Reciprocity in Marital and Social Networks: Illustration with Indian Data

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Abstract Three measures of reciprocity, denoted s_2, s_3, and s_4, that are applicable to both simple and weighted networks are considered here. By reciprocity I mean symmetry or mutuality of ties between different vertices of the network. These measures have simple formulas except in some extreme situations and can be used for most networks. Among the three measures, s_2 is generally preferred, although the choice in any situation depends on the validity of the assumptions underlying its derivation and its discriminating power. I illustrate how reciprocity in the network of marital exchanges between different surnames and settlements can reveal something about the structure of a population. Reciprocity is higher if the endogamous group is close-knit, is well settled in a smaller geographic area, and has a low surname diversity index. Thus reciprocity is high in the Vadde, somewhat high in the Pattusali, and low in the Yanadi. Although s_2, s_3, and s_4 measure reciprocity in a network as a whole, the local reciprocity index can be used to see how reciprocally a particular vertex is tied to others and can help in the study of the direction of the exchanges. The low local reciprocity indexes of the neighborhood settlements of the Yanadi in some regions indicate that the settlements are involved in one-way marital exchanges with other settlements. The study of reciprocity can be relevant in other contexts also. High reciprocity in a well-settled population was also observed in the social networks of 21 villages with respect to the "help" relation. It was found that reciprocity is highly negatively correlated with the percentage of migrants in the village but does not show high positive or negative correlation with other demographic, socioeconomic, and location characteristics of the villages.

Every human population is characterized by a unique structure, which is reflected in the pattern of relationships between groups or individuals. The type, extent, and magnitude of the relationships depend on social, cultural, demographic, and ecological factors. The study of these patterns and their biolog-

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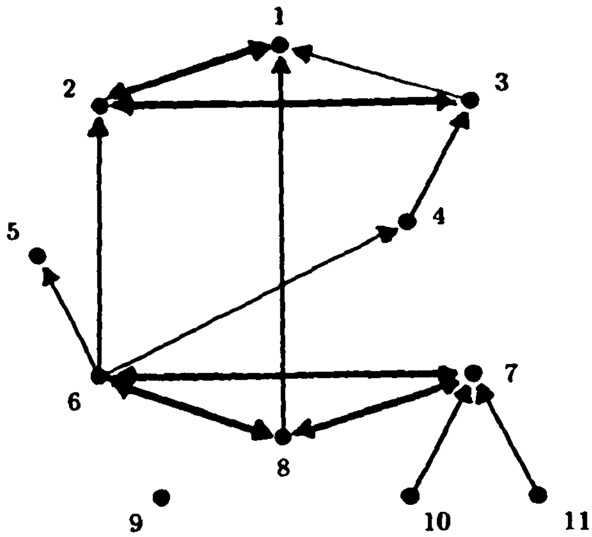

Figure 1. A simple network.

ical (genetic) consequences in different human populations is a main focus in anthropological genetics. Several methods have been developed to study the pattern of these relationships. For example, the bioassay of genetic kinship (Morton et al. 1971), the isonymy method (Lasker 1977; Crow 1980), and the migration matrix method (Cavalli-Sforza and Bodmer 1971; Devor 1988) are frequently used to study population structure and its genetic consequences. Another technique that can be used is network analysis. Here, I illustrate the use of one aspect of the network of relationships, namely, reciprocity, for the study of the structure of a human population.

Theory

Any dyadic interaction can be represented by a network or a digraph. A simple network consists of a set V of vertices and a set E of ordered pairs of distinct vertices called arcs. The vertices can be surnames, regions, households, individuals, etc. An arc is an ordered pair (u, v) of vertices such that u interacts with v according to the particular type of interaction being studied. We usually represent networks by diagrams such as the one in Figure 1, where vertices are represented by points and an arc (u, v) is represented by an arrow from u to v. Note that the positions of the vertices in the diagram can be chosen according to convenience and may not have any significance

We can modify the definition of a network to suit the type of interaction being studied. If the interaction is a priori symmetric, we can consider symmetric networks or undirected graphs in which an arc (usually called an edge) is an unordered pair of distinct vertices and is represented by a line without an arrowhead. If there are weights (which can be frequencies or which represent the intensity of the dyadic interactions) associated with the arcs, we consider a weighted network or a multidigraph. We denote the weight associated with the ordered pair of vertices (i, j) by m_{ij}. If m_{ij} is a nonnegative integer, we can draw m_{ij} arcs from i to j. Then m_{ij} is called the multiplicity of (i, j), and we talk of a multidigraph. If a weighted network has n vertices, we can conveniently represent it by an $n \times n$ matrix with the (i, j)th entry being m_{ij} if $i \neq j$ and 0 if $i = j$.

Although many aspects of networks can be studied, I consider only reciprocity (in the sense of symmetry or mutuality) here. Reciprocity refers to the occurrence of the reverse arc $v \rightarrow u$ when $u \rightarrow v$ is an arc. It represents some sort of balance, whereas a one-way tie (an arc $u \rightarrow v$, where $v \rightarrow u$ is not an arc) generally indicates a hierarchical or patron-client relationship. Reciprocity has been studied by sociologists [e.g., Gouldner (1960)], and some statistical measures have also been proposed (Katz and Powell 1956; Katz et al. 1958), but, as will be explained, I did not find these measures to be discriminating in many contexts. So S. Bandyopadhyay and I developed some measures using graph theory, which I present now.

Measures of Reciprocity in Simple Networks. I now describe how to measure reciprocity in a simple network. Reciprocity is obviously indicated by the number of reciprocal pairs, which is denoted by s_0. A reciprocal pair is an unordered pair of vertices $\{u, v\}$ such that both (u, v) and (v, u) are arcs. Note that the value of s_0 for the network in Figure 1 is 5.

Clearly, s_0 needs to be standardized before it can be used to compare different networks. There are two possible approaches here. One is to assume the null model that the observed network is a realization of a random network and to standardize s_0 using its statistical distribution. However, in practice this often leads to the rejection of the null model, and even a relatively small value of s_0 leads to the conclusion that reciprocity is high, especially when the total number of arcs is small. I prefer the other approach, in which the observed value of s_0 is scaled in its possible range:

$$100 \frac{s_0 - \min s_0}{\max s_0 - \min s_0}, \tag{1}$$

where the factor 100 makes the scaled s_0 a percentage. Here, s_0 is the observed number of symmetric pairs and min s_0 and max s_0 denote the minimum and maximum possible number of symmetric pairs. The computation and interpretation of the measure of reciprocity using this approach is easier and more realistic, and so I adopt it here. For a more detailed derivation and comparison of the various measures of reciprocity, see Rao and Bandyopadhyay (1987).

The minimum and maximum values of s_0 depend on the factors whose effect on s_0 one wants to eliminate. The least one can do is to eliminate the effect of the *order* of the network, that is, the number of vertices n. If this is done, min $s_0 = 0$ and max $s_0 = n(n - 1)/2$. Therefore the measure, which is denoted by s_1, is

$$s_1 = \frac{200s_0}{n(n - 1)}. \tag{2}$$

s_1 can take values from 0 to 100, with the larger values corresponding to higher reciprocity. But often this measure, which can be called the density of reciprocal ties, is small, mainly because the number of arcs is small in comparison to $n(n - 1)$ and not because ties are not reciprocated. Because in Figure 1 $n = 11$ and $s_0 = 5$, $s_1 = 9\%$, which is very low.

My concept of reciprocity is that if $u \rightarrow v$ is an arc, then $v \rightarrow u$ is an arc. It is thus usually better to eliminate the effect of the size also, that is, the number of arcs m. Then min $s_0 = 0$ and max s_0 equals the integer part of $m/2$, so the measure, which is now denoted by s_2, is

$$s_2 = \frac{200s_0}{m - \epsilon}, \tag{3}$$

where ϵ is 0 or 1 depending on whether m is even or odd, respectively. Here I assume that $m \leq n(n - 1)/2$, which is usually the case. For the general formula where this condition may not be satisfied, see Rao and Bandyopadhyay (1987). For the network in Figure 1, $m = 18$, so $s_2 = 56\%$.

Sometimes it is more appropriate to eliminate the effect of the out-degrees $d_1, d_2, \ldots, d_n$ of the vertices, where the out-degree of a vertex is the number of arcs leaving it. This may be either because the d_i are artificially kept fixed or because we want to eliminate the effect of the out-degrees since they might be considered characteristic of the vertices. In any case, min $s_0 =$ 0 and max s_0 equals the integer part of $\Sigma\, d_i/2$; thus the measure of reciprocity, which is denoted by s_3, is

$$s_3 = \frac{200s_0}{\sum_{i=1}^{n} d_i - \epsilon}, \tag{4}$$

where ϵ is 0 or 1 depending on whether $\Sigma\, d_i$ is even or odd, respectively. Equation (4) holds under the assumptions that no d_i exceeds $n/2$ and that the dispersion of the d_i is not too much [for precise conditions, see Rao and Bandyopadhyay (1987)]. Going one step further, one can eliminate the effect of both the out-degrees $d_1, d_2, \ldots, d_n$ and the in-degrees $e_1, e_2, \ldots, e_n$ of the vertices, where the in-degree of a vertex is the number of arcs entering it. Now min $s_0 = 0$ and max s_0 equals the integer part of $\Sigma \min(d_i, e_i)/2$; thus the measure of reciprocity, which is now denoted by s_4, becomes

$$s_4 = \frac{200 s_0}{\sum_{i=1}^{n} \min(d_i, e_i) - \epsilon}, \tag{5}$$

where ϵ is 0 or 1 depending on whether $\Sigma \min(d_i, e_i)$ is even or odd, respectively. Equation (5) holds when the d_i and the e_i are not badly conditioned; if they are, one has to find the actual values of min s_0 and max s_0 and put them in expression (1). For the network in Figure 1 the out-degrees of the vertices are 1, 2, 2, 1, 0, 5, 2, 3, 0, 1, 1 and $s_3 = 56\%$. The in-degrees of the vertices are 3, 3, 2, 1, 1, 2, 4, 2, 0, 0, 0 and $s_4 = 83\%$.

In many situations n, m, the d_i, and the e_i are not too badly conditioned, especially when n is not small; if they are badly conditioned, the right-hand sides of Eqs. (3), (4), and (5) can be used as approximations to the true values of the measures s_2, s_3, and s_4.

Because $\Sigma d_i = m$, s_2 and s_3 coincide for most networks. This common value is generally preferred as the measure of reciprocity, although the choice depends on the validity of the assumptions underlying the measure, as explained, and its discriminating power in a given situation. Note that if the out-degrees differ much from the corresponding in-degrees, then s_2 will be small and s_4 will be much larger than s_2. In any case, in general, s_4 is larger than s_2, as can be seen from Eqs. (3) and (5). Perhaps s_2 together with s_4 can give a complete picture. As already noted, for the network in Figure 1, $s_0 = 5$ and the values of s_1, s_2, s_3, and s_4 are 9%, 56%, 56%, and 83%, respectively.

Measures of Reciprocity in Weighted Networks. In the preceding section I discussed how to measure reciprocity in simple networks. I now extend the discussion to a weighted network or multidigraph in which m_{ij} is the multiplicity of the ordered pair (i, j) of vertices. Here, the crude measure s_0 can be taken to be

$$s_0 = \sum_{i<j} \min(m_{ij}, m_{ji}), \tag{6}$$

which reduces to the earlier s_0 if each m_{ij} is 0 or 1. There is no measure corresponding to s_1 here because no upper bound is assumed for each m_{ij}.

The measures corresponding to s_2, s_3, and s_4 are given by the same expressions as before, where

$$m = \sum_i \sum_j m_{ij}, \tag{7}$$

$$d_i = \sum_j m_{ij}, \tag{8}$$

and

$$e_j = \sum_i m_{ij} \tag{9}$$

(we define $m_{ii} = 0$ for convenience) provided that the m, d_i, and e_i are not too badly conditioned. Note that m is the grand total, d_i is the ith row sum, and e_j is the jth column sum of the matrix representing the weighted network. For the modifications to be done in Eqs. (3), (4), and (5) in extreme situations, see Rao and Rao (1992).

Until now we have been studying the problem of measuring reciprocity in the network as a whole. Reciprocity can also be studied locally. For instance, we can take $200r_i/(d_i + e_i)$ as the local reciprocity index of the ith vertex in the sense of s_2, where

$$r_i = \sum_{j:j \neq i} \min(m_{ij}, m_{ji}). \tag{10}$$

The corresponding local reciprocity indexes in the sense of s_3 and s_4 are

$$200\ r_i/d_i \tag{11}$$

and

$$200r_i/\min(d_i, e_i). \tag{12}$$

Such a microlevel analysis of reciprocity helps in classifying the segments of a population according to their level of reciprocity.

Reciprocity can be studied in various networks, including social, marital, and biological interactions. Here, I concentrate on marital and social networks.

Reciprocity of Marital Exchanges

The study of the marital network, especially preferences and proscriptions and the mutual exchange of marital partners either between specific clans, surnames, or kin groups or between villages or regions, is fundamental for the identification of breeding populations, which in the genetic sense refers to the distribution and extent of the gene pool, the basic unit of study in population genetics. Several aspects of the marital network can be studied, such as endogamy and exogamy, breeding isolation, consanguinity, marriage distance, and migration. In this context surname analysis can provide some insight into migration in the past, breeding isolation, etc.

The study of reciprocity of the marital exchanges between different surnames can reveal the existence of hierarchy or differential status among the surnames (which could be due to socioeconomic or cultural preferences) and thus of a sort of selective breeding. Here, reciprocity refers to the equality of m_{ij} and m_{ji}, where m_{ij} denotes the frequency of marriages with the husband's surname i and wife's maiden surname j.

Similarly, reciprocity of marital exchanges between different villages or regions can also be studied. Here, one can visualize the marital interaction partitioned into its endogamous and exogamous components and the exogamous component divided further into the reciprocal and nonreciprocal parts. The degree of reciprocity with respect to surnames, villages, etc. can vary depending on the ethnic, geographic, and cultural backgrounds, numerical strength, migration history, and degree of settlement of the populations concerned and for the same population can also depend on the time period in the process of modernization.

In the context of reciprocity between villages, it is interesting to note that in some communities in northwestern India village endogamy is practically nonexistent and intervillage marital exchanges must have an extremely low reciprocity because whenever there is a marriage linking two villages, a sort of hierarchy develops between the two (K.C. Malhotra, personal communication, 1993). The situation is the opposite in most of the southern Indian population, who at least traditionally not only show preference for consanguineous marriages but also practice village endogamy, the latter reaching as high as 50% in some traditional populations. Thus the degree of reciprocity may vary depending on the population background. To initiate the study of the pattern of this variation, I now look at the reciprocity of the marital exchanges between surnames in each of three endogamous groups in Andhra Pradesh: the Vadde, Yanadi, and Pattusali.

The three populations differ widely in their subsistence economy, sociocultural variables, and marriage pattern. The Vadde are a fishing caste with a distinctive subsistence economy and cultural identity. They are distributed in and around Kolleru Lake in Andhra Pradesh, and they have a restricted geographic distribution. On the other hand, the Yanadi are a tribe in transition from hunting and gathering to a settled agricultural population and, as such, differ in subsistence economy and associated population structural measures in different regions of their distribution—coastal, plateau, and hill-forest. The Pattusali are a small isolate group who migrated from Gujarat 250 years ago and who currently live in Tirupati. Their traditional occupation is weaving sacred threads in temple towns.

Table 1. Frequency of Marriages between Different Surnames among the Vadde

Husband's Surname	Wife's Maiden Surname																
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*Other*	*Total*
1	–	184	69	34	34	116	16	3	10	1	5	1	1	3	0	1	478
2	203	–	74	88	92	70	13	4	2	4	1	18	1	3	3	3	579
3	62	48	–	37	40	5	1	3	0	4	0	3	0	0	1	0	204
4	26	63	31	–	7	23	4	0	1	0	0	0	2	1	0	3	161
5	47	91	42	7	–	31	3	2	0	0	0	2	1	3	2	0	231
6	114	69	14	35	39	–	2	4	0	1	0	11	1	0	1	0	291
7	9	4	1	1	6	6	–	0	1	0	0	3	0	0	0	0	31
8	6	6	5	1	5	7	3	–	0	0	0	1	0	0	0	0	34
9	8	2	0	0	1	0	0	0	–	0	0	1	0	0	0	0	12
10	0	6	3	3	0	2	0	0	0	–	0	0	0	0	1	0	15
11	10	0	0	0	3	0	0	1	0	0	–	0	0	0	0	0	14
12	2	6	0	1	1	5	2	0	0	0	0	–	0	0	1	0	18
13	0	1	0	0	0	2	0	0	0	1	0	0	–	0	0	0	4
14	3	3	0	0	1	0	0	0	0	0	0	0	0	–	0	0	7
15	0	0	1	0	1	0	0	0	0	0	0	0	0	0	–	0	2
Other	9	6	0	1	0	4	0	1	0	0	0	1	0	0	0	–	22
Total	499	489	240	208	230	271	44	18	14	11	6	41	6	10	9	7	2103

These three populations thus provide somewhat varying cultural backgrounds and numerical strength under which the reciprocity of marital exchanges can be studied. For further background material and the basic data on the Vadde and the Yanadi, see Reddy et al. (1987) and Vasulu (1989). Incidentally, isonymy as a technique is not useful in the Indian context because marriage within a surname is practically nonexistent.

The Vadde. Data on marriage frequencies between different surnames among the Vadde were collected and presented by Reddy et al. (1987). I give these data in matrix form in Table 1, where a row represents the surname of the husband and a column represents the maiden surname of the wife. The total number of couples is 2103. The value of the measure of reciprocity s_2 is 87%, which is very high. Here, the *i*th row (resp. column) total is the total number of husbands (resp. wives) with the *i*th surname and indicates the number of males (resp. females) of the *i*th surname available for marriage. Thus one can also consider the measure s_4 obtained by eliminating the effect of the in-degrees and out-degrees on s_0. The value of s_4 is 94%. Thus, on the whole, surnames do not seem to have differential status in the Vadde, at least with respect to marital exchanges. Note that of the 25 surnames the 6 most frequent surnames (those with the largest row totals) account for nearly 92% of all couples, whereas the 9 most infrequent surnames account for less than 1% of the couples and are of non-Vadde origin.

I next checked whether reciprocity of the marital exchanges between surnames changed over time because it is plausible that reciprocity was high when the community was close-knit. With recent improvement in roads, bridges, and other communication facilities, interaction within the community and with other communities has increased along with the geographic extent of marital interaction, and this might have led to less reciprocal exchanges. To study the variation over time, I consider reciprocity among those couples who were married more than 30 years ago and among those who were married less than 20 years ago. The values of s_2 in these two cases are 81% and 84%, respectively. The corresponding values of s_4 are 89% and 91%, respectively. Thus it seems that no significant change in reciprocity has occurred over the last one or two generations.

The Yanadi. For a large population distributed over a wide area the study of pattern, extent, and direction of marital exchanges between clusters of villages or settlements reveals the extent and formation of breeding isolates. The Yanadi are one such population widely distributed in different regions. Data were collected by Vasulu (1989) on a sample of 13 villages located in coastal, island, plateau, and hill-forest regions. The thirteen villages were classified into five regional clusters: CY (Challa Yanadis), IY (insular Yanadis), P1 (upper plateau), HF (hill-forest), and P2 (lower plateau), each cluster having two or three focal or satellite settlements and some neighborhood (Nb) settlements. The marriage frequencies between different settlements are given in Table 2. Note that in Table 2 the number of marriages within each settlement has been ignored.

Reciprocity among the Yanadi can, in principle, be studied at different levels of interaction: between focal or satellite settlements, between focal or satellite and neighboring settlements, between different regions, and between settlements in all regions taken together. However, it is clear from Table 2 that there is little marital interaction between different regions, and the different regional clusters, especially the CY and IY, form breeding isolates within the Yanadi population. Hence reciprocity is studied only between settlements in all the regions taken together and within each region.

The measures s_2 and s_4 of reciprocity between settlements in all the regions taken together are 58% and 88%, respectively. If we consider the five subpopulations formed by the different clusters, the measure s_2 of reciprocity between settlements in each of them is 50%, 48%, 38%, 76%, and 69% for the CY, IY, P1, HF, and P2 clusters, respectively. Thus the between-settlement reciprocity is higher in the HF and P2 regions and lower in the P1 region than in the other two regions. The values of s_4 within each region are not given because the sample sizes are small and there is little variation possible in the network when both the in-degrees and the out-degrees are fixed.

The local reciprocity indexes (in the sense of s_2) of the Nb settlements in the five regional clusters of the Yanadi are 56%, 27%, 42%, 79%, and 67%

Table 2. Frequency of Marriages between Different Settlements among the Yanadi

Wife's Settlement	*Husband's Settlement* *Challa* *1*	*2*	*Nb*	*Insular* *3*	*4*	*5*	*Nb*	*Upper Plateau* *6*	*7*	*Nb*	*Hill-Forest* *8*	*9*	*10*	*Nb*	*Lower Plateau* *11*	*12*	*13*	*Nb*	*Total*
1	–	0	3																3
2	2	–	2																4
Nb	8	5	–																13
3				–	3	4	2												9
4				5	–	0	0												5
5				5	0	–	2												7
Nb				20	2	4	–												26
6								–	0	6									6
7								4	–	2				1					7
Nb								18	13	–									31
8											–	1	1	9					11
9											0	–	0	7					7
10									2		0	0	–	25		1			28
Nb											7	6	13	–		3			29
11															–	0	0	7	7
12														1	0	–	2	13	16
13															0	3	–	5	8
Nb													1		4	28	3	–	36
Total	10	5	5	30	5	8	4	22	15	8	7	7	15	43	4	35	5	25	253

for the CY, IY, P1, HF, and P2 clusters, respectively, showing roughly the same pattern as s_2.

For the study of the reciprocity of marriages between different surnames in the Yanadi, the number of surnames is much larger (compared with the Vadde) (124), although the number of couples is smaller (568). Hence I do not give the marriage matrix by surnames. The values of the measures s_2 and s_4 of reciprocity are 34% and 46%, respectively, which can be described as low to moderate. Because the details regarding when the couples were married were not available, I did not do any further analysis similar to that carried out for the data on the Vadde.

The Pattusali. There are 16 surnames among the Pattusali, and the marriage matrix is given in Table 3. Here the measures s_2 and s_4 of reciprocity are 63% and 72%, respectively, which are moderate to high. As already mentioned, all the families live in a single location, and because data about when the couples were married were not available, no further analysis was carried out.

Table 3. Frequency of Marriages between Different Surnames among the Pattusali

Husband's Surname	*Wife's Maiden Surname*																
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*Total*
1	–	0	0	0	5	0	2	2	0	1	2	0	0	0	0	0	12
2	0	–	0	0	14	1	0	6	3	2	1	1	1	0	0	0	29
3	0	0	–	0	10	1	2	3	3	4	2	0	0	0	0	0	25
4	0	0	0	–	2	0	0	0	0	2	1	0	0	0	0	0	5
5	9	21	13	1	–	0	0	14	3	2	8	1	0	0	0	0	72
6	4	1	2	0	0	–	0	2	0	0	0	2	0	0	0	0	11
7	5	7	3	0	0	0	–	2	2	4	0	0	0	1	0	0	24
8	3	4	5	0	8	5	1	–	5	1	4	0	2	0	0	0	38
9	3	0	1	0	5	0	2	1	–	0	0	0	0	0	0	0	12
10	0	0	1	0	10	1	5	0	0	–	2	0	0	0	0	0	19
11	0	0	2	0	10	4	0	5	0	3	–	0	2	0	0	0	26
12	1	0	0	2	2	0	0	0	0	0	0	–	0	0	0	0	5
13	0	0	0	0	0	0	0	0	0	1	1	0	–	0	0	0	2
14	1	0	0	0	0	0	0	0	0	0	0	0	0	–	0	0	1
15	0	1	0	0	1	0	0	0	0	0	0	0	0	0	–	0	2
16	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	–	1
Total	26	34	27	3	67	13	12	35	16	20	21	4	5	1	0	0	284

Discussion

The reciprocity of between-surname marriages is high for the Vadde, moderately high for the Pattusali, and low to moderate for the Yanadi. Moreover, reciprocity has not decreased among the Vadde over time. Within the Yanadi, reciprocity of between-settlement marriages is much higher in the hill-forest and lower plateau regions than in the insular and upper plateau regions. Can these various differences be explained in terms of the socioeconomic, geographic, demographic, and cultural-historical factors?

The Vadde are a group of fishermen who have settled in their present locations for several generations without much migration or interaction with outside communities; their distribution is restricted to a small area within and on the fringes of Kolleru Lake in Andhra Pradesh. This factor of being a close-knit community favors a high degree of reciprocity. Moreover, although there are 25 surnames, the 6 most frequent ones account for nearly 92% of the population and the diversity index of the frequencies of the surnames (defined as $1 - \Sigma p_i^2$, where p_i is the proportion of couples with surname i) is somewhat low at 0.82. The lower the diversity index, the less freedom there is for choices, leading to a higher chance of links being reciprocated and, as a consequence, to higher levels of reciprocity. The high degree of reciprocity among the Vadde is not surprising in view of these facts.

Although a reduction in reciprocity might be expected with the passage of time, resulting in modernization, this has not happened with the Vadde, probably because, with their restricted geographic distribution, access between villages was already easy and modernization did not change the situation much.

The Yanadi are essentially hunter-gatherers distributed over a much larger area. The Challa Yanadis form an endogamous group and still live the life of hunter-gatherers. The Yanadi in the other clusters, known as Manchi Yanadi, have benefited from developmental activities to varying extents, a few being owner-cultivators, others being agricultural laborers and/or hunter-gatherers. At least in the past and currently, there has been considerable migration between different regions among the Yanadi, and several surnames among them are probably of recent origin. The number of surnames also is much higher relative to the population, and the population is more evenly distributed among them with a high diversity index of 0.96. These factors probably explain the low to moderate between-surname reciprocity among the Yanadi.

The between-settlement reciprocity is higher in the HF and P2 regions and lower in the P1 region than in the other two regions. A somewhat similar pattern is observed for the local reciprocity indexes for Nb settlements also, although here the index for IY is smaller than that for P1. These results can be explained when the type, size, and formation of Yanadi settlements are considered. In the HF and P2 regions the focal and satellite settlements have been recently established by the government under welfare department programs in which Yanadi families from nearby areas (Nb settlements) have been brought to the settlement. These different factions or splinter groups continue to maintain two-way marital exchanges with the earlier original settlements, and this results in higher reciprocity indexes.

In contrast to this situation, the insular Yanadi have been confined to their island for several generations and mostly marry within the island region. Perhaps even more important is the fact that because of patrilineal marriage practice and possibly because of a somewhat high sex ratio, in most of the marriages taking place between the focal or satellite settlements and Nb settlements, females from the Nb settlements marry males from the focal or satellite settlements, resulting in low reciprocity.

The Pattusali are a close-knit community living in a single location, having migrated there many generations ago. Thus perhaps a high degree of reciprocity is expected among them. However, the number of surnames is relatively high and the population seems to be somewhat well distributed among these, with a diversity index of 0.87, which lies between those of the Vadde and the Yanadi. Hence the reciprocity is higher than that of the Yanadi but not as high as that of the Vadde. The data for the three communities are summarized in Table 4.

Reciprocity in Village Social Networks. I now take a brief look at reciprocity of some village networks to illustrate the use of reciprocity in a dif-

Table 4. Comparison of the Three Communities

	Vadde	*Pattusali*	*Yanadi*
Reciprocity (s_2) between surnames	87%	63%	34%
Number of marriages	2103	284	568
Number of surnames	25	16	124
Diversity index of surnames[a]	0.82	0.87	0.96
Geographic distribution	Restricted	Single location	Wide
Nature of subsistence economy	Settled (fishermen)	Settled (weavers)	Varies from hunter-gatherer to owner-cultivator

a. $1 - \Sigma p_i^2$, where p_i is the proportion of couples with the ith surname.

ferent context. Bandyopadhyay and von Eschen (1980) collected extensive data on 21 villages in the Muhammad Bazar block of central West Bengal. In particular, they meticulously collected data on which households are the households to which any given household goes for help in times of crisis, cross-checking their data from the two ends. Thus they had the social networks of each of the 21 villages with respect to the "help" relation, where the vertices are the households and an arc is drawn from i to j if the ith household goes to the jth household for help. Note that these are simple networks.

Some interesting observations Bandyopadhyay and von Eschen (1980) made from the data were that, contrary to popular expectations, none of the households—whether big or small, whether remote or near the market center or along the road, whether predominantly agricultural or not—were closely tied. In fact, the average out-degree was small, between 1.6 and 3.7 in most of the villages. The variation among the out-degrees was also small, with the maximum out-degree being 19 and more than 98% of the out-degrees being less than 7, although the in-degrees varied much more. Bandyopadhyay and von Eschen also found several villages fragmented into small groups, whereas in others there were much larger connected groups. There was a clear hierarchical structure in some villages that was absent in others. In several villages there were large numbers of isolates, that is, vertices with both an out-degree and an in-degree of 0. Bandyopadhyay and von Eschen then wanted to know for each village how reciprocal the help relation was.

As noted, the total number of ties is small compared with $n(n - 1)/2$ for most of the villages, so the measure s_2 is preferred to s_1. Moreover, d_i represents the expansiveness of the ith household and can be considered characteristic of the household. Thus s_3 is also a good measure in this context. In fact, the values of s_2 and s_3 are equal for each of the villages. Similarly, the in-degree e_i represents popularity or influence of the ith household, and so one can consider the measure s_4. I have found that s_3 and s_4 are highly correlated and that s_4 is highly sensitive to small changes in the networks of some villages. Hence I prefer s_3 as the measure of reciprocity. The values of s_3 and s_4 along with a few demographic, socioeconomic, and location parameters of the villages are presented in Table 5.

Reciprocity varies from low to high in the 21 villages. I wanted to find out why it is larger in some villages and smaller in some others. But reciprocity does not have high correlation (positive or negative) with demographic factors (e.g., number of households, number of caste groups, number of kin groups, or even the density of the village), socioeconomic factors (e.g., percentage of households whose principal occupation is cultivation and percentage of labor force engaged in nonagricultural occupations), or location factors [e.g., distance from the road, market, or urban center and distance from irrigation sources (river or canal)]. After looking at various characteristics of the villages, I found that reciprocity is highly negatively correlated with the percentage of households who are migrants (those who have not settled there permanently), the rank correlation coefficient being -0.90 and Pearson's correlation coefficient being -0.83 (Figure 2).

There are, of course, some villages, for example, villages 4, 9, 12, 16, 19, and 20, (see Figure 2) that deviate somewhat from the trend, but these deviations can be reconciled to a large extent by modifying either the measure of reciprocity or the percentage of migrants in a suitable, although ad hoc way using the incidence of isolates or can be explained by their location, etc. Villages 4 and 9 (Figure 2), which lie below the trend curve, are remote and have relatively fewer isolates, whereas villages 12, 16, 19, and 20, which lie above the curve, are near and have relatively more isolates. On the whole, it is the degree of settlement of a population that seems to have the maximum influence on reciprocity. For further details, see Rao and Bandyopadhyay (1987).

The study of reciprocity may be relevant in various other networks, such as those of trade and migration. Another related problem is the study of reciprocity within blocks and reciprocity between blocks when a partition of the vertex set into disjoint blocks is given. For a discussion on this, see Chatterjee et al. (1993).

Conclusions

I have explained how reciprocity in a network, whether simple or or weighted, can be measured and have illustrated its use by applying it to the networks of marital exchanges between different surnames in three populations in Andhra Pradesh and to the social networks of 21 villages in West Bengal. Of the three measures of reciprocity, s_2, s_3, and s_4, usually s_2 equals s_3, and this can be used in preference to s_4, although the choice really depends

Table 5. Reciprocity and Some Other Characteristics of 21 Villages

Village	s_3	s_4	Number of Households	$\bar{d}$	Number of Isolates	Number of Kin Groups	Number of Caste Groups	Agricultural Households (%)	Distance to Road or Market	Households of Migrants (%)
1	33	100	11	0.6	3	5	1	3	medium	27
2	69	93	11	3.5	0	3	1	19	medium	18
3	38	86	13	2.5	0	5	2	0	low	31
4	45	69	38	2.8	4	6	1	0	high	18
5	0	0	67	0.8	8	8	8	34	low	60
6	44	60	71	3.3	1	24	3	20	low	27
7	99	100	91	2.5	0	23	11	33	medium	8
8	6	22	100	3.3	0	11	8	11	low	64
9	31	54	101	3.5	1	35	10	39	medium	24
10	27	46	116	2.4	5	30	10	36	low	33
11	29	58	130	3.3	1	66	14	24	low	30
12	66	88	150	1.6	82	33	13	25	low	31
13	95	98	152	2.6	7	31	15	34	low	12
14	44	77	152	3.0	0	70	14	36	low	27
15	97	98	160	3.2	0	21	12	36	low	9
16	19	46	166	1.6	21	17	24	33	low	59
17	12	22	167	2.2	6	32	16	25	high	40
18	22	33	218	1.6	32	44	15	42	low	44
19	89	99	239	3.7	89	66	11	30	low	27
20	24	45	257	1.6	28	57	15	24	low	52
21	4	17	286	3.5	15	26	15	37	high	48
ρ^{a}		0.91	−0.2			0.0	−0.2	−0.1		−0.9

a. Rank correlation with s_3.

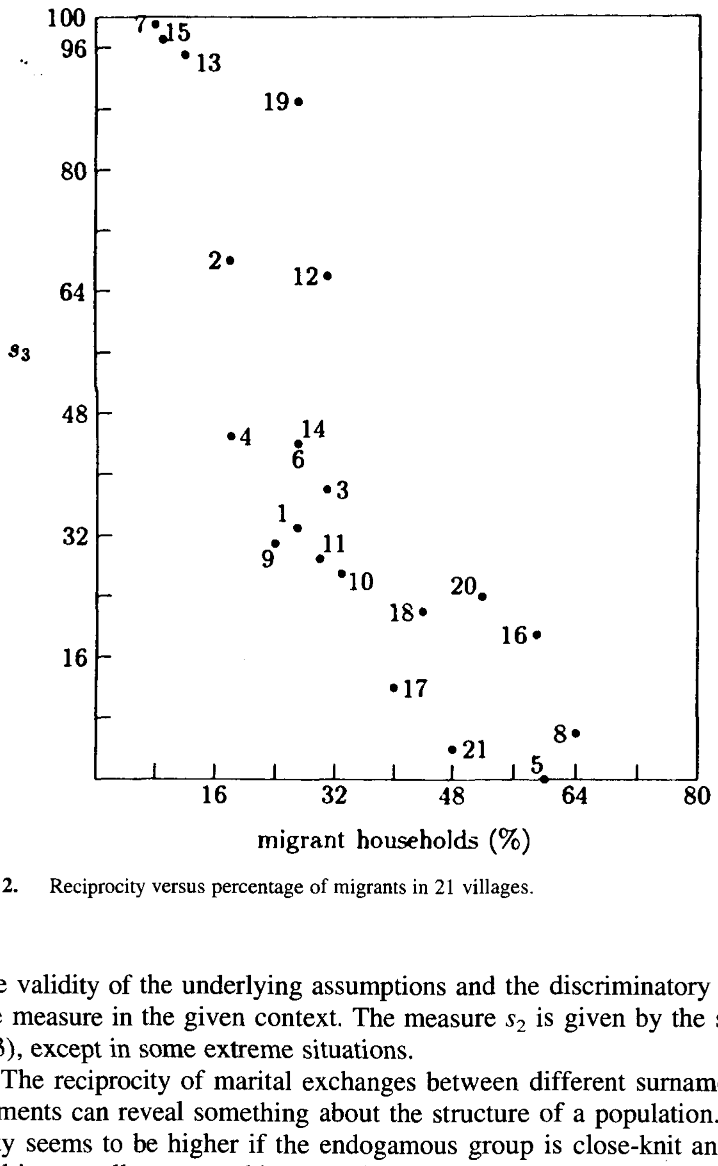

Figure 2. Reciprocity versus percentage of migrants in 21 villages.

on the validity of the underlying assumptions and the discriminatory power of the measure in the given context. The measure s_2 is given by the simple Eq. (3), except in some extreme situations.

The reciprocity of marital exchanges between different surnames and settlements can reveal something about the structure of a population. Reciprocity seems to be higher if the endogamous group is close-knit and well settled in a smaller geographic area with a lower diversity index. Thus reciprocity is high in the Vadde community, moderately high in the Pattusali, and low in the Yanadi. Although s_2 measures the reciprocity in the network as a whole, the local reciprocity index can be used to see how reciprocally a particular element is tied up with others and can help in the study of the direction of the exchanges. The low reciprocity indexes of the neighborhood settlements of the Yanadi in some regions point to the fact that they are involved in one-way exchanges with other settlements.

It was also observed that reciprocity in a social network is high if the population has a smaller percentage of migrants and is thus well settled.

The degree of reciprocity of the marital network can, in general, reflect the degree of inbreeding, particularly of the nonrandom type. This is especially true if the study is more specifically oriented toward finding how often these reciprocal exchanges are of the give-and-take type between specific families rather than between surnames. Then one can consider these reciprocity indexes as directly reflecting homozygosity in a population and test relevant hypotheses. This is especially pertinent because the Hindu caste society with its well-defined social hierarchy has varying concepts of several social units, such as surname and *gotra* (an exogamous unit within a caste whose members claim common descent; *gotras* in some castes are equivalent to lineages), that determine the exogamy rules directing the nature of marital interactions between different sections of a population. However, the concept of surname or *gotra* is different not only between the castes and the tribes but also between upper castes and other middle or lower ranking castes. These differences may be subtly reflected in the pattern of marital exchanges, as has been illustrated in the present study, with implications for the genetic structure of the population concerned. Further well-designed studies should throw light on the exact nature of these implications.

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