Membership Size, Communication Activity, and Sustainability: A Resource-Based Model of Online Social Structures

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As telecommunication networks become more common, there is an increasing interest in the factors underlying the development of online social structures. It has been proposed that these structures are new forms of organizing which are not subject to the same constraints as traditional social structures. However, from anecdotal evidence and case studies it is difficult to evaluate whether online social structures are subject to the same problems as traditional social structures. Drawing from prior studies of traditional social structures and empirical analyses of longitudinal data from a sample of Internet-based groups, this exploratory work considers the role of size and communication activity in sustainable online social structures.

A resource-based theory of sustainable social structures is presented. Members contribute time, energy, and other resources, enabling a social structure to provide benefits for individuals. These benefits, which include information, influence, and social support, are the basis for a social structure's ability to attract and retain members. This model focuses on the system of opposing forces that link membership size as a component of resource availability and communication activity as an aspect of benefit provision to the sustainability of an online social structure. Analyses of data from a random sample of e-mail-based Internet social structures (listservs) indicate that communication activity and size have both positive and negative effects on a structure's sustainability. These results suggest that while the use of networked communication technologies may alter the form of communication, balancing the opposing impacts of membership size and communication activity in order to maintain resource availability and provide benefits for current members remains a fundamental problem underlying the development of sustainable online social structures.

(Online Communities; Electronic Groups; Membership; Dynamics; Social Resources)

Networked social environments that rely on computer-mediated communication systems are increasingly common. Public and private sector organizations are investing in infrastructures with the goal of facilitating communication and learning. Empirical and anecdotal evidence indicate that data communications networks, such as the Internet, can create new opportunities for people to interact (Baym 1993, Kraut et al. 1996, Rheingold 1993). Whether public or private, data networks are increasingly sites of social activity. Although their functionality varies widely, these infrastructures all provide facilities that enable multiperson social communication. Each allows individuals to engage in constrained many-to-many communication by broadcasting and receiving messages within a collection of other people. As a result, each of these systems provides the basic communication capabilities needed to support significant social activity.

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To generate many of the expected outcomes, such as improved information sharing and better coordination, telecommunication networks must do more than simply provide facilities for communication; they must also be sites of social structures that support ongoing activity (Finholt and Sproull 1990, Sproull and Kiesler 1990). However, information technology only provides technical infrastructures in which social activity *may* take place (Hagel and Armstrong 1998, Hof et al. 1997). Like a park or a conference room, these systems simply provide a context in which people can interact. Just as providing a room for a reception at an academic conference encourages but does not ensure social interaction, providing electronic infrastructures supports but does not guarantee the emergence of social activity. The availability of a technical infrastructure does not guarantee that individuals will be willing to join and participate in online social structures. Likewise, efforts to attract new members are likely to be wasted if these social structures fail to maintain the membership necessary to provide valuable benefits over a longer term. Although definitions of success vary from case to case, a computer-mediated communication system's ability to support useful social activity is significantly affected by its ability to encourage the emergence of sustainable online social structures; that is, structures that are able to continue providing benefits for members over the long term.

Drawing from studies of traditional small groups, voluntary associations, and organizations, this paper presents a resource-based model of the internal dynamics of sustainable social structures. At the model's core is a feedback loop linking resource availability, benefit provision, and a social structure's ability to attract and retain members. The model is then examined with longitudinal data collected from a sample of electronic mail (e-mail)-based Internet listservs. A set of log-linear, time-series/cross-section regression models is estimated to explore the relationships proposed in the model. Implications for researchers and practitioners interested in online groups and communities are discussed and areas for future research are described.

Resource Availability, Benefit Provision, and Sustainability

The core premise of the resource-based model of social structure sustainability is that, whether traditional or online, to be sustainable social structures must maintain access to a pool of resources and support the social processes that convert those resources into valued benefits for the participants. Social structures are sustainable when they are able to provide benefits that outweigh the costs of membership (Moreland and Levine 1982). Social structures that can provide positive net benefits are better able to attract and retain members, and hence survive over the long term. Traditional social groups and communities provide many benefits for their members, including opportunities for affiliation or companionship (McClelland 1985, Roberts 1998, Rubenstein and Shaver 1980); opportunities to influence people (Winter 1973); social support (Wellman and Whortley 1989, 1990; Wellman 1990); access to information; the ability to disseminate ideas rapidly (Kaufer and Carley 1993); and support for collective action (Ostrom 1990). Likewise, online social structures provide a variety of benefits by supporting the development of interpersonal relationships, feelings of companionship, and perceptions of affiliation (Furlong 1995, Hiltz 1985, Meyer 1989, Rheingold 1993, Walther 1994); encouraging discussion and knowledge sharing (Abbot 1988, Kraut and Attewell 1993, Wellman 1995); allowing individuals to access information and quickly disseminate their ideas (Constant et al. 1996, Finholt and Sproull 1990, Whittaker 1996); providing social and emotional support (King 1994, McCormick and McCormick 1992, Rice and Love 1987, Walther 1996); and enabling collective activities such as software development and political action (Ogan 1993). Whether traditional or computer-mediated, social structures provide a variety of benefits for individual members, enabling them to attract and retain members.

Underlying a social structure's ability to provide valued benefits is the availability of resources such as knowledge, time, energy, money, and material resources (Rice 1982). Whether its creation is explicitly managed (Fine and Stoecker 1985) or the result of an emergent process, the availability of a resource pool is essential if a social structure is to be sustainable. For example, to provide member organizations with access to new technologies, a research consortium must have financial resources and expertise; to encourage information sharing, an online interest community must

have members who are knowledgeable about relevant topics; to provide emotional encouragement and/or counseling, a support group must have members who are willing to expend the time and energy to be supportive. Whether traditional or online, social structures are sustainable only if they have access to resources that allow them to provide benefits for their members. The creation and maintenance of social structures is, at least in part, a process of gathering resources that can be aggregated to provide valued benefits (Rice 1982). Without resources, it is impossible to provide benefits, and without benefits, it is not possible to attract and retain members.

However, having many sources of resources available is not sufficient to sustain a social structure. It is also necessary for the pool of potential resources to be transformed, through social activity, into benefits for individual members. An online community of knowledgeable professionals will not continue to exist unless it also supports discussions that provide information valued by the members. A support group with many caring members who are willing and able to provide help will not be sustainable if it does not also enable the communication that is necessary to turn an individual's time into the supportive contact that troubled people need. The amount of money and expertise available to a research consortium is irrelevant if the organization is unable to coordinate the activities needed to execute development projects. Whether traditional or online, to be sustainable, social structures must support the social processes that convert resources into valued benefits.

Membership Size, Resource Availability, and Benefit Provision

When members are a primary source of resources, the size of a structure's membership provides a measure of resource availability. Larger voluntary associations typically have access to more economic resources (McPherson 1983). Likewise, by aggregating their members' knowledge, larger decision-making groups have access to more information about the problem at hand (Wittenbaum and Stasser 1996). In larger social structures it is more likely that there is a member who knows the needed information, has the ability to provide social support, or has the time to coordinate collective efforts. When members are able to benefit from interactions both directly as active participants and indirectly as passive observers, larger groups will be able to provide greater benefits as a result of the exponential increase in the number of possible interactions (number of possible interactions = $n^*(n - 1)$ where n is the number of members). Membership size is also a measure of the level of "audience resources" that a social structure can provide. For individuals making announcements, seeking visibility, or looking for an audience for their ideas, accessible listeners are a resource. Larger audiences are preferred over smaller ones with similar members. The value of a structure's "audience resource" is dependent, at least in part, on the size of its membership (Fulk et al. 1996, Markus 1990, Rafaeli and LaRose 1993, Rice 1990). In each of these ways, larger social structures will tend to have access to more resources than smaller structures. Because resource availability is an aspect of benefit provision, larger groups are expected to be more able to provide valuable benefits to members, and hence be sustainable, over time (e.g., Haveman 1993, McPherson 1983, Rafaeli and LaRose 1993).

While increasing size provides access to more resources, it can also have significant adverse effects on the process of converting those resources into valued benefits (Haveman 1993, Moreland et al. 1996, Scott 1992). As traditional social structures increase in size, they are subject to increasing logistical problems (Hare 1976, Indik 1965). In larger face-to-face social structures, individuals have fewer opportunities to participate and less time to talk (Krech and Crutchfield 1948). As a result, while larger membership leads to greater audience resources, it also makes it more difficult for individuals to benefit from that resource. The number of possible interaction partners increases nonlinearly with size, making it substantially more difficult to know the rest of the members (Bossard 1945). This, in turn, may affect the chances that individuals will form personal relationships and receive benefits such as social support or information (Feld 1982). It also decreases the likelihood that individuals will know the entire membership well, increasing the chances that they will not be able to fully access the resources that are available within the structure. These problems can significantly hinder the processes by which resources

are transformed into benefits, ultimately affecting a social structure's ability to attract and retain members.

In addition to causing logistical problems, size may have a negative impact on the benefits provision process because it affects individuals' perceptions and attitudes (Milgram et al. 1969, Slater 1958). Larger social structures are more likely to be subject to free-riding and social loafing (Markus and Connolly 1990, Rafaeli and LaRose 1993, Thorn and Connolly 1990). Individuals will tend to contribute less time, energy, and resources because they expect that other members will provide enough to achieve the desired benefits (Petty et al. 1977). Thus, while larger structures may have more potential resource providers, the amount of contributions per person (and overall) may be lower than in smaller social collectives (Marwell and Oliver 1993, Olson 1965, Thorn and Connolly 1990). If adequate resources are not contributed by the current membership, then the social structure will not be able to provide the benefits necessary to continue to attract and retain members. The undersupply of resources (and hence lower benefit levels) in larger structures is reflected in the general finding that individuals in larger structures tend to be less committed, less satisfied (Cartwright 1968, Indik 1965, Slater 1958), and hence less likely to join or remain members (Baumgartel and Sobol 1959, Cleland 1955, Porter and Lawler 1965).

The internal dynamics of sustainable social structures are characterized, in part, by a complex interaction between the positive and negative consequences of membership size. For resources, the available pool will tend to grow at a constant or declining rate relative to the size of the social structure. On the other hand, many of the problems of size are linked with the complexity of intragroup interaction, and hence tend to rise at an increasing rate as the structure grows (Bossard 1945). As a result, the positive and negative impacts of size combine in a nonlinear fashion, affecting a social structure's ability to provide benefits, and hence attract and retain members. This interaction is further complicated by differential salience of costs and benefits in the processes of member attraction and retention. Individuals entering social groups tend to be optimistic, overestimating the potential benefits and underestimating the likely costs of involvement (Brinthaupt et al. 1991). Consequently, the positive effects of size are expected to have a greater effect on member attraction, while member retention is more affected by the problems.

The interacting effects of size within the benefit provision process combine to limit the size of sustainable social structures. In face-to-face contexts, logistical constraints and free-riding behaviors combine to have negative effects that overwhelm the positive consequences of size in all but the smallest of structures (Moreland et al. 1996). This results in size distributions that are skewed towards small groups (James 1953). Although not as extreme, similar results have been found for social structures that do not rely on continuous interaction, such as voluntary associations (MacPherson 1983), youth gangs (Thraser 1927), and even traditional organizations (Simon and Bonini 1958). Another type of social structure in which the tension between the positive and negative effects of size can be seen is the case of brainstorming groups. Proponents of brainstorming argued that, under the right conditions, teams working together would be able to generate more ideas (i.e., provide more benefits) than individuals working alone (Osborn 1957). However, decades of research examining the operation of brainstorming groups failed to support this assertion, finding instead that the negative logistical and psychological effects of size consistently outweigh the gains from increased "resource" availability (Diehl and Strobe 1987).

There are two general approaches to managing the positive and negative impacts of size on the sustainability of a social structure: development of internal structure or use of alternative communication technologies. Internal structure addresses the negative consequences of size by constraining interaction within a social structure. For example, work teams and organizations both may establish formal roles, structures, and procedures in order to reduce the costs of communication, the difficulty of coordination, and the incidence of free-riding (Galbraith 1973, Haveman 1993, Indik 1965). Internal structures are attempts to, at some cost, alter the balance between the negative and positive consequences of increased size in an effort to enable the existence of larger sustainable social structures.

Another way that the impact of size may be affected is through the use of alternative communication technologies. Underlying many claims about the consequences of a computer-mediated social infrastructure

is the belief that information technology has the potential to drastically reduce the negative consequences of size, leading to social structures that are either larger or not dependent on internal structure. Technology-supported organizations are expected to be "flatter," with less internal hierarchy and more fluid processes and communication patterns (Davidow and Malone 1992, Sproull and Keisler 1990). Through the use of group support systems, which make use of a variety of communication technologies, virtual work teams are expected to be able to draw together the knowledge and efforts of more people (Lipnack and Stamps 1997, Turoff 1991). Studies of online brainstorming have found that, unlike in traditional groups, larger online brainstorming groups are able to generate more ideas than smaller ones (Connolly 1997). Computer-mediated communication infrastructures, which provide features such as communication buffering and archiving, have the potential to drastically reduce the logistical problems that occur in traditional social structures (Nunamaker et al. 1991). Other features, such as member anonymity and the general invisibility of individuals (Finholt and Sproull 1990) may lower the salience of a structure's membership, and hence reduce the negative psychological effects of size. Whether synchronous or asynchronous, archived or temporary, computer-mediated communication systems are expected to reduce the negative consequence of size, potentially shifting the balance from the negative to the positive, even in the absence of internal structure (Rice 1982, 1987).

Communication Activity, Benefit Provision, and Membership Costs

The processes by which social structures provide benefits are based on communication activity. As a result, communication activity is a factor in the dynamics of sustainable social structures. No matter what resources are available within a structure, without communication activity those resources will remain dormant, and no benefits will be provided for individuals. The importance of communication activity is reflected in theoretical definitions of small groups and communities that highlight the importance of interaction (Bonner 1959, Hare 1976, Homans 1950, Stogdill 1959, Shaw 1981). Without some form of communication activity, influence, social support, coordination, or information sharing cannot occur. Thus, in the absence of communication activity, a social structure will fail to provide valued benefits for individuals.

To the degree that communication activity is at the core of the social processes underlying provision of benefits for individuals, there is expected to be a positive relationship between the volume of communication activity and the amount of benefit provided. At the extreme, a social structure in which there is no communication at all cannot provide benefits for its members. Even nominal or minimal structures rely on some basic communication activity to support the formation of an identity among their members. More communication activity is expected to enable more information sharing, development of strong relationships among members, and coordination of more complex activities—all of which correspond to the provision of more benefits for individual members.

On the other hand, benefits are not valued equally by all individuals. Communication activity seen by one individual as providing valuable benefits may be seen by another as noise. As a result, the diversity of content present in a group's communication is expected to affect the sustainability of the social structure (Rafaeli and LaRose 1993). Information that is useful to one member may be distracting to another. Interaction that provides social support for one individual may be perceived as unimportant by others. It is rarely possible to provide benefits that are valued equally by all members. Different types of communication activity provide different benefits, which are, in turn, valued differently by various subsets of a social structure's members and potential members. Thus, communication volume and variation are related to the benefits that arise from that communication activity. Volume and variation interact to determine, for a given membership, the overall net benefits, and hence the sustainability of the structure.

However, while communication activity is an important factor in the provision of benefits, it is also a major source of costs for the members of a social structure. Individuals incur costs when they contribute resources to a social structure. When individuals choose to actively participate in the communication, they are

explicitly deciding to contribute their time, energy, attention, and knowledge. However, members also implicitly contribute resources to a social collective when they choose to remain a member, and hence remain part of the audience that is exposed to the communication activity. Attendees at conferences and meetings incur costs, in terms of time, energy, and financial resources, whether or not they choose to explicitly contribute to the communication activity. Simply by being part of an audience, individuals contribute resources to a social structure, incur costs, and hence receive lower net benefits.

While more and more diverse communication activity is likely to be associated with more benefits, it also imposes higher costs. Longer meetings, more issues of a newsletter, or more electronic mail messages all have the potential to support higher levels of information sharing, social support, and other benefits. However, they also result in higher costs, and hence lower new benefit levels. Longer meetings require that everyone spend more time and energy. Higher message volumes force members to expend more time and attention to process the communication, even if they do not personally benefit. For an individual, more (and more diverse) communication activity is an improvement only if the benefits provided by that communication outweigh the costs of being exposed to it. For a social structure overall, higher volume and diversity of communication activity enhances its sustainability only if the number of members who are attracted or retained because of the additional benefits outnumber those who are lost due to the increased cost.

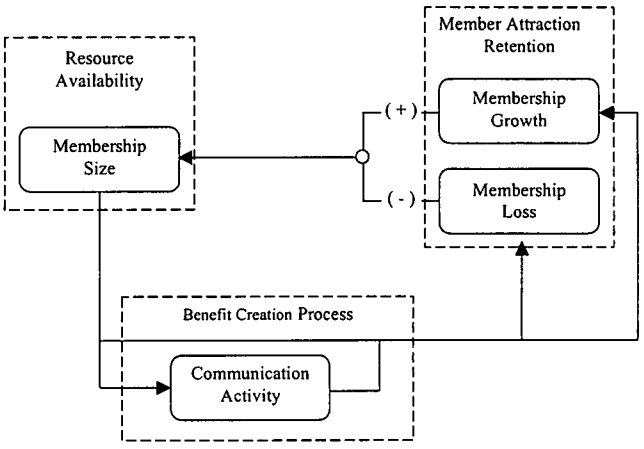
As with size, there are two approaches to managing the positive and negative impacts of communication on the provision of benefits: internal structure or use of alternative communication technologies. Both internal structure and technology facilitate sustainable social structure by altering the costs of communication and/or constraining the content of communication activity. The use of jargon or special symbols reduces the costs of communication activity, making it possible for members to communicate complex ideas more efficiently. Formal summaries, meeting agendas, and structured presentations enable members to more selectively participate in the audience, reducing the costs of being part of a social structure's audience. Editorial control of content also facilitates sustainable social structures by screening out communication activity that imposes costs on large segments of a structure's membership that are not consistent with the benefits provided. Internal structures for managing the effects of communication are attempts to, at a cost, mitigate the negative effects of communication activity in the process of benefit creation.

Using different technologies can also moderate the impact of communication activity on the sustainability of a social structure. In discussions of small groups and communities, it has often been assumed that face-to-face communication must be the basis for these social collectives' communication infrastructures. Underlying this assumption is the observation that physical meeting spaces can be an effective "technology" for supporting communication activity that contributes to the sustainability of a social structure. However, it is an oversimplification to assume that only face-to-face interaction can support sustainable social structures. Kaufer and Carley (1993) argue that the application of print provides many social structures with an alternative to physical space/face-to-face communication infrastructures. Print-enhanced infrastructures, they argue, supported the development of large-scale, long-term social structures, such as professions and academic disciplines. Similarly, as other communication technologies have developed, there has been increased interest in the idea of "virtual" social structures. It has been expected that the use of new communication technologies will reduce or even eliminate the costs of communication activity (Davidow and Malone 1992, Malone et al. 1987). However, it remains unclear whether the use of new communication technologies is itself enough to overcome the negative consequences (i.e., costs) of communication activity within the benefit provision process and hence fundamentally change the internal dynamics of sustainability.

A Resource-Based Model of Sustainable Social Structures

As described above, the resource-based model focuses on a feedback process at the core of the internal dynamics of social structure sustainability (Figure 1).

Figure 1 A Resource-Based Model of Sustainable Social Structures



Current members act as key providers of resources. Through communication processes, those resources are transformed into benefits for individuals which, in turn, enable the social structure to attract and retain members, hence developing and sustaining its resource base. Features of the communication activity mediate the transformation of resources into valued benefits, a process that is posited to underlie the sustainability of a social structure.

The resource-based model of social structure sustainability frames social structure development in terms of a single dynamic process: benefit provision. Other approaches to the study of groups and communities highlight different aspects of these social structures (see Arrow et al. 2000 for summary and discussion). It is not our intent to suggest that these approaches are incorrect or inappropriate. Rather, the goal of this model is to describe the dynamics of a wide variety of social structures in a way that allows us to better understand the general impact of information technology. Toward this end, the resource-based model focuses on benefit provision as a process that is a necessary condition for sustainability in a wide variety of structures. Whether the goal is to support professional development, provide social support, develop the market for a product, or engage in collective action, social structures rely on the continued involvement of individuals. Although the relevant resources, the important benefits, and the form of communication may differ from case to case, benefit provision remains a core process in the ongoing existence of a wide variety of social structures.

Examining online social structures in terms of a resource-based model of sustainability provides a basis for considering whether new communication technologies alter a fundamental aspect of social structure development. Most prior studies relating membership size and communication activity have treated size as a fixed characteristic and asked how size affected the communication activity within the group (Bonito and Hollingshead 1996). On the other hand, studies in which group, club, or organization size is treated as an outcome have generally abstracted away from the internal activities of the structure (e.g., McPherson 1990, McPherson and Rotolo 1996). The resource-based model of sustainable structure is proposed as a bridge between these two general approaches. It suggests that social structures are faced with the fundamental problem of balancing the positive and the negative consequences of size and communication activity. In traditional social contexts, the negative consequences of size and communication activity tend to quickly overshadow the positive effects, creating what appear to be fundamental limits. In response to these limits, traditional social structures adopt various internal structures that mitigate the negative effects of size and activity by constraining membership and limiting communication. However, computer-mediated infrastructures are expected to reduce the negative effects of size and communication activity, resulting in new organizational forms that are subject to different dynamics (Daft and Lewin 1993). In the analysis that follows, the resource-based model will be applied to data from a random sample of e-mail-based social structures (listservs) to consider whether communication technologies, such as e-mail, alter the dynamics of social structure sustainability.

Data, Measures, and Methods

The possibility that telecommunication technologies fundamentally alter the dynamics of sustainability was explored using data from a sample of e-mail-based Internet listservs. These online social structures use Internet-based e-mail and a server (i.e., a list server or listserv) to centrally maintain a mailing list that enables individuals to broadcast text messages to the

other members. E-mail-based social structures were chosen for this study because of their prevalence, availability, and ability to support the necessary data collection. E-mail-based social structures are known to be prevalent in both private and public networked environments (Finholt and Sproull 1990). As a result, e-mail-based Internet communities are both representative of a large class of naturally occurring online social structures and were available for study. Also, unlike other decentralized communications infrastructures, the centralized architecture of a listserv supports measurement of membership size and change.

A stratified random sample was selected to ensure that the included listservs represented a variety of topical focuses and member populations. From a census of approximately 70,000 structures, a stratified base sample of 1,066 listservs was created. While one-third of the initially selected collectives focused on work-related topics, one-third focused on personal topics (hobbies, lifestyles, etc.), and the remaining listservs considered topics that mixed work-related and personal interests (e.g., geographic locations). A multiple-stage confirmation process was then used to construct an analysis sample in which the listservs had comparable technology infrastructures and minimal internal structure. Online structures that integrate different network technologies such as e-mail, WWW conferencing tools, or USENET newsgroups were eliminated, focusing the sample on listservs that relied solely on e-mail for supporting online communication. Social collectives that made use of identifiable internal structures, such as moderated listservs, newsletters, or formal new-member screening, were also removed from the sample. Each listserv was checked to ensure that it was mechanically functional, able to provide the needed data, and available for inclusion in the study. The result of this process was a set of 284 unstructured listservs that relied on e-mail as a basis for online communication. Membership and communication activity records were collected daily for these listservs from August 1, 1997 to November 30, 1997. As data were collected and measures were constructed, the analysis sample was reduced to 206 as listservs ceased operation, changed structure, or restricted access to membership data.

Measures of size, communication activity, and membership change serve as the basis for examining the resource-based model of sustainability (Figure 1). The sample includes only minimally structured electronic groups. This focuses the analysis on the question of whether, in the absence of a strong internal structure, communities that rely on computer-mediated communication technologies remain subject to the fundamental interactions discussed above. Membership size is included as a central characteristic of the community's resource base and as a factor in the benefit provision process. Communication activity, an important aspect of benefit provision, is characterized in terms of volume and topic variation. A social structure's ability to attract and retain members is measured in terms of member gain and loss. The dynamics of resource sustainability are then explored by examining the relationships between size, communication activity, and subsequent changes in membership.

Membership size was measured by counting the number of individuals in a listserv's mailing list at the beginning of each month during the observation period. The raw data consisted of a listing of member's e-mail addresses, which was acquired by sending a command to each listserv's server software. This measure is based on the premise that an online social structure's members are those people who are exposed to its internal communication activity. The impact of a social structure on an individual is limited if she is not exposed to the communication activity. Likewise, the impact of an individual is limited if she is not exposed to or contributing to the provision of benefit through communication. Thus, in a listserv, the relevant members are those individuals who receive the broadcast messages. While this measure may overestimate size by including individuals who receive messages but do not read them, it is conceptually equivalent to counting the number of meeting attendees, a common measure of size in studies of traditional groups and organizations. To simplify interpretation of the empirical results, the size measure was divided by 100.

A listserv's communication activity consists of the text messages that are distributed to all members. The communication volume is measured by counting the number of messages distributed with the mailing list during each month. Communication variation is inferred from the dialog structure of messages. In e-mail

communication, participants typically link related messages by labeling later messages as replies to earlier ones. This linking creates sequences of related messages known as discussion threads. Topic variation in a listserv's communication is reflected by the concentration of messages within the discussion threads. Discussion threads are identified by removing the "re:" marker, a subject line tag commonly used to label messages as replies, and grouping messages based on the first 40 characters of the remaining subject line text. Concentration of messages across the discussion threads is characterized by computing a normalized Herifindal–Hirschman index [HHI][1] (Hirschman 1964) for each day's communication activity. The HHI value was set to 0 in cases where there were no messages, indicating that there is no topic variation when there is no communication activity. The HHI, a measure of concentration with a range from 0 to 1, was reversed (1 − HHI) to create a measure of variation, and the mean value for each month was calculated to determine topic variation of a listserv's communication activity.

This measure provides an indication of participants' assessments of topic variation in the listserv's communication activity. The HHI was chosen as the basis for the topic variation measure because it captures both concentration within a set of categories (i.e., discussion threads) and the number of categories (Davies 1988). Messages are identified as being similar or different based on the labels assigned by the participants themselves. Individuals label messages as replies when they expect their contribution to be of interest to the same individuals who read the earlier messages. Thus, this measure of topic variation is roughly the equivalent of using knowledgeable coders to cluster messages based on the subset of the listserv's members that would be interested in them. While it is subject to noise arising from flawed labeling and alternative uses of the "re:" tag, this measure provides a general indication of whether the communication activity has the potential to provide benefits to few or many subsets of the listserv's membership. In this context, communication, or topic, variation does not indicate how different topics are from one another; rather, it refers to the relative variation in the content of the communication. Low topic variation indicates that the messages in a listserv have focused on a small number of topics, while high topic variation means that many topics were considered.

An online social structure's ability to attract and retain members is reflected in the inflow of new members and the loss of current members over time. Individuals enter and leave listservs by requesting to be added to or removed from the mailing list. Hence, membership gain and loss rates can be determined by recording changes in the mailing list records. Member gain is measured by counting the individuals whose names are added to a listserv's mailing list each month. This count also includes individuals who are coming back to a listserv after a formal absence. However, because across the entire sample returning individuals represent fewer than 10% of all entering members, no adjustment was made. Member loss is measured by counting the people who are removed from a listserv's mailing list during each month. The raw data used to calculate member gain-and-loss measures consisted of a daily list of the individuals on each listserv's mailing list. Daily member loss (gain) was calculated by comparing each day's mailing list to the previous day's to determine the number of individuals who had been removed (or added) in the ensuing 24-hour period. The daily data was then aggregated to create a monthly measure that ensured that individuals who are members of a listserv for less than a month were also included. Monthly measures were used for all constructs because they supported the focus on internal dynamics of these structures. Comparable results were found when analyses were conducted at the weekly and daily levels, but use of the monthly data allowed us to make use of minimal assumptions about external influences such as day of the week, weekend vs. weekday, and holidays.

These measures of size, communication activity,

[1]The topic variation measure is computed according to the following formula:

$$\text{Topic variation} = (1 - \text{HHI}) = (1 - ([S_1^2 + S_2^2 + \cdots + S_n^2]/\text{MsgCount})),$$

where S_i is the percentage of messages [0 . . 1] which are part of discussion thread i and MsgCount is the total number of messages distributed that day.

Table 1 Construct and Measure Summary

Construct	Label	Measure	Units
Membership Size	$Size_t$	The number of people on a listserv's mailing list at the beginning of month *t*.	100's of People
Communication Volume	$Volume_t$	The number of messages distributed to individuals on a listserv's mailing list during month *t*.	Messages/Month
Topic Variation	$Variation_t$	The mean value of a reversed, normalized HHI which reflects the number of topics and the distribution of messages among those topics each day during month *t*.	(Unitless)
Member Gain	$MemberGain_t$	The number of people who are added to a listserv's mailing list during month *t*.	People/Month
Member Loss	$MemberLoss_t$	The number of people who are removed from a listserv's mailing list during month *t*.	People/Month

Table 2 Descriptive Statistics for Listserv Data

	Mean	Std Deviation	Minimum	Maximum
Membership Size	1.68	2.87	0.03	23.92
Communication Volume	33.29	94.77	0.00	1084.00
Topic Variation	0.08	0.18	0.00	0.90
Member Gain	10.20	26.36	0.00	277.00
Member Loss	7.45	20.84	0.00	208.33

member loss, and member gain were constructed for each of the listservs in the sample, resulting in a 206 (listservs) × 4(months) × 5(variables) panel data set (Table 1). The sample contains listservs covering a range of sizes and levels of communication activity (Table 2). The descriptive statistics for the dataset also indicate that there is significant variation in the member gain-and-loss measures.

Analysis and Results

A set of time series, cross-section, random effects, log-linear regression models was used to estimate the relationships in the resource-based model of sustainability. The error structure for each model included a time-period-dependent component, a cross-section- (i.e., listserv) dependent component, and a component that was assumed to be normally distributed and independent of the time period and listserv. Two-way random-effects models were used because both the sampled listservs and the sampled time periods were representative of a large "population" (Greene 1993). Log-linear models were selected because they focus on interaction of size and communication activity, while minimizing problems with nonnormal data. Conceptually, it is the interaction of communication activity and size that is expected to play a role in the sustainability of online social structures. Furthermore, distributions of the various measures are skewed. Applying the log transformation reduces the impact of this nonnormality. Because there were a significant number of cases in which the measures had zero values, a small constant (0.000001) was added to allow the log (base 10) transformation to be applied. The constant was chosen based on the smallest nonzero value in the data set. This minimized the transformation's impact of the ordering of the data.

The presence of mediation, as proposed in the model described above, can be tested by estimating a series of regression models (Baron and Kenny 1986). First, models[2] of size and the membership change variables (gain and loss) are estimated:

$$\text{LOG}(\text{MemberGain}_t) = B_0 + B_1\text{LOG}(\text{Size}_t);$$

$$\text{LOG}(\text{MemberLoss}_t) = B_0 + B_1\ \text{LOG}(\text{Size}_t).$$

Then, models are estimated to assess the relationship between size, communication volume, and topic variation:

$$\text{LOG}(\text{Volume}_t) = B_0 + B_1\text{LOG}(\text{Size}_t);$$

$$\text{LOG}(\text{Variation}_t) = B_0 + B_1\text{LOG}(\text{Size}_t).$$

These log-linear models correspond to the following multiplicative models:

(a) $\text{MemberGain}_t = 10^{B_0}\,\text{Size}_t^{B_1}\,\text{Volume}_t^{B_2}\,\text{Variation}_t^{B_3}$;

(b) $\text{MemberLoss}_t = 10^{B_0}\,\text{Size}_t^{B_1}\,\text{Volume}_t^{B_2}\,\text{Variation}_t^{B_3}$:

Hence, the log-linear models also capture the interaction between size and communication activity described in Figure 1.

Finally, models of both the primary (size) and mediating (volume and variation) factors are considered:

$$\text{LOG(MemberGain}_t) = B_0 + B_1\text{LOG(Size}_t) + B_2\text{LOG(Volume}_t) + B_3\text{LOG(Variation}_t);$$

$$\text{LOG(MemberLoss}_t) = B_0 + B_1\text{LOG(Size}_t) + B_2\text{LOG(Volume}_t) + B_3\text{LOG(Variation}_t).$$

The results are then examined to determine whether there is support for the proposed mediation effect. Together these analyses examine the relationships that comprise the core of the resource-based model of sustainable social structures (Figure 1). The remaining relationships in Figure 1, the links between member gain, member loss, and subsequent changes in size, are deterministic and hence need not be statistically estimated.

The statistical models described above were estimated with the TSCSREG procedure in SAS (v6.12) (Table 3). The regression results suggest that size and communication activity have a significant impact on the ability of online social structures to attract and retain members. The significant coefficients for size and communication activity in the model predicting member gain suggest that these features positively impact a listserv's ability to attract members. Larger and more active listservs see higher rates of member gain. However, the significant coefficients for size, communication activity, and topic variation in the member loss model imply that these features also have a negative effect on a listserv's ability to retain members. Larger listservs and those with more and more varied communication activity have more member loss. Thus, size and communication activity have both positive and negative impacts on the sustainability of the online social structures.

Table 3 Mediated Model Results

	Size & Communication Activity		Member Attraction		Member Retention	
Dependent Variable	(a) Volume (Log)	(b) Variation (Log)	(c) Member Gain (Log)	(d) Member Gain (Log)	(e) Member Loss (Log)	(f) Member Loss (Log)
Intercept	−1.52***	−3.74***	−1.01***	−0.40	−2.03***	−0.54**
Size_t (Log)	2.94***	1.95***	3.25***	2.49***	3.21***	1.78***
Volume_t (Log)				0.22***		0.31***
Variation_t (Log)				0.07		0.27***
R^2	0.10	0.09	0.24	0.31	0.21	0.44

*: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$

$N = 206 \times 4$

It is possible that the negative relationship between size and a listserv's ability to retain members is an artifact of the measure of member loss. Member loss is assessed in terms of an absolute count of number of people who leave a listserv in a given month. This measure is subject to a variable ceiling. The number of individuals who could potentially leave is limited to the number of individuals who are present (size) and the number who have entered (member gain). Thus, it is possible that relationship between size and member loss is a trivial consequence of larger networked social structures having the potential for more people to leave.

To determine whether the effect of size on membership loss extended beyond the trivial ceiling effect, the member loss model was estimated using proportional member loss as an alternative measure of a listserv's ability to retain members. Proportionate member loss was assessed by dividing the absolute member loss by the listserv's size. This measure captures a social structure's ability to retain members, relative to its size. The results of this model indicate that the impact of size on a listserv's ability to retain members is not simply due to the variable ceiling for absolute membership loss (Table 4). The coefficient of size remains statistically significant and positive. These results suggest that larger listservs will tend to have a higher relative loss rate. Not only do larger online structures lose more members, they also lose a larger percentage of their membership than smaller structures.

In addition, the original analysis also provides support for the proposition that communication activity serves as a partial mediator of the effects of size on a structure's ability to attract and retain members. The difference between the size coefficients in the direct models (c and e) and the comparable coefficient n in

Table 4 Proportional Member Loss Model Results

	Proportional Member Loss (Log)
Intercept	−0.74***
Size$_t$ (Log)	1.34***
Volume$_t$ (Log)	0.33***
Variation$_t$ (Log)	0.25***
R^2	0.39

*: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$
$N = 206 \times 4$

the full models (d and f) indicates that for both member gain and loss, there is a mediation structure involving size and communication activity. For member gain, there is a reduction of 0.77 in the size coefficient when comparing the size model (c) with the full model (d) (one-tailed test: $t = 1.85$, $p < 0.05$). This reduction implies that 23% of the impact of size on member attraction is accounted for by the indirect link between size and membership gain that is mediated by communication activity. In the case of member loss, the size coefficient drops by 1.43 (or 44%) when communication volume and variation are included (one-tailed test: $t = 3.51$, $p < 0.001$). Overall these results indicate that some portion of the impact of size on an online social structure's ability to attract and retain members is mediated by communication activity. However, in both cases there remains a significant direct relationship between size and the membership change variables. Thus, while the link between size and communication activity may play a role in the sustainability of online social structures, size has other more direct consequences as well.

Discussion

The resource-based model builds on prior studies of groups, associations, and organizations to consider the role of technology in a fundamental problem of organizing viable online social structures. As discussed above, the component constructs have been used in prior studies of traditional social structures. For example, in applications of public goods theories to communication systems, the critical mass model (Markus 1990) is discussed in terms of resources that are available while discretionary database models (Thorn and Connolly 1990) consider the processes by which resources are converted to benefits for members. While it has been noted elsewhere that these models address different aspects of online social structure (Markus and Connolly 1990), issues of resource availability and benefit provision have not been well integrated (Rafaeli and LaRose 1993). One contribution of this paper is to explicitly link resource availability, benefit provision, and member attraction and retention in a model of sustainability.

However, the resource-based model presented here also differs from prior work in a more fundamental fashion. Although it draws on prior studies for both theoretical and operational constructs the resource-based model is structured around what Robey and Boudreau (1999) have called "logics of opposition." That is, instead of characterizing changes in online social structures in terms of outcomes predicted by a set of factors, the resource-based model frames the study of online structure sustainability in terms of sets of opposing forces that serve to simultaneously promote and hinder the processes of change (Robey and Boudreau 1999). It is in the identification of these opposing forces, and their implications for the development of online social structures, that the primary value of the resource-based model lies.

At the lowest level, the resource-based model is characterized not by unidirectional links between resource availability, benefit provision, and sustainability, but rather by links that involve opposing effects. The empirical relationships between size and member gain and loss show that the role of size in the development of online social structures is not as a single, positive effect, as it is often characterized in critical mass analyses (Markus 1990, Rafaeli and LaRose 1993, Rice 1990), but rather the result of the interaction of opposing effects with greater size being associated with both more member gain and more member loss. This result is significant in part because it suggests that, at least within the context of Internet listservs, the implications of increasing size for online social structures are more complex than typically posited in prior studies. The development of online communities is not a process which proceeds smoothly at an increasing

rate as the value of the available resource increases (Markus 1990), but rather it is a process which involves significant "churn," with members coming and going even as the magnitude of available resources increases. Practically, the association of increasing size with both increased ability to attract members and a decreased ability to retain members is important because it indicates that increased rates of member loss may not be a bad sign. While it is clearly a problem if member loss outpaces member gain, this study suggests that developers of online social structures should expect to see increasing member loss as part of the development process of a growing online community.

Similarly, the empirical results indicate that the impact of communication activity on sustainability is also not a unidirectional effect, but rather the aggregate consequence of opposing forces of communication activity on member gain and loss. Although communication activity is a primary mechanism for benefit provision, it is an activity that is not costless or uniformly beneficial for all individuals. Hence, characterizations of online social activities that consider only the benefits of communication fail to accurately reflect the complete role of this activity in the development of sustainable online structures. For practitioners, this implies that efforts to manage message activity, whether through technological change, editorial control, or social intervention, are double-edged, each having both positive and negative impacts on a group's ability to maintain a resource base and provide benefits in the future.

The low-level structures of opposition underlying the impact of resource availability (i.e., size) and benefit provision (i.e., communication activity) are further complicated in the resource-based model when they too are linked—creating yet another set of opposing effects. The coefficient of size in the member gain model (Model d in Table 3) is larger than the coefficient of size in the member loss model (Model e) (one-tailed t-test: $t = 1.76$, $p < 0.05$) indicating that the net effect of increased size on a listserv's sustainability is positive. However, comparison of the communication activity effects suggests that these are in the opposite direction. The negative impact of more varied communication activity on the retention of members is significantly greater than the positive impact on member attraction (one-tailed t-test: $t = 1.717$, $p < 0.05$). In addition, while the difference is not statistically significant, the negative impact of communication volume is also greater than its positive effects. Thus, while the direct impact of size on a listserv's ability to attract and retain members is generally positive, the net impact of communication features, specifically variation, is negative. This is further complicated by the presence of a relationship between size, communication volume, and communication diversity. Size is positively associated with communication volume and variation, which in turn negatively impact sustainability (Table 3, Models a and b). Together these results describe a multilayered structure of opposition in which resource availability in the form of member presence, and benefit provision in the form of communication activity, combine through a series of opposing effects to ultimately impact an online group or community's future resource sustainability.

The interplay of size and communication features in the empirical results, mirroring the linked constructs of resource availability and benefit provision, brings to the fore limitations inherent in conceptualizations of online social structure that are not balanced in their consideration of the development process. For example, critical mass models (Markus 1990, Rice 1990) highlight the number of members, in either absolute or relative terms, as a significant positive factor in the development of communication systems and online social structures. Likewise, discussions of the impact of technology on social structure often focus on the impact of alternative infrastructures on communication activity without simultaneously considering the consequences of those changes for size (Butler 1999). The empirical results presented above indicate that theories of online social structure that consider either factor alone are likely to be, at best, incomplete. For developers of online communities, these results imply that identification of a "critical mass" is inherently tied to the features of the communication activity, and that analyses of technology or policy impact on a group's communication activity must also take into account impacts on future resource availability. The concept of an online social structure's critical mass of members is only meaningful when coupled with assumptions about

the type and volume of communication activity. Conversely, technological or procedural design choices that affect the type and volume of communication activity must be evaluated in terms of their impact on the attraction and retention of members (and hence the availability of resources in the future).

Limitations and Future Research

The resource-based model of sustainable social structures is not a theory of technological impacts, but rather a theory of social structure that allows us to consider the consequences of technology.

To create a general framework, the current study focuses on developing the constructs of resource availability, benefit provision, and social structure sustainability with minimal models of resources and communication. This approach furthers our understanding of the general problem of social structure sustainability in several ways. First, by articulating the resource-based model in terms of elementary constructs that are both simplified and grounded in prior empirical and theoretical studies, this work can serve as the foundation for computational and analytical models that consider other aspects of the dynamics of online and traditional social structures. The resource-based framework describes a process of resource accumulation and benefit generation. The empirical analysis considers evidence for the nature of specific relationships that comprise the process. However, it is beyond the scope of this study to systematically examine the full implications of that process model to understand the long-term evolution of social structures, as might be done in future computational or analytical modeling studies.

Developing the resource-based theory with minimal models of resources and communication also allows it to be used as a common framework for studies of both online and traditional social structures in a variety of contexts. Although the individual operational constructs (size, communication volume, etc.) and the links between them have been considered in prior studies of traditional social structures, the resource-based theory of sustainability has not been directly tested in those contexts. Studies of sets of constructs and processes in traditional groups, associations, or organizations would strengthen claims regarding the generality of the resource-based theory of sustainable social structures. Additional work might also be done to develop the resource-based model of sustainable social structure as a more detailed description of the fundamental problem of organizing. In this vein, future work might benefit from consideration of prior studies of organizational demographics, group composition, and communication processes and structure (e.g., Berthod et al. 1996, Bonito and Hollingshead 1996) as sources for elaborating the constructs and processes underlying the model.

Likewise, the empirical work presented here is based on a sample of online social structures that make use of one type of technology (centralized e-mail servers), have minimal internal structures, and exist in a public network (the Internet). Although this sample represents a common type of online social structure, future work that considers other types of technology and different contexts would also increase the validity of the general model as a description of one of the fundamental problems of social organization. While knowledge of the fundamental problems is valuable, practitioners also benefit from systematic examinations of the tools and designs they can use. In the case of social structure development, future work might consider whether structures based on pull technologies, which require that users explicitly request each message (e.g., WWW conferencing), or hybrid infrastructures, which combine traditional and computer-mediated communication infrastructures, differ significantly in terms of their sustainability from the structures considered here which use a push technology (e-mail), presenting messages to members without the need for an explicit request. Assessment of the impact of internal structures, such as moderation and member screening on a structure's ability to attract and retain members would also be useful when developing the social and managerial infrastructure to support online communication. Finally, consideration of social structures operating within other, larger contexts, such as within an organization or a well-defined community, would provide additional insight into the factors that underlie the relationships between size, communication activity, and sustainability (Rice 1987). In all of these cases, the resource-based model of sustainable social structures provides a theoretical framework for

examining the impacts of new technologies on the viability of long-term social structures.

The results of this study suggest that the use of computer-mediated communication infrastructures is not likely to fundamentally change the problems underlying the development of sustainable social structures. Size and communication activity have both positive and negative effects on the sustainability of online social structures. Larger listservs are better able to attract members, but they are also less able to keep them. Likewise, listservs with more communication activity are more able to attract members, but less able to retain them. Thus, while new communication technologies may serve to reduce spatial and temporal constraints on communication (Rice 1980, Sproull and Kiesler 1990), the growth of online social structures does not appear to be limited only by the availability of interested participants. Rather, as with traditional social structures, developing and maintaining sustainable online social structures requires that the fundamental problem of balancing the positive and negative impacts of size and communication activity be solved in order to maintain a resource pool for the future while providing benefits for the members in the present. This suggests that rather than focusing on computer-mediated communication technologies as revolutionary forces that fundamentally change the problem of social organization, researchers and practitioners would be better served by theories that characterize them as additional tools in the organizers' repertoire for dealing with certain fundamental problems. While the model presented in this work provides an initial step, there is much work that remains to be done in the development of a practical understanding of the challenges of organizing and the true opportunities provided by new technologies in the realm of developing and maintaining sustainable social structures.

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