vector of probabilities at time t for the K possible patterns of exchange transactions, V_t is an NxN matrix of expected payoffs at time t for N actors from each of their possible transactions, f is a bargaining model describing how the probability distribution for the possible patterns of exchange is related to the payoffs from exchange transactions, and g is a probabilistic model describing how payoffs affect the probability distribution for the possible patterns of exchange. (For details on the probability and bargaining models see Friedkin 1995). At the start of this process, actors are assumed to be uncertain about their preferences for exchange partners, and their initial probabilities of exchange are based on a random sequence of transactions in which the values of possible transactions are ignored.

This iterative process is proposed as a description of an exchange process containing repeated sequences of exchange transactions: for example, in the repeated trials of an exchange experiment on the same group. In this respect, the expected-value model differs from the game-theoretic core and power-dependence models: Those models were not intended to describe the processual features of the exchange process.

METHODS

Four Networks

In this study we require networks in which power and patterns of exchange vary with changes in the relative values of the relationships, and for which the theories make different predictions. After examining a number of networks, we selected the four shown in Figure 2. Capital letters represent positions in the networks; lowercase letters represent the values of the dyadic relations.

These four networks contain three to six relationships; for clarity of exposition and results, however, we used only three parameters — *a, b,* and *c* — to represent the values of all the relationships. Because they provided strong contrasts between the different approaches, we selected the values shown in Table 1 for the relationships.

The Experiment

Our subjects were recruited from the student population of a large West Coast university. These subjects were assigned randomly to positions in an exchange network, sat in separate rooms, and interacted through computer terminals. In the task (common in experiments on exchange networks), connected pairs of subjects bargain over the division of a set number of points, namely the *a, b,* and *c* parameters described in Table 1. On each trial of the experiment, a subject could complete no more than one exchange, and bargained (via offers and counteroffers) with those other subjects to whom he or she was directly tied in the network. A five-minute period of bargaining began after all subjects had presented an initial offer to all those actors to whom they were directly tied.

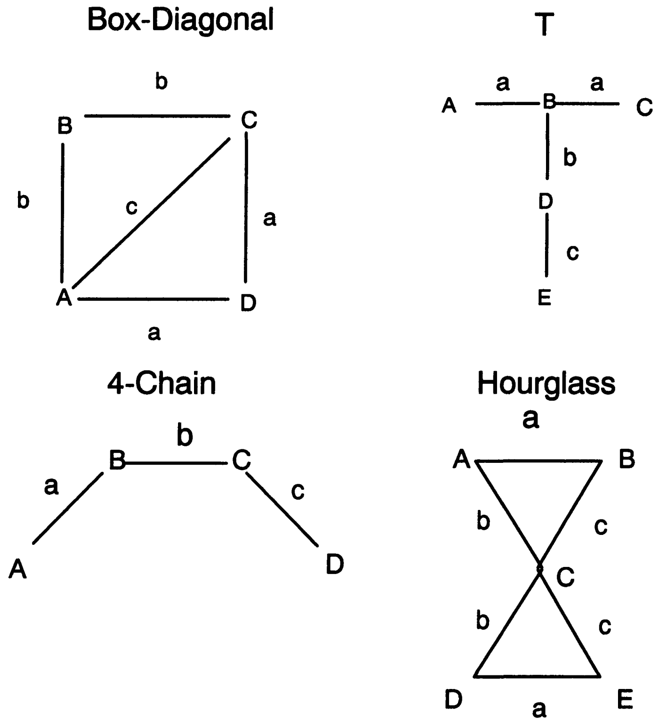

Figure 2. Four Networks

Table 1. Values of Exchange Relations Used in the Experiment

	Values of Exchange Relations		
Networks	*a*	*b*	*c*
Tee			
	6	9	9
	6	12	6
	6	15	3
Hourglass			
	14	8	2
	8	8	8
	2	8	14
4-Chain			
	8	8	8
	6	12	6
	4	16	4
Box-Diagonal			
	8	8	8
	6	6	12
	4	4	16

As bargains were struck, the subjects who had agreed on a division of the value of their relationship were eliminated as potential bargaining partners. A trial was completed when all feasible bargains had been struck or when the five minute "offer and acceptance" period had passed. Subjects were not aware of the form of the network, nor of their positions within it. During these trials, subjects held fixed positions.

Because of scheduling problems, we ran a different number of groups on each of the networks: tee (16), hourglass (15), 4-chain (16), and box-diagonal (20). With few exceptions, each of these groups completed 30 trials of the experiment. Many aspects of the experiment were designed to limit the possible effects of subjects' preferences for equity. This preference would have taken the form of either an equal division of the points within an exchange or equality of payments in the course of the entire experiment. That the subjects knew nothing of the shape of the network, their position within the network, or the other players' earnings should have inhibited the effects of any desire for equality in earnings over the entire experiment.

We did not use two other methods that have been employed to reduce the effects of subjects' desire for equality. Cook et al. (1983) devised an experiment in which subjects did not know how much their partners in an exchange were earning. This feature, however, has not become part of the standard design for social exchange experiments. The NET group (see, for example, Markovsky, Willer, and Patton 1988; and Markovsky et al. 1993) rotate subjects through all positions in the network during an experiment. Random assignment of actors to fixed positions accomplishes the same purpose, however, as does rotation of subjects through positions; we chose not to risk the possible artifacts that might be introduced by this procedure, such as subjects' efforts to compensate for previous disadvantaged positions in the structure. Yet the fact remains that our results may have been affected by subjects' desire for equality despite our best precautions.[2] The results should be interpreted cautiously in this light.

FINDINGS

Predictions and Experimental Results Concerning Trading Patterns

All three approaches predict trading patterns as a function of the values of relationships. The predictions of the core and the power-dependence models on trading patterns will always be identical because, as mentioned earlier, the power-dependence model contains an assumption implying that outcomes will be in the core. Figure 3 shows the predictions of the models and the proportions of selected trading patterns in the experiments. For all four networks, the differences between the three experimental conditions are significant at the .05 level.

The proportion of B-D exchanges in the tee network. The experimental data indicate that the proportion of B-D exchanges increases and then decreases as the value of the B-D exchange increases relative to the other relations. All theories predict an increase. No theory, however, is particularly effective in predicting the form of the relation. The core and power-dependence approaches predict a much more dramatic increase than we actually found. The expected-value approach somewhat underestimates the actual proportion of B-D exchanges.

The proportion of A-B/D-E exchanges in the hourglass network. The experiment shows a regular decline in the proportion of A-B/D-E exchanges with an increase in the value of two of the exchanges involving the middle position C. This pattern is predicted by all theories. The core and power-dependence approaches, however, predict a much sharper decline than actually occurred. The predictions of the expected-value approach are more consistent with the observed proportions than are the predictions of the other two approaches.

The proportion of B-C exchanges in the 4-chain network. We find more B-C exchanges as the value of the B-C relation increases, although the entire effect occurs between the first two values. The power-dependence approach and the core overestimate the effect. Some B-C and A-B/C-D exchanges occur, even when they are not "rational." The expected-value approach underestimates the effect of increases in the value of the B-C exchange, although less severely than the core and power-dependence approaches overestimate it.

The proportion of A-C exchanges in the box-diagonal network. The experimental

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[2] Our findings, however, suggest indirectly that equity effects are modest except in one instance, which we will discuss. Our experimental design produced substantial inequalities within certain exchange networks (an outcome that is inconsistent with strong equity effects). Also as we will show, the expected-value model is reasonably successful in predicting these inequalities. If equity effects were dampening inequalities, then the expected-value approach should have overestimated the degree of inequality within relations; such was not the case, however.

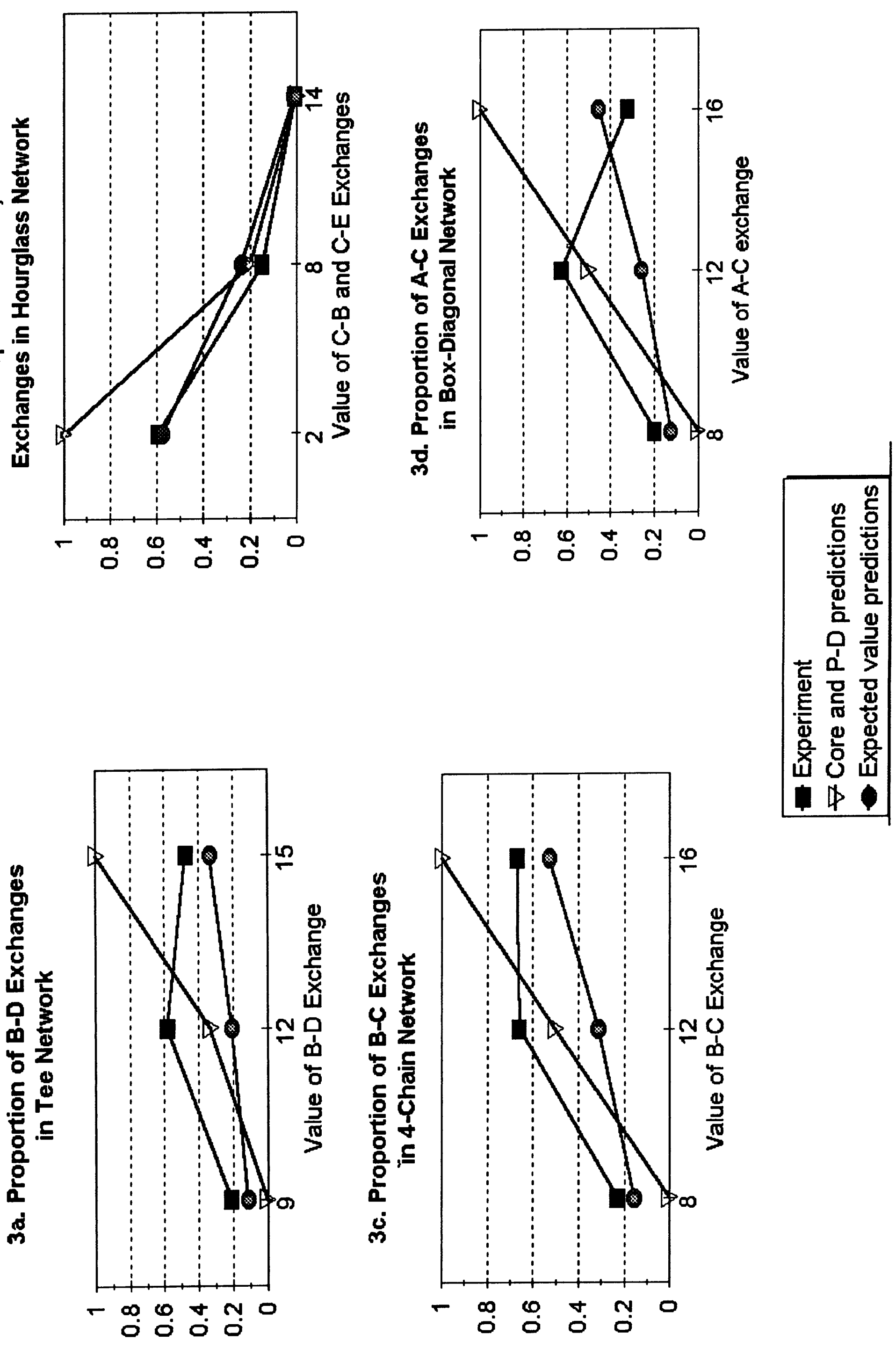


Figure 3. Proportions of Selected Trading Patterns in Experiments

data show an irregular pattern not predicted by either theory: When the A-C exchange is worth a great deal, groups avoid it. All theories predict instead a monotonic increase in the proportion of A-C exchanges as its value increases.

Predictions and Experimental Results Concerning Power

The expected-value approach predicts power outcomes for all trading patterns. As described previously, we have extended the power-dependence approach so that it also predicts power in all trading patterns, not only those patterns which it predicts will occur. The core cannot be extended to predict power in trading patterns that it predicts should not occur. Furthermore, in some cases, the core predicts a range of power outcomes rather than one specific value.

Figure 4 shows the predictions of the models and our findings on the power of positions. In these figures the power of one position over another is measured by the proportion of the reward earned by the former position when it trades with the latter. Thick vertical lines show the ranges predicted by the core. There are three instances in which we extended the power-dependence approach via the kernel: the power-dependence point estimate is based on the kernel in Figure 4a for B-D exchanges that have a value of 9, in Figure 4c for B-C exchanges that have a value of 16, and in Figure 4d for A-C exchanges that have a value of 16.

Power of B in B-D exchanges in the tee network. The value of the B-D relation has no effect on the power of B in the experiments. The expected-value approach predicts this lack of relation. The power-dependence approach and the core predict an effect that does not exist. The results are consistent with the ranges predicted by the core.

Power of C in exchanges with A or D in the hourglass network. The treatment effect is significant at the .01 level. Both the power-dependence and the expected-value theory correctly predict the direction of this effect. The power-dependence predictions seriously overestimate the effect. The expected-value predictions are close to the observed outcomes, except in one case.

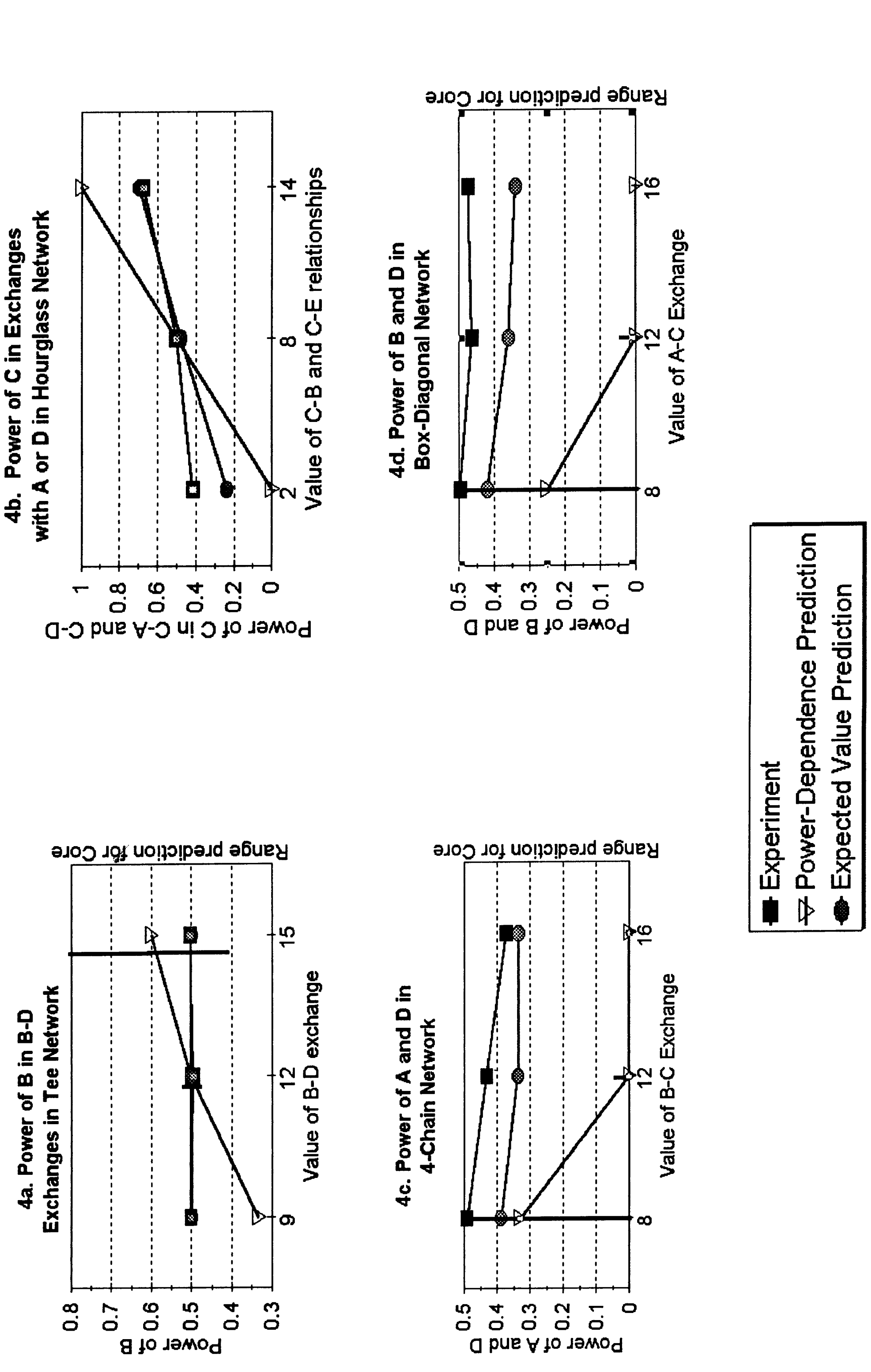
Power of A and D in the 4-chain network. The observed modest decline in the power of A and D accompanying an increase in the value of the B-C relation is not statistically significant. The expected-value model predicts a slight effect. Both the power-dependence and the core model predict much larger effects than appear in the data.

Power of B and D in the box-diagonal network. The observed differences in power are small and statistically insignificant. The expected-value predictions underestimate the power of B and D but are clearly more consistent with the results than are the power-dependence and core predictions.

DISCUSSION

In this paper we make two contributions to the literature on exchange networks. First, we show that the power-dependence model (Yamagishi and Cook 1992) is a special case of a game-theoretic model known as the kernel. Second, we show that network exchange theory can be applied to exchange structures in which the values of exchange relationships are mixed; in doing so, we break out of an experimental paradigm that has characterized network exchange research for the past several decades. Although current theoretical approaches clearly are applicable to heterogeneously valued exchange networks, we still have much to learn about network exchange phenomena in such networks. As evidence, we point to three of our results: discrepancies between the theories and the data in predicting trading patterns and exchange outcomes.

First, it appears that subjects resist the development of trading patterns in which many of their available trading partners are excluded from exchange. In the box-diagonal network, fewer A-C exchanges occurred when the A-C relation was worth four times the other relations than when it was worth twice the others. This odd result may have occurred because equity issues were forced to the front under this set of conditions. Even though subjects did not know the values of all the relationships in the network (but only those with which they were directly involved), subjects in positions A and C may have surmised that other relationships were


4a. Power of B in B-D Exchanges in Tee Network
Power of B
Value of B-D exchange
Range prediction for Core
4b. Power of C in Exchanges with A or D in Hourglass Network
Power of C in C-A and C-D
Value of C-B and C-E relationships
4c. Power of A and D in 4-Chain Network
Power of A and D
Value of B-C Exchange
Range prediction for Core
4d. Power of B and D in Box-Diagonal Network
Power of B and D
Value of A-C Exchange
Range prediction for Core
Experiment
Power-Dependence Prediction
Expected Value Prediction

less valuable than theirs. When, in the box-diagonal network, the A-C relationship was worth four times the other relations, the A and C positions would have had to trade with the other disadvantaged positions more frequently to achieve some internal standard of equity. Some such thinking may have encouraged subjects in the A and C positions to be more inclusive even when their relationship to each other had the highest value.

Perhaps it is time to extend social exchange models to include not only heterogeneously valued relations, but also equity effects. Equity effects have been viewed as confounding the study of structural effects, but they may be worth including as part of the specification of a general social exchange model.

Second, current theoretical approaches do not provide a highly accurate account of trading patterns in heterogeneously valued networks; in comparison, we have become accustomed to dealing with high levels of accuracy in homogeneously valued networks. The core and power-dependence models tend to overestimate the probability of exchange transactions. The predictions of the expected-value model, although closer to the observed values than those of the core and power-dependence models, leave much room for improvement.

Third, the core and the power-dependence approach overestimate the degree of inequality within relations. The predictions of the expected value model provide a substantially more accurate account of the inequalities in power that emerged in these networks; this approach, however, often underestimates the power of positions.

In short, our findings suggest that we should not be complacent about the current status of social exchange theory, that the field concerned with network exchange phenomena is wide open, and that no single theory currently dominates the theoretical scene. The pursuit of a theory of social exchange that can account accurately for trading patterns and power development in heterogeneously valued networks should be a high priority for the field — not only because such networks are ubiquitous, but also because the study of such networks is likely to help us understand more fully how exchange patterns and power generally develop in exchange networks. Through the study of such networks, we may even discover that we did not have a proper theoretical understanding of the simple homogeneous networks that have received so much of our attention.

Advances have been made in network exchange theory by research addressing the effects of structural variation on trading patterns and power inequalities among actors in homogeneously valued networks. These advances include work from various theoretical perspectives: the game-theoretic core model, the expected-value model, the power-dependence model, and models based on the graph-theoretic power index (GPI). We suggest that it is time to break free of the research paradigm that stimulated these advances and to examine a wider spectrum of exchange structures, including those in which the values of relations are unequal. We fear that the field will become increasingly technical, esoteric, and eventually moribund if it does move beyond this paradigm and attempt to increase the scope of social exchange theory.

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