Persistent Parochialism:
The Dynamics of Trust and Exclusion in Networks

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Abstract

Networks such as ethnic credit associations, close-knit residential neighborhoods, 'old boy' networks, and ethnically linked businesses play an important role in economic life but have been little studied by economists. These networks are often supported by cultural distinctions between insiders and outsiders and engage in exclusionary practices which we call *parochialism*. We provide an economic analysis of parochial networks in which the losses incurred by not trading with outsiders are offset by an enhanced ability to enforce informal contracts by fostering trust among insiders. We model one-shot social interactions among self-regarding agents, demonstrating that trusting (cooperating without seeking information about one's trading partner) is a best response in a stable equilibrium if the quality of information about one's partner is sufficiently high. We show that since larger and more heterogeneous networks have lower quality information but greater trading opportunities, there is a range of degrees of parochialism for which parochial networks can coexist with the anonymous market.

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1 Introduction

Diffuse social affiliations, such as those arising from residential relationships, 'old boy' networks, and ethnic or religious identity, have received little attention from economists. We will call these *networks*, defined as sets of agents engaged in non-anonymous interactions structured by high entry and exit costs, but lacking a centralized authority. The trust that networks sometimes support, and their contribution to economic performance are often considered to be aspects of social capital (Glaeser, Laibson and Sacerdote 2001, Bowles and Gintis 2001). But this term covers a diverse array of behaviors and structures; our focus here is considerably narrower.[1]

Networks arise in part because people choose to associate with others who are similar to themselves in some salient respect (Lazarsfeld and Merton 1954, Thibaut and Kelly 1959, Homans 1961). Among the salient characteristics on which this choice operates are race and ethnic identification, political orientation, drug use and other forms of deviant behavior, religion and even experimentally induced trivial similarities (Berscheid and Walster 1969, Cohen 1977, Kandel 1978, Tajfel, Billig, Bundy and Flament 1971, Obot 1988). Conversely, people often seek to avoid interactions with those who are different from themselves.

Among the reasons for the persistence of networks is their ability to facilitate to facilitate the informal enforcement of incomplete contracts. Networks manage such common pool resources as fisheries, irrigation, and pasturage (Acheson 1988, Wade 1988a, Ostrom 1990), regulate work effort and risk sharing in producer cooperatives (Whyte 1955, Homans 1961, Lawler 1973, Craig and Pencavel 1992, 1995, Platteau and Seki, 2001), enforce non-collateralized credit contracts, (Udry 1993, Banerjee, Besley and Guinnane 1994) promote neighborhood amenities in residential communities, (Sampson, Raudenbush and Earls 1997) and privately enforce contracts among traders in securities (Baker 1984) and diamond (Bernstein 1992) markets in the U.S., and food markets in Madagascar (Fafchamps and Minten 2001).

Networks often do quite well economically. as the flourishing informal ethnic business linkages among new immigrants to the United States and the United Kingdom attest (Rauch 1996, Granovetter 1985, Kotkin 1993). For instance, Cambodians run more than 80 per cent of California's doughnut shops, raising funds from friends, family, and ethnic credit associations (Kaufman 1995). Similarly, Indians own more than a third of the motels in the United States, frequently raising

[1] The theory of social exchange, initiated in sociology by Blau (1964) and Homans (1958), and in anthropology by Sahlins (1972) provide insights into the economics of networks. For contributions by economists, see Ben-Porath (1980), Hollander (1990), Iannaccone (1992), Kandori (1992), Wintrobe (1995), Greif (1994), Akerlof (1995), Pagano (1995), Bénabou (1996), Durlauf (1996), Kranton (1996), Taylor (1997), and Glaeser (1997).

initial capital through unsecured loans from extended family members (Woodyard 1995).

Among the problem-solving capacities of networks are the powerful contractual enforcement mechanisms made possible by small-scale interactions, notably effective punishing of those who fail to keep promises, facilitated by close social ties, frequent and variegated interactions, and the availability of low cost information concerning one's trading partners. This problem-solving capacity allows networks to counteract the restricted gains from trade and foregone economies of scale due to small size and exclusionary practices.[2] Members, of course, do not normally express their identification with networks in terms of their economic advantages. Rather, they typically invoking religious faith, ethnic purity, or personal loyalty. These sentiments often support exclusion or shunning of outsiders. We model these practices, which we term *parochialism*, in Section 2.

We seek to illuminate the following puzzle: why do parochial sentiments and practices, often identified with archaic social distinctions and intolerance of strangers, persist in modern market-based and liberal societies? Our response, briefly, will be that parochialism is not an anachronistic remnant of the past, perpetuated by inertia, but rather that networks based on parochialism solve economic problems that are resistant to market- or state-based solutions. Persistent parochialism is thus explained at least in part by the problem solving capacities of the network interactions that parochialism underpins. We do not suggest, of course, that the contribution of parochial sentiments and practices to economic performance of groups is the sole reason for their persistence. Ethnic, racial and other group identities arise and persist for a multitude of reasons, many of them far less benign than those studied here. Loury (2001) provides a compelling account of some of these reasons.

The mechanism for the success of networks explored in this paper is their ability to promote *trust*.[3] We consider a large population of agents who, while economi-

[2]The advantages of trade with those deemed "outsiders" is a common explanation of the permeability of network boundaries in small scale societies (Adams 1974) and of the extinction of very restrictive networks in favor of more inclusive entities (Gellner 1985, Weber 1976). A particularly well-documented example of this tension is Greif's (1994) account of how the competitive advantages stemming from the superior within-network contractual enforcement capabilities of the tight-knit 13th century community of Maghribi merchants was eventually offset by their lesser ability to engage in successful exchange with outsiders, resulting in their inability to compete with the more individualistic Genovese traders. Yoram Ben-Porath (1980) develops similar reasoning concerning the economic capabilities of families and other face to face networks:

> The transactional advantages of the family cannot compensate for the fact that within its confines the returns from impersonal exchange and the division of labor are not fully realizable. (p. 14).

[3]Our model develops insights provided by a number of contributions to the sociology of networks.

cally identical, are distinguishable by markers indicating group membership. These agents take three types of actions. First, they locate in one of a variable number of networks, or remain outside any network in what we will call the 'anonymous pool' of traders. Second, they choose strategies that govern their behavior with trading partners. Third, they update these strategies in light of their relative payoff compared to other available trading strategies. We explore the evolution and equilibrium frequency of behaviors within networks, the distribution of population between networks and the anonymous pool, and the size and number of networks, under the influence of parochial practices. We conclude with a series of implications of the model concerning the impact of the evolving information structure of modern economies on the likely future importance of parochial networks.

2 Parochialism and Heterogeneity in Networks

Individuals implement their desires to associate with others like themselves by engaging in what we term *parochial practices*. These practices take the form of refusal to trade with 'outsiders' that, *ceteris paribus*, lower the returns to members of parochial networks. McMillan and Woodruff's (1999) study of trust among businesses in Vietnam suggests the salience of this tradeoff:

> Trading relations in Vietnam's emerging private sector are shaped by two market frictions: the difficulty of locating trading partners and the absence of formal third party enforcement of contracts.…firms able to resolve the difficulties of more specialized production and/or more distant trade grow more rapidly. By contrast, buying from suppliers managed by family members or friends involves fewer contracting problems. (p. 23)

Thus, in some cases, homogeneity may offer advantages offsetting the foregone gains from trade. Parochial communities such as the Pennsylvania Amish and the Canadian Hutterites have expanded their numbers and thrived economically.[4]

Granovetter (1985) writes:

> …social relations, rather than institutionalized arrangements or generalized morality are mainly responsible for the production of trust in economic life. (pp. 490-491)

For additional ways in which networks solve coordination problems stemming from incomplete contracts, see Bowles and Gintis (1998).

[4]See Wilson and Sober (1994) and Kraybill (1989). Hechter (1990) found that two indicators of group homogeneity—common ethnic background and uniform style of dress—were among the few robust predictors of survival of utopian communes established in the late 18th and early 19th century in the United States. He interprets this finding as in part reflecting variable information costs. See also Longhofer (1996) for a model of the relationship between cultural affinity and monitoring costs.

Among the Amish, for example, distinctive dress, dialect, and technology construct a "cultural moat" around the group and, acting as "armaments of defense, they draw boundary lines between church and world [to] announce Amish identity to insider and outsider alike." (Kraybill 1989:50,68). Yet the boundaries erected around Amish culture have not prevented economic success and population growth. Further, the record of successful ethnic business affiliations suggests that parochialism may not only foreclose opportunities, but also contribute to the success of networks.

We model parochialism as a filter on given ascriptive traits of those with whom one might interact, a particular form of parochialism excluding those with 'objectionable' traits.[5] Individuals who do not exclude those with objectionable traits are themselves objectionable, even if their traits *per se* are not objectionable.[6] Thus any parochialism filter different from one's own is assumed to be objectionable so networks will made up of individuals with the same type of parochialism. However different they are in other respects (for example, pursuing different strategies in economic interactions, or differing in a trait not covered by the parochialism filter) they will agree on the common traits for which their parochialism selects.

Suppose in pairwise strategic interactions, agents can condition their actions on whether the other player is an 'insider' or an 'outsider.' Each individual has a certain set of traits (ethnicity, language, physical attributes, cultural or demographic characteristics, and the like), which we take to be fixed. We label these traits $j = 1, \ldots, n$, each individual being characterized by a trait profile $a = a_1 \ldots a_n$, where each $a_j = 1$ or $a_j = 0$ according as the individual does or does not possess trait j. Let A be the set of all possible trait profiles. An individual with traits $a \in A$ may have a 'parochialism filter,' defined as a vector $b \in A$ such that $b \leq a$, in the sense that the individual with traits a also has all the traits indicated by b.

Let us define an individual as *b-parochial* if he has all the b traits, and he trades only with other b-parochial individuals. We also refer to b-parochial agents as *insiders* (the trait vector b being assumed), and we refer to a non-insider as an *outsider*. A outsider is therefore an individual who lacks one or more of the b-traits, or who trades with someone who lacks one or more of these traits, or who trades with someone who trades with someone who lacks one or more of these traits, and so on. In effect, b-parochial agents choose a subset of the traits they possesses (the unit-entries in b that are also unit-entries in a), and consider as insiders exactly those agents who have these traits and are 'like-minded' in the sense that they have

[5] Iannaccone (1992) analyzes a more active form of parochialism, in which membership in a network subject to participatory crowding is restricted to those who are willing to accept "stigma, self-sacrifice, and bizarre behavioral restrictions."

[6] Lazarsfeld and Merton (1954:26ff) term this second order exclusiveness "value homophily" and present evidence for it with respect to racial attitudes: white 'racial liberals' prefer not to associate with white 'racial illiberals' and conversely.

the same criteria for distinguishing between insiders and outsiders. We assume throughout that the property of being b-parochial is common knowledge.

This formalization reflects our view that the immense variety of noticeable individual differences and similarities is the raw material on which parochialism works. A particular b-parochialism makes some subset of these differences behaviorally salient while ignoring others. For instance, suppose the array of traits are ('female','French speaking'). An agent with characteristics $a = 11$ is a female Francophone. Such an individual could be b-parochial for $b = 11$ (insiders are like-minded female Francophones), $b = 01$ (insiders are like-minded Francophones), $b = 10$ (insiders are like-minded females), or $b = 00$ (insiders are like-minded—i.e. they treat all others as insiders).

It is clear from this example that individuals may differ in the extent of their parochialism. As we will see below, these differences will affect both the size and heterogeneity of networks, which in turn will influence the gains from within-network trading. But first we need to formalize the *degree of parochialism* of a network, and the *expected communication difficulty* within a network.

Suppose, for example, there are three salient binary traits, language, nationality, and "race." We define trait profiles so that a person with the trait profile $a = 111$ is French-speaking, European, and "white," while a 000 is non-French-speaking, non-European, and non-white. A 010 person is a non-French-speaking, European non-white, and so on, covering all eight possible trait-types generated by these categories. The *degree of parochialism*, ρ, is a measure of the stringency of an individual's filter, as indicated by the minimum number of ways another must resemble the individual in order to be considered an insider. Thus $\rho = 0$ indicates the total absence of parochialism, while $\rho = 3$ indicates complete parochialism (for the three-trait case), meaning that such individuals will associate only with those identical to them in all three traits. Because networks will be homogeneous with respect to the degree of parochialism, we can speak of ρ as a network trait.

We cannot in general compare the degree of parochialism between arbitrary filters. We can, however, determine which of two filters that differ only in one entry is more parochial. For instance, we cannot say excluding Jews or excluding blacks is more parochial, but we can say that excluding Jews and women is more parochial than simply excluding Jews. By extension, we can compare two filters if their differences can be expressed by a series of such comparisons. In other words, parochialism filters *partially order* the set $\mathcal{P}$ of parochial networks.[7] Given networks $\mathcal{N} \in \mathcal{P}$ consisting of $b(\mathcal{N})$-parochial agents and $\mathcal{M} \in \mathcal{P}$ with $b(\mathcal{M})$-parochial agents, we say $\mathcal{M}$ is *more parochial* than $\mathcal{N}$ if $b(\mathcal{M}) > b(\mathcal{N})$, so every

[7] Formally, a partial ordering $<$ on a set S is a transitive binary relation on S, and a total ordering on S is a partial ordering such that, for any two elements $A, B \in S$, either $A = B$, $A < B$, or $B < A$.

member of $\mathcal{M}$ would be admitted to $\mathcal{N}$.

To explore the impact of the degree of parochialism on the ability of network members to cooperate effectively, we assume that communication difficulty rises with the number of trait differences. Let μ_{ij} represent the *communication difficulty* between individuals of trait types i and j, defined as the number of traits on which they differ. In the three trait case, for instance μ_{ij} can take on the values 0, 1, 2, and 3.

Now consider the communication difficulty arising among randomly paired individuals in networks with a given parochialism filter. Suppose there are m types of agents in the network, where the frequency of type i is $p_i \geq 0$, $i = 1, \ldots, m$. Assuming random pairing of agents, the *expected communication difficulty* is then given by

$$\mu = \sum_{i,j=1}^{m} p_i p_j \mu_{ij}.$$

For instance, continuing our previous example, assume that each of the eight trait types is equally common in the larger population from which the networks are drawn, and the relative frequency of types who are admitted to a network is equal to their relative frequency in the larger population. Then if $\rho = 3$ there are no communication difficulties, as all members of the network have the same three traits, so $\mu = 0$. If $\rho = 2$, by contrast, the network will be composed of equal numbers of two types similar with respect to two traits and different with respect to the other trait. Thus a random pairing will yield pairs with a one-trait difference approximately half the time, yielding an expected communication difficulty $\mu = 1/2$. By similar reasoning $\rho = 1$ yields $\mu = 1$ and $\rho = 0$ gives $\mu = 3/2$. This reasoning is readily generalized to larger numbers of traits and trait groups of unequal size.

We can show that μ is decreasing in ρ on any totally ordered subset of the set $\mathcal{P}$ of parochial networks. Consider a network $\mathcal{N} \in \mathcal{P}$, and suppose there are m types in $\mathcal{N}$, type i occurring with frequency p_i, and consider the more parochial network $\mathcal{M}$ gotten by replacing members of $\mathcal{N}$ who lack a certain previously ignored trait, say trait 1, with agents who possess this trait and have otherwise identical trait profiles as the agents they replace. Then, provided the fraction of agents in $\mathcal{N}$ with trait 1 lies strictly between zero and one, members of the newly constituted, more homogeneous, network $\mathcal{M}$ will enjoy strictly less communication difficulty. To see this, note that before the change an agent had a positive change of meeting and agent with a different value of trait 1, and now has a zero chance. Moreover, no other meeting probability has changed, so communications costs must fall for all agents. It follows that

Theorem 1. Parochialism and Communication Difficulty. *Increasing parochialism in any totally ordered subset of the set of parochial networks $\mathcal{P}$ reduces communication difficulty μ.*

3 The Costs and Benefits of Networks

In this section, we analyze the effect of the degree of parochialism on the information and trading opportunities available to members of a single network, taking as given the composition of and payoffs to members in other networks and the anonymous pool of traders. Theorem 1 shows that level of expected communication difficulty $\mu(\rho)$ is decreasing in ρ on any totally ordered subset $\mathcal{P}^o \subset \mathcal{P}$. We shall assume network size $x(\rho)$ is decreasing in ρ on $\mathcal{P}^o$, for the obvious reason that increased parochialism reduces the pool of potential migrants to the network. We will later examine the manner in which the size $x(\rho)$ of a single network depends on the composition of other networks and the anonymous pool.

Suppose members of any network $\mathcal{N} \in \mathcal{P}^o$ are either *trustworthy* or *untrustworthy* (we model trustworthiness in Section 4). We will call the trustworthy members *cooperators* and the untrustworthy members *defectors*. We will show that for agents trading within a network the quality of the signal $p(\rho)$ is an increasing function of ρ on $\mathcal{P}^o$, and the probability $q(\rho)$ of meeting a partner for mutually beneficial trade is a decreasing function of ρ on $\mathcal{P}^o$. Signal quality $p(\rho)$ is increasing in ρ on $\mathcal{P}^o$ for two reasons. First, more parochial networks are smaller, and smaller networks possess more information concerning each individual. Second, more parochial networks have lower communication costs, leading to a higher likelihood of correctly ascertaining the trustworthiness of potential trading partners. Similarly, $q(\rho)$ is decreasing in ρ on $\mathcal{P}^o$ because more parochial networks have fewer members, and hence each member faces a lower probability of meeting a potentially mutually beneficial trading partner. Moreover, a more homogeneous set of agents is less likely to enjoy complementary patterns of excess supply and demand.

For any totally ordered set of networks $\mathcal{P}^o \subset \mathcal{P}$, we define a *network information structure* $I(x(\rho), \kappa, p_o(\rho))$ with the following properties. Each member of a network of $x(\rho)$ individuals knows the type (cooperator/defector) of κ other members. An individual who seeks to known the type of a specific member j of the network receives informant messages randomly from members of the network, until a message arrives from an informant who knows j's type. The informant's report of j's type is correctly communicated with probability τ, which varies inversely with $\mu(\rho)$. We can then express the probability that the individual receives the correct information, $p(\rho)$ as follows. Let q be the probability of receiving correct information if the agent does not know his partner. Then

$$p = \frac{\kappa}{x} + \left(1 - \frac{\kappa}{x}\right) q \tag{1}$$

$$q = \frac{\kappa}{x}\tau + \left(1 - \frac{\kappa}{x}\right) q. \tag{2}$$

Equations (1) and (2) have the following interpretation. With probability κ/x person j is known to the individual, but with probability $(1 - \kappa/x)$ the individual, not knowing j personally must consult an informant. The informant will know j with probability κ/x and will communicate this successfully to the individual with probability τ. However with probability $(1 - \kappa/x)$ the informant will not know j, and the individual must seek another informant, yielding the recursion expressed above.

Equations (1) and (2) may be solved as:

$$p(\rho) = \frac{\kappa}{x(\rho)} + \left(1 - \frac{\kappa}{x(\rho)}\right) \tau(\rho). \tag{3}$$

Clearly $p(\rho)$ is increasing in ρ, since $x(\rho)$ is decreasing and $\tau(\rho)$ is increasing. Therefore we have

Theorem 2. Parochialism and Signal Quality. *Consider a totally ordered subset $\mathcal{P}^o \subset \mathcal{P}$ of parochial networks, and let $I(x(\rho), \kappa, \tau(\rho))$ be the information structure of a network in $\mathcal{P}^o$. Then the average signal quality $p(\rho)$ on $\mathcal{N}$ is an increasing function of the level of parochialism.*

We model this as a problem of finding partners with whom to exchange goods or services, but an equivalent formulation would model the problem of finding advantageous matchings for some joint production activity, with skill complementarities between demographic groups giving an advantage to more heterogeneous group. To specify the shape of $q(\rho)$ on $\mathcal{P}^o \subset \mathcal{P}$, suppose agents produce goods for trade in the morning, and take them to market for trade in the afternoon. Goods are perishable, and cannot be stored. Suppose there are $x(\rho)$ agents in the network, and there are goods $1, \ldots, k$, corresponding to which there are 'marketplaces' that have exogenously given relative sizes $f_1, \ldots, f_k$ ($\sum_i f_i = 1$). Marketplace i thus has absolute size $x_i = f_i x(\rho)$ for $i = 1, \ldots, k$. The members who are to compose this x_i are assigned randomly at the start of the trading period. Each agent decides to be a buyer or a seller that period. Buyers and sellers in the same marketplace are randomly paired, and if the number of buyers and sellers differ, a random selection of agents will make no trade at all, and as a result trades on the anonymous market, receiving a payoff normalized to zero. Suppose the distribution of individual capacities and preferences differ among groups, so a network composed of many groups will have a greater variance of both preferences and production possibilities than a homogeneous group. To capture the effect of heterogeneity on the probability of trade, we assume that agents of the same type are more likely to be located on the same side of the market. Thus the expected fraction $\psi_i(\rho)$ of agents on the demand side of marketplace i will be distant from 1/2 when networks are very homogeneous, and close to 1/2 when networks are heterogeneous.

The more parochial a network is, the less likely will agents be able to make a trade, for two reasons. First, the more parochial networks will be more homogeneous, so bunching of many agents on one side of the market will happen frequently. Second, even if the expected number of buyers and sellers were equal in every market, the smaller each market is, the more likely will mismatches be on any particular market day. Theorem 3, reflecting this logic is proved in the Appendix.

Theorem 3. Gains to Network Heterogeneity. *Let $q(\rho)$ be the probability of making a trade when network parochialism is ρ. Then $q(\rho)$ is decreasing in ρ.*

4 Trust in Networks

To model the population of traders, consider a game G where many agents are randomly paired to play a one-shot prisoner's dilemma in which each receives c if they both defect, each receives b if they both cooperate, and a defector receives a when playing against a cooperator, who receives d. The assumptions of the prisoner's dilemma then require $a > b > c > d$ and $2b > a + d$ (the latter inequality ensuring that mutual cooperation yields higher average payoffs than defect/cooperate pairs). The coordination failure underpinning the prisoner's dilemma structure of this interaction arises because some aspects of the goods or services being exchanged are not subject to costlessly enforceable contracts. The Defect strategy, for example could represent supplying shoddy goods where product quality is not subject to contract.

We assume that any agent can trade in the anonymous market, the payoff to which we normalize to zero. As agents in this market are unknown to one another, their interactions are effectively nonrepeated, precluding the kinds of informal contractual enforcement that may be possible for interactions within networks. It is reasonable to suppose that the kinds of goods and services traded in the anonymous market will tend to be those for which relatively complete and easily enforceable contracts can be written. Networks, by contrast, may specialize in the exchange of more difficult to contract goods and services.

An agent in a network can refuse to trade with his current partner, in which case we assume he trades on the anonymous market instead. If an agent does trade within the network, the payoffs to mutual cooperation exceed the payoffs available in the anonymous market ($b > 0$) but at the same time the payoffs to mutual defection are inferior to the payoffs of trades in the anonymous market ($c < 0$). This assumption is based on the notion that with incomplete contracting, trading agents expose themselves to a greater level of harm than would be the case with complete contracting. Thus operating within a network is disadvantageous compared with operating in the anonymous market, unless the level of cooperation within the network is sufficiently high.

We assume each agent precommits to following one of three available 'norms.' The first, which we call *Defect*, is to defect unconditionally against all partners. The second, which we call *Trust*, is to cooperate unconditionally with all partners. The third, which we call *Inspect*, is to monitor an imperfect signal based on information provided by other members of the network indicating whether or not one's current partner defects against cooperators. We assume the signal correctly identifies a Defector with probability p and correctly identifies a non-Defector with the same probability p. The Inspector then refuses to trade with a partner who is signalled as a Defector, and otherwise plays the cooperate strategy. Thus when either partner to a within-network exchange refuses to trade, each receives payoff 0 which, according to the reasoning of the previous paragraph, is better than the mutual defect payoff $c < 0$.[8] We assume that the signal is costlessly observed. Assuming a (not excessively large) positive cost of inspecting changes our results in an intuitively expected way, so we abstract from such costs in the interests of simplicity. The payoff matrix for a pair of agents has the normal form shown in Figure 1. We write $G(p)$ for the game with signal accuracy p.

	Inspect	Trust	Defect
Inspect	bp^2, bp^2	bp, bp	$d(1-p), a(1-p)$
Trust	bp, bp	b, b	d, a
Defect	$a(1-p), d(1-p)$	a, d	c, c

Figure 1: The Inspect-Trust-Defect Game

Let α_t, β_t, and δ_t be the fraction of the population playing Inspect, Trust, and Defect at time t, respectively. We assume these are continuous variables. Let π_I^t, π_T^t, and π_D^t be the payoffs to the strategies Inspect, Trust, and Defect at time t,

[8]It is easy to show that other actions available to an Inspector who receives a signal indicating a defecting partner involve either mimicking the behavior of Trusters or Defectors, or else are strictly dominated by playing as indicated above. We thus lose nothing by ignoring such alternatives.

respectively, against the mixed strategy given by $(\alpha_t, \beta_t, \delta_t)$. We find that

$$\pi_I^t = bp(p\alpha_t + \beta_t) + d(1-p)\delta_t \tag{4}$$
$$\pi_T^t = b(p\alpha_t + \beta_t) + d\delta_t \tag{5}$$
$$\pi_D^t = a(\alpha_t(1-p) + \beta_t) + c\delta_t \tag{6}$$
$$\overline{\pi}^t = \alpha_t\pi_I^t + \beta_t\pi_T^t + \delta_t\pi_D^t. \tag{7}$$

where $\overline{\pi}^t$ is the average payoff in the game. Equating the payoffs to the three pure strategies, we find that the Nash equilibrium frequencies $(\alpha^*, \beta^*, \delta^*)$ satisfy

$$\alpha^* = (-adp + b(d(2p-1) + c(1-p)))/D \tag{8}$$
$$\beta^* = p(ad(1-p) - b(d(2p-1) + c(1-p)))/D \tag{9}$$
$$\delta^* = ab(1-p)(2p-1)/D, \tag{10}$$

where

$$D = a(b(1-p)(2p-1) - dp^2) + b(1-p)(d(2p-1) + c(1-p)).$$

We have

Theorem 4. A Trust Equilibrium. *There is a $p_* < 1$ such that for $p_* < p < 1$, $G(p)$ has a unique Nash equilibrium $(\alpha^*(p), \beta^*(p), \delta^*(p))$. In this equilibrium all three types of players occur as strictly positive fractions of the population. The payoff $\pi^*(p)$ in this equilibrium is positive and an increasing function of p, the fraction of Defectors $\delta^*(p)$ is a decreasing function of p, and the fraction of Trusters is an increasing function of p*

To prove the theorem, define

$$p_* = \max\left[1 - \frac{c}{d}, \frac{a}{2b}\left(\sqrt{\frac{4b}{a} + 1} - 1\right)\right]. \tag{11}$$

Note that $p_* \in (0.618, 1)$, since $d < c < 0$ and $a > b > 0$. Then it is easy to show that

$$d(1-p) > c \quad \text{and} \quad bp^2 > a(1-p). \tag{12}$$

for all p such that $p_* < p < 1$. The inequalities in (11) imply that Inspect is a best response to Defect, so mutual defect cannot be an equilibrium, and that Defect is not a best response to Inspect, so a Defect-Inspect equilibrium is precluded. A routine check then indicates that there are no Nash equilibria involving fewer than all three strategies.[9] Hence by Nash's existence theorem, there is an equilibrium of

$G(p)$ involving all three strategies. This proves that p_* has the asserted property. Equations (8)-(9) imply

$$\pi^* = -abd(2p-1)^2/D, \tag{13}$$

so $\pi^*/\delta^* = -d(2p-1)/(1-p) > 0$, showing that payoffs are positive. A tedious calculation verifies that

$$\frac{d\pi^*}{dp} = \delta^{*2}(-d)\frac{b(d(2p-1)+2c(1-p)) + a(b(2p-1)-2dp)}{ab(1-p)^2(2p-1)}.$$

The denominator in the fraction is positive and the numerator can be written as

$$2(b(a-c)-d(a-b))\left(p-\frac{1}{2}\right) + bc - da,$$

which is clearly positive. To prove the final assertion, we calculate

$$\frac{d\delta^*}{dp} = \frac{\delta^{*2}ab(2p-1)^2(1-p)^2}{bc(1-p)^2 + adp(3p-2)}.$$

The denominator in this expression is less than $bc(2p-1)^2 < 0$, from which the assertion follows. ■

The intuition behind Theorem 4 is simple. Consider the simplex

$$T = \{(\alpha, \beta)|\alpha, \beta, \alpha+\beta \in [0,1]\}.$$

By Nash's Existence Theorem there is an equilibrium within T. However Trust is strictly dominated by Defect, and Inspect is strictly dominated by Trust (since Inspectors refuse some profitable trades, while Trusters do not). When the two inequalities (12) hold, Defect is also strictly dominated by Inspect. Therefore all Nash equilibria must be confined to the interior of T. But it is easy to check that there is only one possible candidate, which thus exists and is unique. A phase diagram for the model is presented in Figure 2.[10]

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[9] When the second inequality in (11) fails, but

$$p < \frac{\frac{a}{b} + \left(1-\frac{c}{d}\right)}{1 + \frac{a}{b} + \left(1-\frac{c}{d}\right)}$$

there also is no Nash equilibrium involving fewer than three pure strategies. We will ignore this alterative, for ease of exposition.

[10] We must also check on the dynamic properties of the interior Nash equilibrium. There is no guarantee that this equilibrium is evolutionarily stable. Indeed, the reader can check that for $a = 2$, $b = 1$, $c = -1$ and $d = -2$ the equilibrium is not evolutionarily stable for $p \geq 0.78$, while if we change a to $a = 3$, it is evolutionarily stable. However, evolutionary stability is a sufficient, though by no means necessary, condition for dynamic stability (Gintis 2000):Ch. 10. Therefore we must inspect a plausible dynamic, which we take to be the replicator dynamic (Friedman 1991, Gintis 2000).

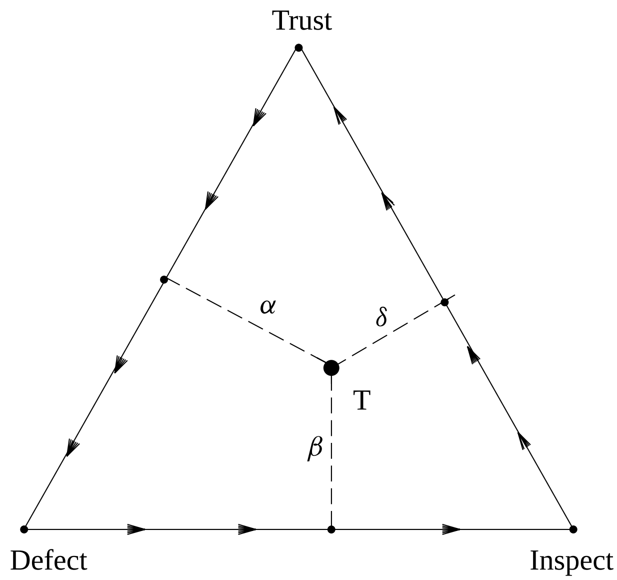

Figure 2: A Simplex Phase Diagram for $G(p)$ when $p_* < p < 1$. The frequency of Inspect, Trust, and Defect are α, β and δ respectively. The trust equilibrium is at T. Note that there are no equilibria along the two-dimensional boundary of the simplex, since each pure strategy can be invaded by another.

The replicator equations are then given by

$$\frac{d\alpha_t}{dt} = \alpha_t(\pi_I^t - \overline{\pi}^t) \tag{14}$$

$$\frac{d\beta_t}{dt} = \beta_t(\pi_T^t - \overline{\pi}^t), \tag{15}$$

reflecting our assumption that norms are implicated in the response to relative payoffs.

We then have

Theorem 5. Stability of the Trust Equilibrium *For $p > p_*$, the unique equilibrium $P = (\alpha^*, \beta^*, \delta^*)$ of $G(p)$ is either stable or paths starting sufficiently near P converge to a periodic orbit of the replicator dynamic. In the latter case, the time averages of the payoffs along the periodic orbit for the three strategy types are all equal to $\pi^*(p)$. Thus in either the stable or limit cycle case, the long-run expected payoff to an agent is $\pi^*(p)$, which is an increasing function of the signal quality p.*

The first assertion follows directly from the Poincaré-Bendixson Theorem (Perko 1991):227, and the second from an ergodic theorem—Theorem 7.6.4 (p. 79) in

Hofbauer and Sigmund (1998). By virtue of this theorem, we will therefore refer to either the stable or limit cycle case as a *stable equilibrium* of $G(p)$.

It is easy to check that when $p < p_*$, there are only All Defect, or Defect/Inspect equilibria, both of which yield negative expected payoff. The first is stable and the second unstable in the replicator dynamic. We assume the network disbands in such cases, so we take $\pi^*(p) = 0$ for $p < p_*$.

5 The Limits of Sustainable Parochialism

The characterization of the equilibrium given by Theorems 4 and 5 allow us now to consider the effects of varying the degree of parochialism on the payoff to network members.

Consider the game $G'(\rho)$, where ρ is the degree of network parochialism, differing from G in two ways. First, the payoff to the prisoner's dilemma stage game is the payoff in G multiplied by the decreasing function $q(\rho)$ (see Section 3) minus a fixed cost $\bar{c} > 0$ of seeking a within-network transaction. Second, we assume the probability p of correctly identifying the type of a potential trade partner is an increasing function $p = p(\rho)$ within any totally ordered set $\mathcal{P}^o \subset \mathcal{P}$ of networks, as per Theorem 2. We call the game $G'(\rho)$ the *variable parochialism network* game.

We assume that there is a degree of parochialism $\rho_{\min}$ on $\mathcal{P}^o$, such that $p(\rho) > p_*$ for $\rho > \rho_{\min}$. Thus there is a stable interior equilibrium for $G'(\rho)$ for $\rho > \rho_{\min}$. The equilibrium payoff in $G'(\rho)$, for $\rho > \rho_{\min}$ is then

$$\overline{\pi}(\rho) = q(\rho)\pi^*(p(\rho)) - \bar{c}, \tag{16}$$

and the equilibrium frequencies of Inspectors and Trusters can be written as $\alpha^*(p(\rho))$ and $\beta^*(p(\rho))$ on $\mathcal{P}^o$, respectively.

The next theorem says that if the number of agents of a particular type are either too small or too large, this type cannot sustain a network equilibrium. This reflects the common observation that networks generally consist of 'minorities, but when insufficiently numerous, such minorities can do no better than operate within the anonymous pool, because trading opportunities become too rare to offset the transactions cost $\bar{c}$ of seeking a within-network trade. Similarly, when the network becomes too large, signal quality becomes too low to support a trust equilibrium. We have

Theorem 6. Equilibrium Network Size. *Let $\mathcal{P}^o \subset \mathcal{P}$ be a totally ordered set of networks, so that each network $\mathcal{N} \in \mathcal{P}^o$ is characterized by a particular parochialism level ρ. For sufficiently small transactions cost $\bar{c}$, there is a nonempty interval $(x_{\min}, x_{\max})$ such that a trust equilibrium that is stable in the replicator dynamic exists if and only if $x_{\min} < x(\rho) < x_{\max}$,* To prove the theorem, we equate $p(\rho)$ in (3) with p_* in (11) and solve for x, which gives

$$x_{\max} = \min\left[\frac{d\kappa(1-\tau)}{c+d(1-\tau)}, \frac{2b\kappa(1-\tau)}{\sqrt{a^2+4ab}-(a+2b\tau)}\right] \tag{17}$$

as the maximum feasible network size for the stage game. Now (16) shows that for sufficiently small $\overline{c} > 0$, equilibrium profits are strictly positive in the variable parochialism game as well. To determine $x_{\min}$, we first find $\rho_{\min}$, the level of parochialism such that expected payoffs in a trust equilibrium are zero (by setting (16) equal to zero and solving for ρ) and then letting $x_{\min} = x(\rho_{\max})$. We illustrate this situation in Figure 3.

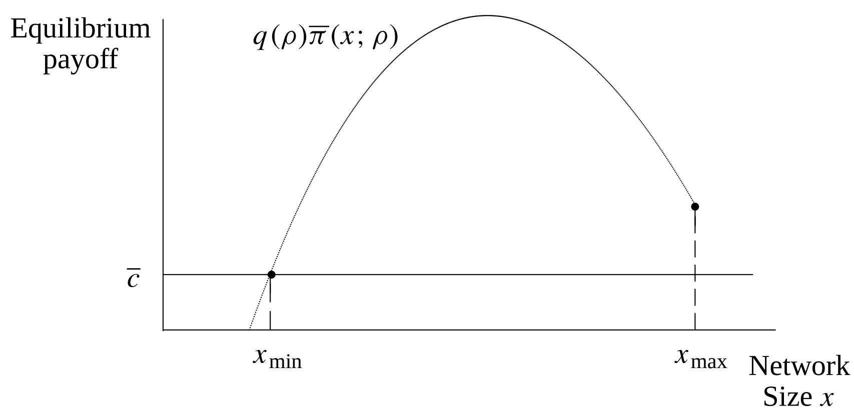

Figure 3: Payoffs in a Trust Equilibrium and Network Size for a Network with a Given Level of Parochialism. Note that $x_{\max}$ is given by (17), and $x_{\min}$ is determined implicitly by the equation $q(\rho)\overline{\pi}(\rho) = \overline{c}$.

Note that it will generally be the case that $x_{\min}$ and $x_{\max}$ differ across totally ordered subsets of parochialism filters. The reason is that one subset may implement large size with little heterogeneity (thus allowing a larger $x_{\max}$ as the information costs of larger size would be partially offset by lesser communication difficulty) while another subset may implement a high level of heterogeneity even for relatively small size. Similarly, if equilibrium payoffs differ across networks (because of different parameters a, b, c, d, τ, κ and $\overline{c}$), $x_{\min}$ will also vary.

6 Parochialism and the Anonymous Market

In our model, individuals not in networks make up the anonymous pool of traders, unconditionally defecting and receiving a payoff normalized to zero. We now study a population-level equilibrium in which agents may migrate among one or more networks and the anonymous pool and they do so when movement would increase their expected payoffs. For simplicity, we assume the cost of movement is zero and that networks accept all immigrants who satisfy the network's parochialism filter. We will identify the conditions under which parochial networks may survive under these conditions.

It is easy to see that if parochialism filters are very coarse such that, given some population composition, a limited range of sizes of groups is possible, it may be that no feasible network falls within the $x_{\min}$ and $x_{\max}$ identified in Theorem 6. Our first condition for the presence of parochial network is that at least one filter be sufficiently fine in the following sense. Since there are n traits, there are 2^n possible trait profiles $a \in A$. Let $f(a)$ be the frequency of profile $a \in A$ in the population, and let $F(a)$ be the fraction of the population that satisfies parochialism filter $a \in A$. We thus have

$$F(a) = \sum_{b \geq a} f(b).$$

For simplicity, we suppose the cost to an agent of moving from the anonymous pool to a network that will accept him is zero, and networks accept all immigrants who satisfy the network's parochialism filter. On any totally ordered subset $\mathcal{P}^o \subset \mathcal{P}$, we can associate the degree of parochialism ρ with a particular parochialism filter $a(\rho) \in A$, in which case we have $x(\rho) = F(a(\rho))$. Moreover, if $\mathcal{P}^o$ is a maximal totally ordered subset, $F(a(0)) = 1$ and $F(a(n)) = 0$.[11] We call a maximal totally ordered set $\mathcal{P}^o \subset \mathcal{P}$ *ϵ-fine* if, for every filter a_N of a network $\mathcal{N} \in \mathcal{P}^o$, there is a network $\mathcal{M} \in \mathcal{P}^o$ with associated filter a_M such that $|F(a_N) - F(a_M)| < \epsilon$. Let X be the size of the population. We then have

Theorem 7. *Suppose there is a ϵ-fine maximal totally ordered subset $\mathcal{P}^o \subset \mathcal{P}$, where $\delta = (x_{\max} - x_{\min})/X$ for $x_{\max}$ and $x_{\min}$ given by Theorem 6. Then there exists a parochialism filter a and a network $\mathcal{N}$ using parochialism filter a that is a stable equilibrium of the replicator dynamic.*

Note that in equilibrium, all members of the population who satisfy the parochialism filter a migrate from the anonymous pool to the network $\mathcal{N}$.

Under the conditions given in Theorem 7, there must exist a filter and a level of parochialism implementing a group size within the given range, which by Theorem 6 supports a stable equilibrium with an average payoff $\overline{\pi} > 0$. If there are no other networks, the network in question will attract all population members conforming to the filter.

[11] This assumes that no agent has all n traits, which will be the case, for instance, if the traits include national origin.

Suppose now that agents can move not only to networks costlessly, but can also move among networks costlessly. We define a *population-level equilibrium* as a set of networks $\mathcal{N}_1, \ldots, \mathcal{N}_k$ such that (a) each network is a stable equilibrium of the replicator dynamic; (b) no individual can gain by moving from the anonymous pool to a network; (c) no individual can gain by moving from one network to another network; and (d) there is no parochialism filter a such that a network based on a could draw individuals from either one of the existing networks or from the anonymous pool. We have

Theorem 8. *Suppose the conditions of Theorem 7 are satisfied. Then there is a population-level equilibrium with at least one network.*

To prove this theorem, let $\mathcal{N}_1$ be the viable network with highest payoff. We know such a network exists by Theorem 7 and the fact that there are only a finite number of possible networks. If (a)-(d) in the paragraph preceding the theorem are satisfied, we are done. If not, (d) must be violated. No additional network can draw members from $\mathcal{N}_1$, since the latter has the highest possible payoff. Among the viable networks that can draw members from the anonymous pool, let $\mathcal{N}_2$ be the one with the highest payoff. If (a)-(d) are now satisfied, we are done. Otherwise only (d) can be violated. We repeat the process until (d) is no longer violated.

7 Conclusion

Networks have properties that allow them to persist in a market economy despite their relative inability to exploit economies of scale and the other efficiency-enhancing properties of markets. Among these properties, and the one explored in this paper, is the capacity of networks to support enforcement of prosocial behavior among network members. Networks have this capacity by virtue of their ability to reduce information costs, thus permitting the emergence of 'trusting' Nash equilibria that do not exist, or are unstable, when information costs are high. Our particular model of these relationships could readily be extended to capture other salient aspects of the determinants of network formation, parochial exclusion, and network extinction. For example, because parochialism makes networks not only smaller, but more homogeneous as well, corresponding efficiency enhancing effects of similarity or social affinity with parochial networks may be important.

The value of the informal contractual enforcement capacities of networks, the viability of networks, the range of viable network sizes, and the range of feasible degrees of parochialism all depend importantly on the nature of the goods and services that make up economic exchanges. Kollock (1994:341) investigated "the structural origins of trust in a system of exchange" using an experimental design based on the exchange of goods of variable quality. He found that trust in and commitment to trading partners as well as a concern for ones own and others' reputations emerges when product quality is variable and non-contractible but not when it is contractible. These experimental results appear to capture some of the structure of actual exchanges. Siamwalla's (1978) study of marketing structures in Thailand contrasts the impersonal structure of the wholesale rice market, where the quality of the product is readily assayed by the buyer, with the personalized exchange based on trust in the raw rubber market, where quality is impossible to determine at the point of purchase. Thus, were technologies to evolve such that quality and quantity of the goods being transacted are readily subject to complete contracting, preferential trading within networks would be of little benefit and would likely be extinguished due to the implied foregone gains from trade. Conversely, were the economy to evolve in ways that heighten the problem of incomplete contracting we would expect to see growing economic importance of networks.

Applying this reasoning to our model, we consider the latter more likely. As production shifts from goods to services, and within services to information-related services (Quah 1996), and as team-based production methods increase in importance, the gains from cooperation will increase as well, because such activities involve relatively high monitoring costs and are subject to costly forms of opportunism. If this is the case the benefits associated with the mutual defect payoff (c) relative to the mutual cooperate payoff (b) will decline over time.[12] Further, advances in communications technology arguably increase the number (κ) of acquaintances from whom we can gather information at limited cost, and increase the intelligibility of messages, especially across cultural, linguistic, or other group boundaries. The result would be to enhance the signal quality (p) for a given degree of parochialism and hence level of network heterogeneity. The following are consequences.

The following are consequences. First, differentiating (13) we find that an increase in b, κ or τ, or a decrease in c, raises the payoff π^* to network members in a trust equilibrium for a given size of network, thus making network membership more

[12] An increase in the cooperative payoff b does not make the standard prisoner's dilemma interaction any 'easier to solve' of course, but it may enhance evolutionary pressures for the emergence of new rules of interaction that effectively mitigate the dilemma. Wade (1987:774-5) describes such a process:

> …a significant number of the villages (in one small part of Upland South India) have institutions for the provision of public goods and services, which are autonomous of outside agencies in origin and operation. …Only a few miles may separate a village with a substantial amount of corporate organization from others with none…Why the differences between villages? It is not because of differences in norms or values, for the villages are located within a small enough area for the culture to be uniform. It is rather because of differences in net collective benefit.

attractive relative to trading in the anonymous pool. Second, differentiating (17) with respect to the same variables we find that the effects of κ, τ, b, c, and x_{max} are of the same sign as for π^*. Thus, better communication or higher payoffs to mutual cooperation relative to mutual defection in the network will increase the largest network size at which the signal quality will support a trust equilibrium. Third, because $\pi^*(x(\rho), \rho)$ is increasing in x at x_{min}, the upward shift in the π^* function reduces x_{min}. The intuition behind this result is that the increase in equilibrium payoffs in the trust equilibrium for a given size allows a network to bear increased costs of forgone trading opportunities occasioned by smaller size, without becoming unviable.

As a result potential networks characterized by parochialism filters which would in the past have resulted in groups either too large or too small to sustain a trust equilibrium may become viable as contract become more costly to express completely and to enforce and as communication improves, and the payoffs to existing parochial networks may rise relative to the payoffs among anonymous traders.

On the other hand the kinds of social exclusion motivating network-based parochialism often violate strongly held universalistic norms and may encounter legal prohibition or other public policies motivated by a positive valuation of both tolerance and diversity of social interactions.

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8 Appendix: Proofs (Not for Publication)

Proof of Theorem 3: At the marketplace for good i, the number ξ_i of buyers and the number χ_i of sellers are independently distributed binomial random variables with means $x_i\psi_i(\rho)$ and $x_i(1-\psi_i(\rho))$ respectively, and variance $x_i\psi_i(\rho)(1-\psi_i(\rho))/2$. The expected number of agents not finding a trade is thus $E[|\xi_i-\chi_i|]$, where the expectation is with respect to the product distribution. Consider a single marketplace, and let $\psi=\psi_i(\rho)$ be the probability an agent is a buyer, given level of parochialism ρ. Let $\tilde{x}$ be a random variable that takes the value 1 with probability ψ and -1 with probability $1-\psi$. The sum of x independent random variables distributed according to $\tilde{x}$ has expected value $x(2\psi-1)$ and variance $4xp(1-\psi)$. We assume $x(\rho)$ large enough relative to k that the normal approximation to the binomial is sufficiently accurate ($x>10$ is enough to ensure this). The excess number of buyers is thus distributed as a normal variate with mean $x(2\psi-1)$ and variance $4x\psi(1-\psi)$. It is easy to check that the probability of obtaining a trade is given by

$$q(x,\psi)=1-\frac{g(x,\psi)}{x},$$

where

$$g(x,\psi)=4e^{-\frac{(1-2\psi)^2x}{8\psi(1-\psi)}}\sqrt{\psi(1-\psi)x/2\pi}+(2\psi-1)x\mathrm{erf}[\frac{(2\psi-1)x}{\sqrt{8\psi(1-\psi)x}}],$$

and $\mathrm{erf}[y]=(2/\sqrt{\pi})\int_0^y e^{-t^2}dt$. We then find that

$$\frac{\partial q}{\partial x}=\frac{e^{-\frac{(1-2\psi)^2x}{8\psi(1-\psi)}}\psi(1-\psi)}{\sqrt{\pi\psi(1-\psi)x/2}(x-g(x,\psi))},$$

which is strictly positive. Thus $q(x,\psi)$ is increasing in x. Since $x=x(\rho)$ is a decreasing function of ρ, q is a decreasing function of ρ *via* its first argument.

The expression for $\partial q/\partial\psi$ is complicated, but has the opposite sign of

$$2e^{\frac{(1-2\psi)^2x}{8\psi(1-\psi)}}\mathrm{erf}\left[\frac{(2\psi-1)x}{\sqrt{8\psi(1-\psi)x}}\right]+\frac{(1-2\psi)\sqrt{2}}{\sqrt{\pi\psi(1-\psi)x}}.$$

By expanding the integral in the erf function, we can show that this expression has the same sign as $(2\psi-1)$ for $x\geq 1$. Thus if increased parochialism increases the average disparity between buyers and sellers in market i, q is a decreasing function of ρ *via* its second argument as well. ■