EXPERIMENTS
ON
THE DYNAMICS OF COMMUNITY FORMATION

Thesis by

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Abstract

I study the dynamics by which populations with heterogeneous preferences for local public good provision, or for other local policies, sort themselves into communities. I conduct a series of laboratory experiments to consider whether the ability to "vote with one's feet," by moving between communities, is sufficient for a population to reach optimal public good allocations and community compositions, and to assess which institutions may best facilitate efficient self-organization when residents are able to move freely between locations.

I find that communities allowing residents to make voluntary contributions toward the provision of a public good are characterized by instability, cyclical fluctuations in local provision, and a dynamic in which low demanders continually chase high demanders through locations. Institutions requiring all residents of a community to pay equal taxes enable subjects to sort by type into stable communities. However, populations can find themselves stuck at one of two types of local, inefficient equilibria. First, though sorted, residents may fail to attain the level of public good provision best suited for them, and, in that case, the system dynamics are crucial for determining whether subjects reach the communities that offer optimally designed expenditure bundles. When residents are able to vote for local tax policies with their ballots as well as with their feet, the inefficient local equilibria are eliminated, and I find that each community converges to the most efficient outcome for its population. Second, populations may sort into an inefficient equilibrium partition of residents across communities. I find that subjects moving between locations with fixed local policies segregate by type, even when pooling their resources with similar types is more efficient. Again, when subjects are able to vote on local policies, they typically succeed in forming communities of the optimal size and membership composition.

These experimental results suggest that the ability to vote with one's feet may not be sufficient for achieving optimal outcomes and that voting, or another mechanism by which residents may influence local policy internally, may also be necessary.

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Chapter 1

Introduction

This dissertation uses laboratory experiments to study the underlying processes of endogenous group formation and community sorting. Specifically, I study the dynamics by which people with very different preferences for public good provision, or other local policies, sort themselves into communities.

Americans are highly mobile – in fact, every year, nearly fifteen percent of us move to a different location – and a fundamental question is how we choose our communities and, perhaps, sort ourselves geographically. At the same time, one of the most important roles of our communities is to provide public goods and services, such as roads, parks, schools, libraries, police and fire protection, and so forth. Residents typically vary in their demand for these services, and how to provide them efficiently in light of this heterogeneity is a central problem of public economics.

The canonical model from local public finance is the *Tiebout model* from the 1950s, which says that, if households can move freely between jurisdictions, then residents will *vote with their feet* and move to the community where the local taxes and public expenditures best suit them. In this way, they will sort themselves by their preferences for public goods and they can then be taxed according to their demand. Thus, mobility can lead to an optimal allocation of public goods at the local, community level.

However, the question remains as to whether populations do indeed sort themselves into communities so as to achieve efficient public good provision. The inability to measure a household's true demand for public goods makes it very difficult to test whether migration patterns in our communities are in fact driven by these preferences, and direct tests of the Tiebout hypothesis have been varied and inconclusive. But it is this difficulty in measuring public goods preferences that make this an ideal problem to study with laboratory experiments. Preferences can be readily generated in the lab by varying the payoffs that subjects receive from standard public goods games and we can then observe the dynamics of movement within a controlled setting. This is the approach taken in this dissertation and, ultimately, the findings reported here suggest that the ability to vote with one's feet is *not sufficient* for achieving optimal allocations.

I conduct a series of experiments that each follow the same basic setup. Subjects come to the lab and are randomly assigned different preferences. *High Types* receive very high returns from public good provision and *Low Types* receive very low returns. There are several available locations that remain fixed for the duration of the experiment. In each period, each subject simultaneously chooses a location, they see the number of other people who have chosen the same location, and they make a contribution to the public good there. They then receive a payoff from the total contributions made only within their location. Finally, they see the outcomes in all locations, including the number of people in each and the total contributions made there, before making their next move. However, they do not receive any information on the identity of the other subjects, their individual contributions, or the payoffs of the others.

In the first set of experiments, presented in Chapter 2, I consider a voluntary contribution mechanism, which allows subjects to contribute any amount that they wish. This enables different types to contribute different amounts within a single location. I find that subjects move in response to both provision and community composition but that the growth and stability of these communities are dictated by movement costs and crowding. When the public good is *congestible*, such that returns are lower for larger populations, communities are characterized by instability, cyclical fluctuations in local provision, and a dynamic in which Low Types continually chase High Types through locations. The High Types enter previously empty locations at an immediate cost to themselves and make substantial contributions. The Low Types enter as soon as this community surpasses their own, provision declines, and the High Types exit once again. While communities with high entry fees primarily attract those with high public good returns, segregation is not sufficient for overcoming free-riding. When congestion is eliminated, such that a single populated community is both efficient and strong Nash stable, agents with different preferences sometimes co-exist. However, chronic, inefficient movement persists. Less than half of movement appears to be driven by congestion, and the High Types continue to exit even when the presence of Low Types does not diminish their payoffs. This suggests that people have intrinsic preferences for the composition of their community and that additional institutional structure on how contributions are determined may be necessary for community stability.

Therefore, in Chapter 3, I compare the voluntary contributions environment with three different institutions requiring all members of a community to contribute the same amount. How the subjects' contributions are determined depends on the institution governing their experimental session and I consider which institutions may best facilitate efficient self-organization when residents are able to move freely between locations. Under the first institution, each location is associated with a different fixed, posted tax that all subjects must pay in each period that they reside there. Among these locations are those offering the optimal tax rates for each of the two types. Under the second institution, each location is associated with a fixed, posted total contribution level and all subjects must contribute an equal share of this amount. Under the final institution, the location's current members vote on the tax in each period, the median voter's preference is implemented, and all residents are required to contribute this amount. These three institutions generate the same unique *strong Nash equilibrium* in which the types separate, consolidate, and consume their optimal, tax provision pair.

Under all three of the institutions requiring all members of a community to make equal contributions, subjects separate by type into an optimal partition. When they are able to vote only with their feet, by moving between communities offering fixed taxes or provision levels, subjects often become stuck at local, inefficient equilibria such that they under-provide or over-provide the public good. In other words, though they sort into separate, homogeneous communities, the subjects often fail to attain the optimal provision within these communities, because they are unable to coordinate on the location offering the optimal tax-provision bundle for their type. This is striking because it suggests that, even with fixed local taxes as in the original Tiebout model, voting with one's feet may not be sufficient: Existence of communities with optimally designed policies does not guarantee that they will be entered, and inertia, or the desire to be around others, can prevent optimality from being reached.

However, under the voting institution, which enables subjects to vote both with their feet and with ballots, the inefficient local equilibira are eliminated and these communities converge to the optimal outcome for their populations. Voting with their feet enables subjects to sort by moving to the community that they like, while voting with their ballots enables them to then adapt the community to their liking once they have arrived. This suggests that an internal mechanism that allows residents to influence community policy without needing to relocate may be necessary for overcoming coordination failure and achieving optimal allocations.

Chapter 4 builds on the results of Chapter 3 by incorporating a more refined spectrum of preference types and focusing on the *partitioning* of agents by type across locations, rather than the optimal provision of public goods. The experiments in this chapter address the dynamics by which heterogeneous populations partition themselves into groups when there is a trade-off between increasing returns to group size and attaining a group policy closest to an ideal point (as is the case in Chapter 3 when communities provide a public good through mandatory tax rates). Two experimental conditions are conducted in which subjects can move freely between locations, with group policy either fixed by location or determined by member vote. The same set of Nash stable partitions exists in each condition, with the most efficient stable state requiring subjects to form heterogeneous groups and compromise on policy. I find that subjects who are only able to move between locations with fixed policies always over-segregate, failing to sustain heterogeneous groups or build locations with compromise policies. However, when mobility is combined with the ability to vote on local policy, subjects successfully form heterogeneous groups and most reach the optimal partition. This suggests that local governance is relevant for determining whether populations will pool their resources into larger groups, even when voting does not alter the set of stable states, and that the dynamics, in addition to stability concepts, are important for understanding the effects of institutional and other environmental factors on group formation.

The experimental results presented here suggest that the ability to vote with one's feet is not sufficient for populations to either obtain optimal public goods expenditure bundles or to sort into optimal partitions across communities.

Chapter 2

Community Dynamics in the Lab: Congestion, Public Good Provision, and Local Instability

2.1 Introduction

Local communities often vary greatly in their overall character and culture and, over time, can experience substantial transformations and changes in population. One defining attribute of communities is the public goods and services they offer, whether provided by local government through tax revenue, such as schools, libraries, and recreation areas, or voluntarily by residents, such as neighborhood watch programs, volunteer fire departments, street festivals, resident-built playgrounds, and community gardens. Residents typically vary in how much they value such amenities. This chapter uses laboratory experiments to study the dynamics of local community formation, development, and stability when agents receive very different returns from a public good.

One common pattern of community transition often described by urbanists is the process of revitalization, typically thought to be initiated by "urban pioneers."[1] New residents enter uninhabited commercial districts or (far more controversially) lower-income neighborhoods and expend considerable effort modifying the location, by making aesthetic improvements, providing cultural amenities, renewing the housing stock, and making formerly commercial areas habitable. Conventional wisdom among both urban economists and real estate investors has been that these pioneers are members of artistic and bohemian populations, who provide a public good in the form of the cultural, aesthetic, and nightlife amenities that most benefit them and, in doing so, further

[1] See, for instance, Hudson (1980)'s application of the invasion-succession model to urban revitalization.

attract similar residents.[2] Eventually, the efforts of the new residents make the neighborhood attractive to higher-income populations, sometimes referred to as "settlers."[3] In the final step of neighborhood shift, the initial pioneers, who had been voluntarily providing a public good, are typically displaced once the neighborhood becomes popular. This pattern played out most famously in SoHo in the 1970s, but can also be observed in other New York City neighborhoods such as TriBeCa and the East Village, as well as those of other cities.[4]

In this chapter, I use laboratory experiments to study the main forces underlying such dynamics. I conduct simple linear public goods experiments in a free-mobility environment to gain insight into the basic processes of movement, community formation, and the phenomenon of one type of agent chasing another. Within this setting, I induce *heterogeneous preferences* for the public good and study the dynamics of movement and voluntary local public good provision. Those subjects who receive high payoffs from public good provision are then analogous to the populations typically thought to be urban pioneers, while those with weaker preferences resemble the settlers who later enter the community. To the best of my knowledge, this chapter represents the first experimental study of the importance of preference heterogeneity in the dynamics of group formation and movement.

Most local public goods and services are, to some extent, *congestible*, in that the presence of more residents diminishes the benefit that each individual may obtain. I analyze the importance of payoff congestion in public good returns for movement dynamics and stability, by comparing sessions in which the public good is pure (non-rivalrous) with sessions in which the public good is congestible.

These experiments are designed to address the following questions: 1) Is movement driven by agents' preferences for the public good? 2) Are instability and cyclical movement patterns caused primarily by congestion? and 3) Can entry fees facilitate sorting and local cooperation?

Communities often face social dilemmas, in which individual incentives diverge from the interests of the community as a whole, that may hinder the efficient provision of public goods. Since all members may consume the public good, regardless of whether they contribute to it, they have an incentive to under-contribute relative to their true demand, and equilibrium behavior

[2] Florida and Mellander (2007)

[3] Hudson (1988) expands the invasion-succession model to include this second wave.

[4] For instance, Cole (1987) describes the displacement of artists from New York City neighborhoods and Ley (2003) describes the movement of artists from gentrifying neighborhoods of Canadian cities.

results in individual free-riding and a suboptimal allocation of the public good provided in the community. Efficient provision is even more difficult to achieve when residents have different, unobservable preferences for public good consumption, since a community cannot require different contributions or behavior from those who would benefit most. For instance, residents not concerned with local school quality typically do not pay lower taxes, just as those who care strongly about the neighborhood's appearance cannot be required to contribute to its upkeep.

Charles Tiebout (1956) addressed the problem of efficient public good provision with the insight that many of the public goods and services that we consume are provided by our local communities and that non-residents may be geographically excluded from consuming them. He proposed that residents who are able to move freely between local jurisdictions would enter the community that best satisfied their preferences for the public good along with other local non-economic features.[5] By moving in response to differences in local communities, residents reveal their true preferences and an efficient public good allocation can be achieved at the local level. The fundamental premise of Tiebout's argument has implications far beyond local public finance and public good provision and Tiebout's proposal is routinely invoked across disciplines to capture the idea that if we dislike our current situation we can move elsewhere – somewhere better, where the people and policies better suit our preferences, and the outcomes are more to our liking.

The experiments reported in this chapter incorporate two fundamental features of Tiebout's framework: that public goods are spatially excludable and may be consumed only by local residents, and that residents are both fully mobile and fully informed of the differences between locations. One dynamic result emerging from the Tiebout literature is that of the poor chasing the rich, or the so-called *musical suburbs problem* (Hamilton, 1975; Wilson, 1998). This is commonly subverted in practice through the implementation of zoning policies, which lead to uniform tax rates, or, historically, even through restrictions placed on the mobility of the poor.[6] However, as the pattern of settlers following pioneers in the process of urban revitalization indicates, similar movement patterns may be found if residents relocate in response to a public good that is provided voluntarily, rather than through tax revenue.

[5]For instance, Tiebout specifically references the desire of residents to have "nice" neighbors (Tiebout, 1956, p.418).

[6]Throughout U.S. history, the ubiquity of this concern may be seen in limitations on the mobility of the poor in federal legislation, ranging from the Articles of Confederation, which excluded "paupers" from those who had the right to move freely between states, to the Personal Responsibility and Work Opportunities Reconciliation Act of 1996, which prevented newcomers from receiving welfare benefits beyond what they had been receiving previously for up to a year following their move (Donahue, 1997).

I introduce two different types of agents: those who benefit greatly from the public good (High Types), but may be highly sensitive to congestion, and those who receive very low returns from the public good but are indifferent to the presence of others (Low Types). Subjects are randomly assigned different returns from public good provision at the start of the experiment and participate in a standard linear public goods game, during which they can move between communities.[7] There are six available locations that remain fixed for the duration of the experiment, and the subjects play a dynamic game that lasts for sixty-five to eighty periods (allowing for ample time to assess the stability and long-run dynamics).

In each period, the subjects first simultaneously choose a location. They then observe the number of others who chose the same location, and make a voluntary contribution to the community's public good. They receive a payoff that depends on the total contributions made only within their own location, as well as their assigned marginal return from the public good. Finally, the subjects learn the outcomes in all locations before making their next move. Consistent with the difficulty in observing public goods preferences of other households, which is at the root of the problem of inefficient public good provision, the subjects do not receive any information on the returns from the public good received by fellow participants.

This chapter also analyzes the extent to which community instability may be driven by payoff congestion, by directly comparing experimental sessions with a congestible public good to sessions with a pure public good. When the public good is congestible, High Types receive lower returns from public good provision in more populated communities. In the absence of congestion, the most efficient outcome occurs when the population pools its resources into a single community and, in this case, there is no set of residents who may increase their payoffs by collectively relocating.

Each location is associated with an entry fee. These fees capture the cost that a household incurs by moving, but also vary between locations, capturing the existence of communities that are less easily accessible, for instance due to geographical location, higher real estate prices, or substantial joining fees or requirements for initiation. Movement into three of the six locations carries a very low cost (equivalent to twenty percent of the subject's per-period endowment), while movement into the other three locations carries a much higher cost (equivalent to sixty percent of the subject's endowment). Since the Low Types benefit little from public good provision, these

[7] In the typical public goods experiment, subjects receive an endowment in each period and, without discussion, choose how much to keep for private consumption and how much to contribute anonymously to the group. The total amount contributed is multiplied by a factor less than 1 and each subject receives this amount in addition to the portion of his endowment he kept for himself.

entry fees are relatively higher for them, and imply that provision in another community must be far greater than in their own in order for them to gain by moving. Such fees can therefore serve as a mechanism that coordinates separation by type and allows the High Types to avoid congestion.

I find, first, that subjects' behavior varies greatly by their assigned public good preferences. While the Low Types contribute little and, over time, learn not to contribute anything at all, the High Types do contribute, and they sustain these contributions for the duration of the experiment. But, though the High Types tend to contribute consistently, the locations themselves experience vast, cyclical fluctuations in public good provision. Local provision peaks immediately after the community is formed and then declines steadily over the life of the community. This is reminiscent of the pattern of urban revitalization in which the most substantial contributions are made by the early entrants, making the community attractive to others.

Consistent with the fundamental premise of Tiebout's model, the subjects do, in fact, move in response to these differences in local public good provision. Perhaps more importantly, this movement is greatly shaped by the subjects' exogenously assigned preferences for the public good. The High Types are far more responsive to differences in local provision. While neither type remains in communities with low provision, the High Types have a significantly lower threshold for movement, and are typically in the community with the highest provision level. Thus, taken statically, or without consideration of the changes in communities over time, there is some evidence of sorting by type.

Congestion seems to play an important role in community dynamics. Communities tend to be highly unstable when the public good is congestible, and there is a clear pattern of the Low Types chasing the High Types through locations. The High Types frequently exit populated communities with declining provision levels in favor of previously unoccupied locations and at an immediate cost to themselves. They make substantial contributions to the public good and are quickly joined by other High Types. Once their community becomes competitive, they are followed by the Low Types, provision deteriorates, and the cycle starts once again. Movement is frequent, with at least one subject typically moving in each period, and never subsides over the course of a sixty-five period experiment.

Though movement is less frequent in sessions without congestion, the chasing dynamic and community instability persist. The heterogeneous population of subjects is often able to co-exist in a single location for many periods. However, less than half of the overall movement appears to be driven by congestion and the High Types continue to exit even when the presence of Low Types does not diminish their payoffs. In addition, frequent movement is associated with lower payoffs. This suggests that the chasing phenomenon is not driven purely by payoff-based incentives, but that people may also have intrinsic preferences for the composition of their community and that movement is partially driven by an unwillingness to be around those who do not contribute to the community.

With respect to entry fees, I find that local fees can facilitate the High Types' coordinated avoidance of the Low Types but do not promote long-term community stability. The existence of locations with differing entry fees allows the High Types to coordinate on a community and to avoid congestion caused by the Low Types. Locations associated with high fees are entered almost exclusively by High Types and the subjects contribute more when they are there. However, even when High Types segregate, provision is not sustained and these communities are ultimately no more stable than those with low entry fees.

The experimental results described in this chapter show clear patterns of movement driven by subjects' assigned preferences for public good provision that strongly resemble those observed in neighborhood transitions. Those subjects who benefit most from public good provision often enter previously unoccupied locations and make substantial contributions to the public good. They are joined, first, by those with similar preferences, and, eventually, by those who benefit little and do not contribute, before exiting once again. Further, the continual exit of the pioneering subjects is only partially driven by local crowding, suggesting that community instability may be partially attributed to an intrinsic unwillingness to provide for those who do not contribute.

2.1.1 Related Literature

Experimental studies have consistently shown that voluntary contributions in fixed-group, linear public goods games begin midway between optimal and one-shot equilibrium levels but decline with repetition, typically approaching the theoretical equilibrium unless supported by institutions, such as sanctions or taxes for those who contribute too little (Ledyard, 1995; Ostrom, 2000).

However, it is rarely the case that individuals are assigned to a fixed community. Instead, we nearly always enter our communities voluntarily, with some expectations of the group outcome based on the local history or norms, and with the understanding that we can move elsewhere should we disapprove of the behavior of our neighbors. Therefore, a more practical approach is to study the public goods problem at the local level, where association is voluntary and movement is possible.

Despite the abundance of applications, only recently has experimental research jointly considered voluntary public goods contributions and endogenous group formation. The results thus far suggest that mobility in itself is not sufficient to solve the public goods problem without the implementation of formal boundary rules that restrict group entry. When individuals have complete freedom to move between groups then free-riders will continuously chase contributors between societies.

Ehrhart and Keser (1999), the first to conduct such experiments, study a congestible linear public goods game. They find a group-level dynamic in which groups with high contributions grow, contributions in large groups decline, and groups with declining contributions shrink, and an individual-level correlation suggesting that higher contributors exit larger groups in favor of smaller ones. A pair of studies compared treatments in which subjects can freely move between groups, can enter only with their new group's consent, or can exit only with their former group's consent (Ahn, Isaac, and Salmon, 2008/2009). They find that subjects often vote to deny entry or approve exit, even in the pure public good treatment when groups benefit from having more members, and so, while restricted entry serves to increase contributions, earnings are lower for cooperators when the public good is pure.

Several other experimental studies have found that high contributions can be sustained in voluntary contribution public goods games when subjects are provided with a mechanism to build their groups and control membership composition (Page, Putterman, and Unel, 2005; Weber, 2006; Charness and Yang, 2010).

There is evidence that declining contributions may be explained by conditional cooperation – the willingness of subjects to cooperate only if their partners do as well – and approximately half of experimental subjects decrease their contributions if their group members contribute less (Fischbacher, Gächter, and Fehr, 2001). Faced only with the choice of how much to contribute, subjects locked into fixed groups have no other means of retaliation against free-riders and quickly learn to cease attempts at cooperation. Several experimental studies have tested conditional cooperation by sorting subjects based on the propensity for cooperation that they exhibit in earlier periods or games, and nearly all find that contribution is sustained at a higher level when cooperators only ever encounter other cooperators.[8]

Experiments allowing subjects to buy entry into separate games designed to be more attractive to cooperators typically find moderate but incomplete sorting (Bohnet and Kübler, 2005; Brekke, Hauge, Lind, and Nyborg, 2008). Finally, when subjects may "vote with their feet" for local institutions and choose between groups with or without punishment mechanisms, they initially separate, with only the most cooperative joining the punishment community. However, the entire population eventually gathers in the community with punishment and achieves high levels of efficiency (Gürerk, Irlenbusch, and Rockenbach, 2006).

Many important aspects of this problem remain unexplored. In addition to having different preferences for contributing or free-riding, as these studies suggest, individuals in a society typically obtain varying benefits from public good consumption. These differences are at the core of the preference revelation problem and the inability of a central government to efficiently provide public goods. While there have been several fixed-group public goods experiments considering heterogeneous preferences, there has not been any experimental work that incorporates such differences into the local public goods framework, and, to my knowledge, this is the first experimental study on the dynamics of group formation when agents have heterogeneous preferences.

2.2 Experimental Design

2.2.1 Setting

The experiments in this chapter consider a local, linear public good that is provided by voluntary contributions from community members. There are nine agents in the population and six available locations. In each period, agents make the dual choice regarding where to locate and how much to contribute to their community once they are there. Each agent belongs to exactly one community in each period, and consumes only the public good provided within his location (there are no spillovers).

[8]Experimental studies that have found sustained cooperation in groups formed of previously cooperative subjects include: Gunnthorsdottir, Houser, and McCabe, 2007; Rigdon, McCabe, and Smith, 2007; Gunnthorsdottir, Vragov, McCabe, and Seifert, 2008; Yang, Yu, and Yue, 2007; Cabrera, Fatas, Lacomba, and Neugebauer, 2009; Burlando and Guala, 2005; Ones and Putterman, 2007; and Gächter and Thöni, 2005. The one exception is Ockenfels and Weimann (1999), which uses the very low MPCR of 0.33, a value at which contributions tend to be low even among cooperative subjects.

All agents have the same per-period endowment of 25 units each and differ only in their *marginal per-capita return (MPCR)*, which is the increase in profits that the agent receives from someone in his community contributing an additional unit to the public good. Agents whose payoffs are sensitive to congestion experience declining MPCR over the number of members in their community. Let L_t^i be the location that agent i chooses in period t. In each period, each agent i receives a payoff that depends on his personal contribution, c^i, the total contributions made at his location, the total number of members at his location, $n(L_t^i)$, and any entry fees he may have incurred by selecting a different location than in the previous period, $f(L_t^i)$.

In each period t, agent i's payoff is equal to:

$$\pi_t^i = 25 - c_t^i + MPCR^i(n(L_t^i)) * \sum_{j|L_t^j = L_t^i} c_t^j - f(L_t^i) * 1_{L_t^i \neq L_{t-1}^i} \tag{2.1}$$

where MPCR is equal to:

	Congestible Public Good Sessions	*Pure Public Good Sessions*
Low Types:	$MPCR = 0.15$	$MPCR = 0.15$
High Types:	$MPCR = 1 - 0.08(n(L^i) - 1)$	$MPCR = 0.8$ if $n(L^i) > 1$ $MPCR = 1$ if $n(L^i) = 1$

Entry fees are the same for all agents and vary by location entered: three of the six locations have an entry fee of 5 units and the other three locations have an entry fee of 15 units. In each population of nine agents, there are five "High Types" whose MPCR is very high, such that they greatly benefit from local public good provision. In the congestible public good sessions, the MPCR of the High Types declines sharply with the number of other members in their community, thus making them very sensitive to the presence of free-riders. In the pure public good sessions, their MPCR remains high regardless of the community size. In both pure public good and congestible public good sessions, the MPCR is set at 1 when a High Type is in a community by himself, thus ensuring that between-condition differences are not driven by signaling costs. The remaining four agents in the population are "Low Types" who have an extremely low marginal per-capita return, which is constant across the number of members.

When the public good is congestible, the most efficient outcome occurs when all High Types and two Low Types locate within a single location and contribute their entire endowment of 25 units each, while avoiding the other two Low Types who locate elsewhere and contribute nothing. When the public good is pure, the most efficient outcome has all High Types and Low Types in a single location, contributing their full endowments.

2.2.2 Experimental Procedure

Experiments were conducted using the experimental software z-Tree (Fischbacher, 2007) in the Laboratory for Experimental Economics and Political Science at the California Institute of Technology and in the Harvard Decision Science Laboratory at the Harvard Kennedy School of Government. Nine subjects participated in each session, and were paid based on their performance in the game. There were thirteen sessions in total: six in which the public good was pure (non-rivalrous) and seven in which the public good was congestible.

In the initial period of each session, the subjects were randomly assigned to three communities of three members each and chose how to allocate their endowment between private and public consumption. In subsequent periods, all six locations were available, and the participants made their decisions in two stages.

First, the subjects chose whether to stay in their current location or to move to a different location for a fee. While making this choice, they were able to observe the total contributions and number of community members in all locations, as well as their own contributions and returns, in each of the previous three periods.[9] Movement into one of the three original locations incurred the low fee (5 units: equivalent to 20 percent of their per-period endowment) while movement into one of the other three locations incurred a much higher fee (15 units: 60 percent of their endowment). As shown in Equation 2.1, entry fees were subtracted from their payoffs at the end of the period and thus did not restrict contributions.

Once they made their location decisions, the subjects then observed how many others were in their chosen location and made a contribution to that community's public good. Subjects were able to observe only the number of people and the total contributions in the locations, and did not receive any information regarding the location of specific subjects or individual contribution levels.

[9]Through pilot experiments it was determined that subjects who were provided with the full history never looked back more than two to three periods while choosing their location. Thus the available history was restricted to three periods to reduce clutter and confusion.

2.3 Provision of the Public Good

I first analyze the voluntary provision of the local public good, before considering movement in response to local provision, the role of congestion in community stability, and the effect of entry fees in the subsequent sections. All of the results are presented separately for the congestible public good (CPG) and pure public good (PPG) sessions. It is worth noting at the outset that many of the differences observed between the two types of sessions appear to be driven by community instability and frequency of movement. In particular, there is a clear dichotomy in the pure public goods sessions. In half of these sessions, movement is very rare (occurring in 4% of opportunities) and the entire population is nearly always in a single community. In the other half of PPG sessions and the CPG sessions, movement is common (occurring in 16.9% of opportunities in the PPG sessions and 18% in the CPG sessions). This will be further discussed in Section 2.5, which specifically addresses congestion and community stability, but in the meantime I will mention any results that vary between infrequent movement PPG sessions and frequent movement PPG sessions.

The main insight emerging from the analysis of public good provision is that there is a pronounced difference in the contribution patterns of the two types. The High Types provide the local public good. While the Low Types contribute very little, the High Types contribute nearly half of their endowment and they sustain their contributions for the duration of the experiment. Finally, the High Types tend to contribute less in larger communities, even in the absence of congestion, while the Low Types contribute more.

Table 2.1 reports estimates of a regression of community provision on the number of residents of each type along with the number of periods that the community has been continuously populated (unpopulated locations are not included). Regressions are run separately for the congestible public goods and pure public goods sessions and standard errors are given beneath the coefficients.

First, we see that the presence of High Types has a large positive effect on community provision, while the presence of Low Types does not have a statistically significant effect. This is the case in both the congestible and pure public goods sessions.

Although contributing nothing is the dominant myopic strategy for both types, the High Types do contribute to the public good. The average contribution per period is 10.9 for High Types compared to only 3.2 for Low Types and the difference in contributions of the two types is significant at any reasonable level. This is consistent with previous results showing that MPCR

	Congestible	Pure
Number of High Types	9.6***	12.12***
	(.37)	(.58)
Number of Low Types	.18	.4
	(.47)	(.75)
Time Populated	-.32***	-.06
	(.04)	(.04)
Intercept	11.13***	4.0***
	(1.02)	(.51)
R^2	0.43	0.56
Observations	1109	852
** Significant at 5% Level *** Significant at 1% Level		

Table 2.1: OLS Regressions of Provision on Community Features

affects contributions.[10] There are no differences in average contributions between the pure public good and congestible public good sessions.

From Table 2.1 we also see that provision declines over the length of time that the community has been populated. In both the CPG sessions and the frequent movement PPG sessions, community provision is highest in the first period in which at least two subjects are in the community, peaking at approximately 37 and then declining by an average of 3 units in each of the next few periods.[11]

To understand the community dynamics we must also consider how the contributions of the two types change over time and in response to community size. In addition to the differences in average contributions, the types also exhibit differences in their contributions over time. Interestingly, part of this difference appears to be driven by how frequently the subjects are together in a single community.

Figure 2.1 shows the average contribution over time for each type. First, we see that the contributions of Low Types decline significantly over the course of the experiment and, in the CPG sessions, approach zero.[12] In contrast, the contributions of the High Types are sustained for the duration of the experiment. In fact, when the public good is congestible, approximately half of the

[10] See for instance: Isaac, McCue, and Plott (1985) and Isaac, Walker, and Thomas (1984).

[11] The formation of new communities is rare in the PPG sessions without frequent movement and so there are not enough observations to make meaningful statements about how provision changes in the early periods of the community.

[12] The decrease in contribution over time is significant for Low Types at $p < .001$ with fixed effects in both the CPG and PPG sessions.

High Types actually increase their contributions from the initial periods to the final periods.

There is evidence that this difference in contributions over time may be partially driven by community instability. If we exclude periods in the PPG sessions in which the entire population is located in a single community, the contributions over time exhibit the same patterns as in the CPG sessions. When all subjects are in a single community, the divergence in behavior between High and Low Types is less stark: Some Low Types continue their contributions to the end of the session, while most High Types moderately reduce their contributions. This suggests that subjects are more likely to contribute according to their type when communities are less stable.

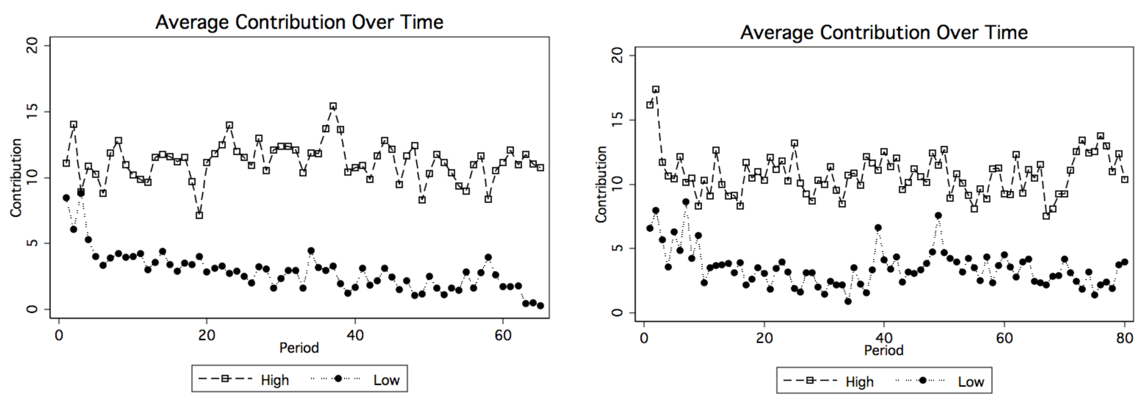

Figure 2.1: Average Contribution over Time in Congestible (left) and Pure (right) Sessions

We next look at how subjects' contributions vary over community size. Figure 2.2 shows the average contributions of each type over community size in the CPG and PPG sessions.

First, we see that the contributions of High Types decline over community size when the public good is congestible. This is not surprising, since the High Types in these sessions receive lower returns from public good provision in larger communities and we have already observed that the subjects' contributions are responsive to MPCR.

Communities may also experience *behavioral* congestion: Collective action problems would cause both types of agents, in both conditions, to contribute less in larger communities. In fact, Figure 2.2 shows that High Types' contributions also decline over community size in the PPG sessions, when MPCR is constant. High Types' contributions are negatively correlated with community size in both types of sessions (significant at the .01 level for each), with the magnitude of the effect approximately double in the congestion sessions.

In contrast, contributions of Low Types actually *increase* slightly over community size. Low

Type contributions are weakly positively correlated with community size in both the congestion and pure public good sessions, and both are significant at the .01 level.

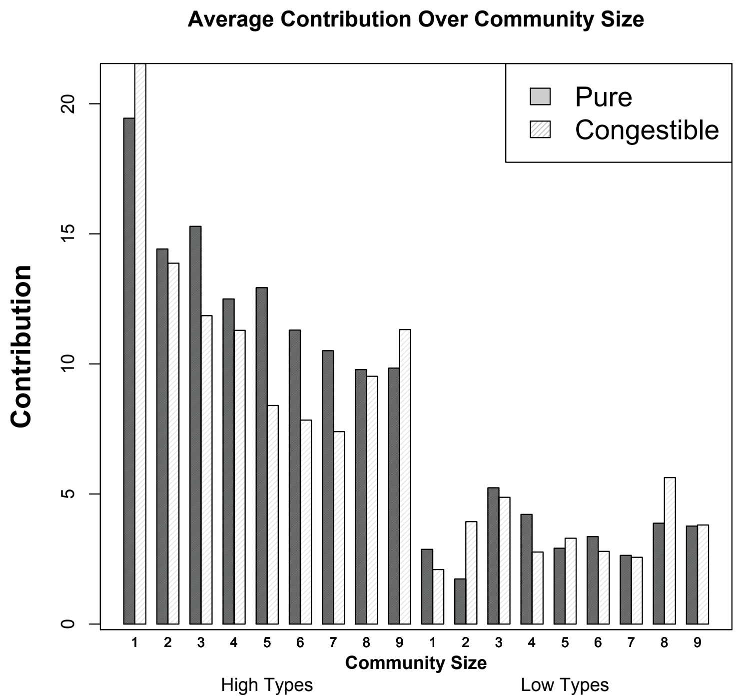

Figure 2.2: Average Contribution by Community Size

Similarly, community size has a significantly negative effect on the likelihood of the High Types contributing any non-zero amount in both the congestible and the pure sessions, and a significantly positive effect on the likelihood that the Low Types contribute.

2.4 Movement in Response to Public Good Provision

I next analyze the extent to which movement is influenced by local public good provision for each of the two types of agents. While the voluntary contribution mechanism differs from the environment considered by Tiebout and the incentives for location choice are very different in this game, movement in response to variation in local provision history does provide support for Tiebout's fundamental premise. The results described in this section strongly suggest that subjects move in response to provision and, further, that this movement is greatly shaped by their returns from provision.

First, subjects are most frequently in the community with the highest provision level and typically move if there is a community with vastly higher public good provision than in their own. Figure 2.3 presents cumulative distribution functions for subjects of each type in both the CPG and PPG sessions. The horizontal axis shows the discrepancy between the total contributions in the subject's location and those in the location with the highest total contributions.

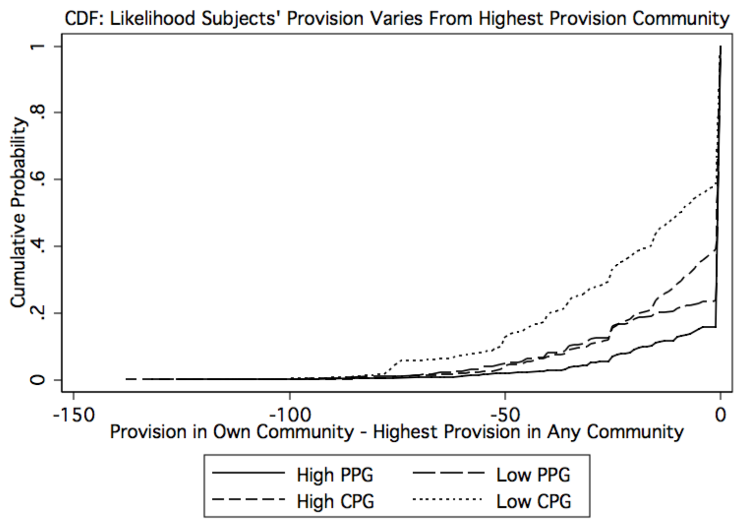

Figure 2.3: Likelihood that Subjects Are in a Community with Inferior Provision Levels

The likelihood that subjects are in an inferior community clearly depends on the magnitude of the difference in provision levels. Subjects are in the community with the highest total provision 52% of the time in the congestion sessions and 80% of the time in the no congestion sessions. This suggests that multiple populated communities can persist only if they offer similar provision levels.

To ascertain the main driving forces behind the movement decision, I estimate a series of probit models of the subjects' decisions to move based on several features of their community in the previous period as well as its performance relative to the other available communities. Specifically, the explanatory variables considered are: the difference in community provision relative to the highest provision community (*provision difference*), the difference in per-capita community provision relative to the community with the highest per-capita provision (*per-capita difference*), the difference in the subject's payoff in the previous period and the highest payoff he would have received had he been in a different community making the same contribution (*best alternative difference*), and the difference between the subject's contribution and the average contribution in the community (*contribution deviation*). The estimates are presented in Figure 2.4.

First, these estimates show that the probability of exiting a community is significantly driven by the difference between provision in one's own community and in the community with the highest provision. Second, the decision to move is also significantly affected by the difference in *per-capita* contributions and, in conjunction, these two variables have more explanatory power than how much a subject's payoffs differ from the best he could have done. Finally, High Types are more likely to exit communities when their personal contribution exceeds that of the community average.

CONGESTIBLE PUBLIC GOOD SESSIONS								
	HIGHS				LOWS			
Provision Difference	0.021*** (.002)	0.014*** (0.002)	-	0.014*** (0.002)	0.017*** (0.002)	0.016*** (0.002)	-	0.014*** (0.002)
Per-Capita Difference	-	0.039*** (0.004)	-	0.039*** (0.004)	-	0.024*** (0.005)	-	0.027*** (0.005)
Best Alternative Difference	-	-	0.031*** (0.002)	-	-	-	0.108*** (0.011)	-
Contribution Deviation	-	-	-	0.022*** (0.005)	-	-	-	-.035*** (0.01)
Intercept	-0.99*** (0.039)	-1.22*** (0.048)	-1.144*** (0.046)	-1.27*** (0.05)	-1.454*** (0.06)	-1.501*** (0.073)	-1.463*** (0.062)	-1.82*** (0.094)
Log Likelihood	-926	-883	-905	-865	-569	-568	-573	-552
Observations	1875	1875	1875	1875	1500	1500	1500	1500
PURE PUBLIC GOOD SESSIONS								
	HIGHS				LOWS			
Provision Difference	0.036*** (0.002)	0.028*** (0.003)	-	0.029*** (0.003)	0.039*** (0.002)	0.033*** (0.002)	-	0.032*** (0.002)
Per-Capita Difference	-	0.059*** (0.005)	-	0.06*** (0.005)	-	0.035*** (0.005)	-	0.034*** (0.006)
Best Alternative Difference	-	-	0.038*** (0.002)	-	-	-	0.25*** (0.014)	-
Contribution Deviation	-	-	-	0.014*** (0.005)	-	-	-	0.008 (0.009)
Intercept	-1.47*** (0.041)	-1.77*** (0.053)	-1.53*** (0.044)	-1.18*** (0.057)	-1.801*** (0.06)	-2.03*** (0.076)	-1.83*** (0.06)	-2.01*** (0.08)
Log Likelihood	-678	-596	-668	-592	-435	-415	-433	-415
Observations	2295	2295	2295	2295	1836	1836	1836	1836

Figure 2.4: Probit Estimates of Movement Decision

When the subjects do move, they typically select the community that performed best in the previous period, based on either total or per-capita contribution levels, or the community that would have given them the highest payoff in the previous period. Figure 2.5 shows the likelihood that the subjects who move make the "best" location choice by entering the community with the highest average or total contributions, by entering the community in which they would have received the highest payoff had they been in that community making the same contribution in the previous period, or by entering a community satisfying at least one of these three criteria. These graphs exclude the movement of subjects into previously empty locations, as such moves are never myopic best responses and, as we will see later in this section, these subjects exhibit other strategic differences.

Figure 2.5 shows that the counterfactual tends to best explain which community the subjects enter in nearly all of the conditions, though there is considerable overlap and the difference is slight. While Low Types are just as likely to choose their new community based on total contributions or average contributions, High Types are more attracted to communities with greater per-capita contributions – even when there is no congestion in their payoffs.[13] Subjects select the previously best performing community with a frequency significantly greater than if they were choosing randomly, either among all of the locations or among all of the low entry fee locations.[14] However, neither are they fully myopically best responding to the previous state.

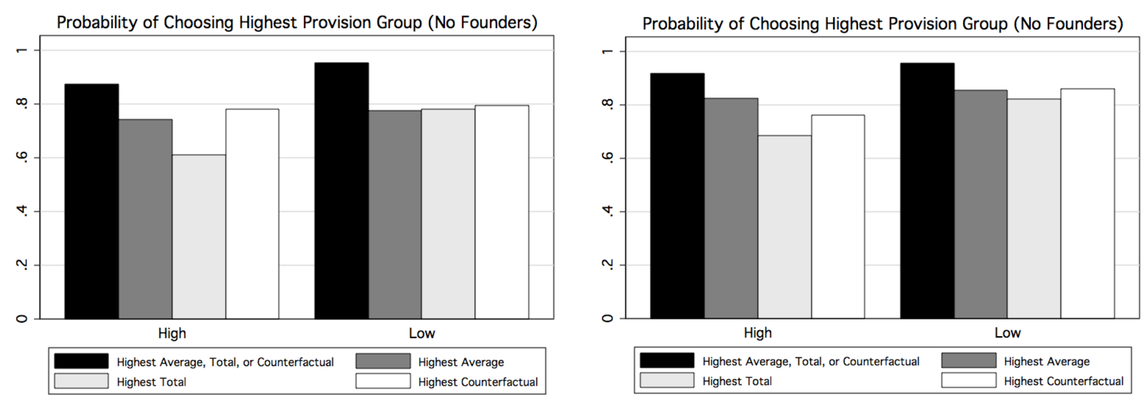

Figure 2.5: Probability Subjects in Congestible (left) and Pure (right) Sessions Move to Highest Provision Community

I next analyze how movement patterns vary for each of the two types.

High Types have a much lower threshold for exit than Low Types and, though in similarly sized communities, High Types experience higher provision levels than Low Types. Figure 2.3 clearly shows that High Types are more likely to be in the community with the highest provision level than the Low Types are, suggesting that the entry fees do generate some sorting.

Figure 2.6 presents the provision levels and sizes of the communities entered and exited for each preference type and each condition. The darker gray bars show the average provision and population size in the community *exited* (not including the subjects themselves or their own

[13]These likelihoods are identical for Low Types in the PPG and CPG conditions. High Types are more likely to enter the community with the highest average contributions than they are to enter the community with the highest total contributions and this difference is significant at the $p < .001$ level in both conditions.

[14]All $p < .001$

personal contributions) and the lighter gray bars show the average provision and population size in the community *entered* (based on the outcomes in the previous period, which is the information the subjects had while making their movement decisions).

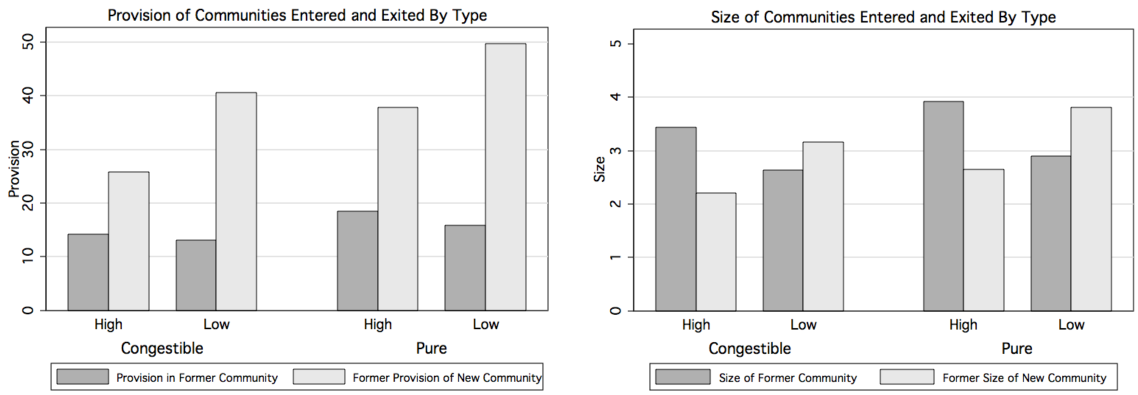

Figure 2.6: Features of Communities Entered and Exited

While both High Types and Low Types tend to exit communities where the others are contributing little in favor of communities with much higher provision levels, the average provision in the community entered is much greater for the Low Types. This is shown in the left panel of Figure 2.6. The first thing to note is that the provision level in the exited community is significantly lower than in the entered community for both types in both conditions. Second, this difference is smaller for the High Types, further suggesting that they have a lower threshold for movement. In the CPG sessions, the High Types who move enter communities with a previous provision of 25.8 while Low Types move into communities with a previous provision of 40.6. This difference is similar in the PPG sessions: The communities entered by High Types have an average previous provision of 37.9 while the communities entered by Low Types have an average previous provision of 49.7.[15] This suggests that entry fees do deter Low Types from moving into higher performing communities unless these communities offer substantially greater provision.

In addition to differing in their responsiveness to public good provision, the two types also respond very differently to community size and membership. The right panel of Figure 2.6 shows that the two preference types exhibit opposing patterns of movement based on community size. While Low Types exit smaller communities in favor of larger ones, High Types actually tend to exit very large communities and enter small communities. Importantly, this pattern holds in both the

[15] The difference between types in the provision of the community entered is significant at $p < 0.001$ in the CPG sessions and $p = .06$ in the PPG sessions in two-sided t-tests with fixed effects.

congestible and the pure public goods sessions, in which the presence of others does not diminish the payoffs of the High Types.[16]

The High Types are also much more likely to *found* communities, by moving into previously empty locations. Seventy of the seventy-eight founders in the congestion sessions are High Types and forty-two of the fifty-nine founders are High Types in the pure public good sessions. Given that we observe High Types entering smaller communities than the Low Types do, it is important to note that this difference in community size is not driving the result that High Types have lower thresholds for movement (by dragging down the average provision of the community entered). The pattern depicted in the left panel of Figure 2.6 holds even if we exclude those subjects who move into previously empty locations or locations with provision lower than in their former community.

When subtypes are classified by contribution level, the differences in contributions among the High Types are strongly associated with differences in movement patterns in the congestible public good sessions. The High Types who contribute more also move into smaller communities and repeatedly found new communities. Figure 2.7 presents the average contribution of each subject plotted against the average size of the communities he joined, along with linear fits for each type. When the public good is congestible, there is a very strong negative relation between the size of communities that High Types join and their average contributions.[17] There is no such across-subject association between size of communities entered and contributions when the public good is not congestible. This pattern exists only in those PPG sessions with frequent movement. In addition, the Low Types who found communities: 1) contribute more than other Low Types (both in the period that they found[18] and overall[19]) but less than High Type founders[20]; and 2) tend to exit communities of similar size as those communities exited by High Type founders.

In summary, we have thus far seen that the High Types provide the public good and that they are more responsive to differences in local provision, but they also respond to differences in per-capita provision and are willing to exit populated communities in favor of previously empty locations. When these results are considered together, a clear dynamic emerges in which the Low

[16]The difference between size of community entered and size of community exited is significant at the p = 0.01 for High Types and significant for Low Types only in PPG sessions at p = 0.05.

[17]Removing contributions to singleton communities – which is a costless signal for High Types – from the average does not alter this result.

[18]7.29 vs. 3.5

[19]6.04 vs. 3.5

[20]High Type founders contribute 22 units on average in the period they start a new community, while Low Types contribute 7.29.

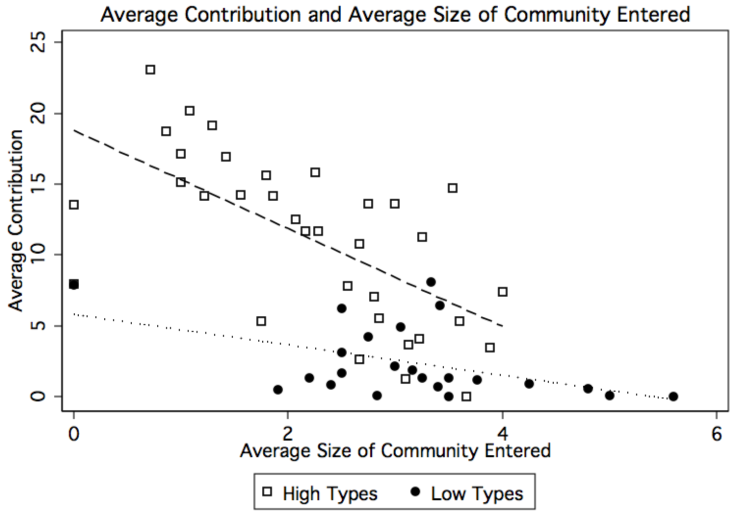

Figure 2.7: Average Contribution Vs. Average Size of Community Joined for Each Subject

Types continually chase the High Types through locations, a pattern that never ceases or slows over the course of experimental sessions. The High Types enter previously empty locations at an immediate cost to themselves and contribute once they are there. They are then joined by fellow High Types and provision peaks. The Low Types follow as soon as this new community surpasses their own, provision levels decline, and the High Types exit once again.

The dynamics of community composition are shown in the probit regressions presented in Table 2.2. These models estimate the likelihood that a subject resides in a location using the number of High Types present in the previous period, the number of Low Types present in the previous period, and the change in the number of High Types in the previous period, along with dummy variables for whether the subject was in that location in the previous period and whether the location has a high entry fee. These results show that both High and Low Types are more likely to be in a community where High Types resided in the previous period, as well as where there was a previous *influx* of High Types. Additionally, the presence of Low Types has a significant negative effect on the likelihood of High Types being in the community in the subsequent period. These patterns are the same for both the congestible and the pure public good sessions.

	Congestible		Pure	
	High Type	Low Type	High Type	Low Type
Number of Highs_{t-1}	.08***	.2***	.54***	.42***
	(.03)	(.03)	(.03)	(.03)
Number of Lows_{t-1}	-.12***	-.04	-.20***	-.07
	(.03)	(.05)	(.03)	(.05)
Number of Highs_{t-1}	.16***	.14***	.18***	.25***
- Number of Highs_{t-2}	(.04)	(.05)	(.03)	(.04)
High Entry Fee Location	-.04***	-.54***	-.50***	-.58***
	(.08)	(.11)	(.06)	(.08)
Previously in Community	4.07***	4.36***	1.82***	2.5***
	(.09)	(.116)	(.073)	(.1)
Intercept	-2.3***	-2.5***	-2.01***	-2.18***
	(.06)	(.080)	(.039)	(.05)
Log Likelihood	-689	-418	-1566	-1018
Observations	11460	9168	13590	10872

* Significant at 10% Level ** Significant at 5% Level *** Significant at 1% Level

Table 2.2: Community Composition Dynamics: Probit of High or Low Type Currently in Community on the Previous Community Composition

2.5 The Role of Congestion in Community Stability

Congestion plays an important role in community stability. Movement is far more frequent when the public good is congestible, and the subjects are typically dispersed across several locations. There is a sharp division between sessions when the public good is pure, allowing them to be easily classified into two categories. In one-half of the pure public goods sessions, community stability is similar to the congestible sessions. In the other half, movement is rare and the entire population resides within a single community during most periods.

Movement is frequent in the congestible public good sessions – occurring in over three-quarters of all periods – and does not cease or slow over the course of the experiment. Overall, movement is moderately less common when the public good is pure. Subjects move in 18.35% of opportunities in the CPG sessions compared to 10.8% of opportunities in PPG sessions, suggesting that approximately 41% of the movement is driven by congestion. There is considerable variation in the population dynamics between sessions when the public good is pure. In two sessions, subjects move more than 18% of the time (equivalent to the congestion sessions), while in other sessions they move as infrequently as 1% of all opportunities.

Figure 2.8 shows the distribution of the number of populated locations per period in both the CPG and PPG sessions. This figure shows that there are typically three or more communities in existence when the public good is congestible. The entire population of subjects resides in a single community during these sessions in less than 7% of all periods. This contrasts sharply with the pure public good sessions, during which subjects are most frequently in a single community.

Again, this result varies starkly across pure public good sessions. In the three sessions with the least movement, all subjects are together in 72.3%, 73.8%, and 93.8% of periods respectively, while in the other three sessions subjects are together only 10%, 26.3%, and 36.3% of periods.

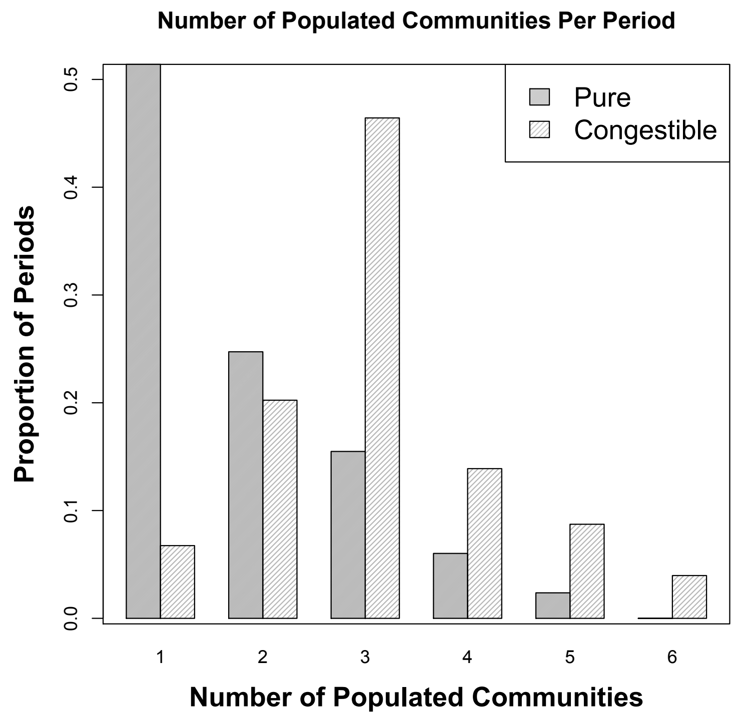

Figure 2.8: The Number of Populated Communities Per Period in Pure and Congestible Sessions

There are clearly observable patterns in how these differences arise. At the beginning of each session, subjects typically attempt to create one all-inclusive community, and most participants move into the same location by the fifth or sixth period. In the CPG sessions, contributions decline, this community is soon deserted, and after the fifteenth period there are typically at least three populated communities in any period. Occasional renewed attempts to establish larger communities also quickly disintegrate. In PPG sessions not characterized by frequent movement, the all-inclusive community endures over most periods, and exit is occasional and temporary. This process of exit and re-entry is associated with a spike in contributions in the community. The average community provision level is 50.4 in the final period before the all-inclusive community breaks up and is 74.8 in the first period in which it has been re-formed.[21] This suggests that temporary exit may be used as a tool to sustain provision.

Whether the subjects' exit is temporary and they will soon rejoin the larger community, or others instead will join them in defection, depends on the relative provision levels offered in the old and new communities – though less is needed to entice High Types to follow when the public good is congestible. If a community founder offers a provision level that rivals that in the original community, exit becomes not just a temporary threat that increases cooperation, but instead sets off a cascade of movement to a new location. This, however, can only occur if contributions in the original community have deteriorated dramatically – so that one subject's contribution rivals that of eight – or if a subject founds another community before the others have fully coordinated on a single other location. The substantial between-session differences appear to be driven both by the willingness of some subjects to follow a community founder even when the payoffs in their current community are higher and by the willingness of some subjects to continue founding communities before the other communities have stabilized.

Table 2.3 shows the number of singleton communities in CPG, frequent movement PPG, and infrequent movement PPG sessions, along with how often the community is either eventually joined by others or eventually abandoned by the single member. The fate of singleton communities appears to capture the between-session differences in community stability. In sessions characterized by frequent movement, communities with a population of one are typically joined by others. In both the CPG and the frequent-movement PPG sessions, others eventually enter the community 83% of the time, compared to 38% of the time in the PPG sessions with frequent movement.

Finally, I consider whether movement in the congestible and pure public goods sessions may be considered a best-response. The results in Section 2.4 suggest that subjects who move tend to select the community in which they would have done the best in the previous period, but the question remains whether such movement is, in fact, profitable. Though it is impossible to construct a perfect counterfactual for their continuation payoffs had they not moved, this question may be analyzed through a couple of other approaches.

First, I consider the immediate effect of movement on subjects' earnings. Table 2.4 gives fixed

[21]This difference is significant at $p = 0.01$.

	Congestible	Pure; Frequent Movement	Pure; Infrequent Movement
% of Populated Communities that are Singletons	33%	31.5%	13.2%
Persist to Next Period	67.8%	70%	65%
End with Defection (Community Disappears)	17.2%	16.67%	61.57%
End with Invasion (Community Grows)	82.8%	83.33%	38.46%

Table 2.3: The Growth of Singleton Communities

effect regression estimates of each subject's public good returns on the decision to move, along with the size of the community entered, and the subject's personal contribution. The first two columns show that movement is associated with slightly higher public good returns in the period that the subject moves. The third and fourth columns present estimates of the same model with the entry fee subtracted from public good returns. We see that, when the entry fees are accounted for, movement is associated with an immediate loss of 4.8 units in the CPG sessions and 5.7 units in the PPG sessions. Thus, while the subjects tend to better their location by moving, the difference is not great enough to immediately recoup the entry fees.

	Return from Provision		Return - Entry Fee	
	Congestible	Pure	Congestible	Pure
Move	2.00**	.64	-4.87**	-5.56**
	(0.41)	(0.76)	(0.41)	(0.762)
Community Size	.91**	3.42**	.96**	3.47**
	(0.08)	(0.11)	(0.075)	(0.11)
Contribution	.93**	.79**	.92**	.79**
	(0.02)	(0.03)	(0.02)	(0.03)
Intercept	3.41**	-3.57**	3.24**	-3.88**
	(0.45)	(0.90)	(0.45)	(0.91)
R^2	0.5	0.32	0.47	0.33
Observations	3438	4185	3438	4185
* Significant at 5% Level ** Significant at 1% Level				

Table 2.4: Fixed Effects Regressions of Public Good Returns on Movement and Features of the New Community

This, however, does not necessarily imply that the move does not increase the subject's payoffs over multiple periods, and so it is important to also consider the effect of movement on overall earnings for the experiment. Table 2.5 gives regression estimates of each subject's total profits

	Congestible		Pure	
	High Type	Low Type	High Type	Low Type
Moves	51.89***	31.47***	-84.65***	-17.6**
	(11.64)	(10.36)	(19.76)	(7.67)
Contribution	-6.05	-36.60*	-54.18**	-49.30***
	(15.88)	(19.58)	(23.14)	(14.21)
Intercept	1435***	1233***	5727***	2522***
	(217)	(129)	(319.2)	(96.56)
R^2	.35	.37	.49	.42
Observations	35	28	30	24

* Significant at 10% Level ** Significant at 5% Level *** Significant at 1% Level

Table 2.5: OLS Regression of Total Profits on Number of Moves

on the total number of times he moves during the experiment as well as his average contribution. When the public good is congestible, frequent movement is associated with significantly higher total earnings for both types. Additionally, there is only a small, statistically insignificant earnings advantage for those who "chase" rather than found and develop new communities, controlling for contributions.

Conversely, frequent movers of both types tend to earn *lower* payoffs in the pure public good setting. This effect is particularly large and highly statistically significant for the High Types: a single additional move is associated with a lower payoff of 85 units – over triple the subject's single period endowment and double the typical per-period earnings. This is strong evidence that movement is not a successful strategy for achieving higher provision when the public good is pure, and that frequent movement is not driven by payoff-based incentives.

2.6 Entry Fees

Finally, I consider the extent to which entry fees promote separation by type and local provision. Locations with differing entry fees can facilitate coordinated congestion avoidance. Since Low Types receive only a 15% return from the public good, best responders should move into a low entry fee community only if the difference in expected contributions between the new community and their current community is greater than 33. However, when the cost of entering is three times as great, the difference in contributions must be greater than 100 units for the Low Types to recoup the entry fee.

In CPG sessions, high entry fee locations are entered almost exclusively by High Types and both average and total provision levels are much higher there. High Types account for 85% of the movement into the high entry fee locations. Contributions in these communities are more than double the contributions in the low entry fee locations and total provision is also significantly higher. Figure 2.9 shows the total contributions and average contributions in low entry fee and high entry fee locations.

However, these communities are no more stable than the low entry fee communities and neither their population nor their provision levels are sustained for any longer. Thus, even when the High Types are able to successfully coordinate and separate, provision levels cannot be maintained and the free-riding and chronic relocation problems persist.

In the PPG sessions, high entry fee locations are entered less frequently. The Low Types are just as likely to enter as are the High Types and, while average contributions are higher in the high entry fee locations, total provision levels are lower. While subjects are in high entry fee locations approximately 11% of the time in the CPG sessions, they are in these locations only 6.8% of the time when the public good is pure. Although average contributions in PPG sessions are slightly higher in the high entry fee locations, the average population is less than half that in other communities, and the total provision levels do not rival those in the low entry fee locations.

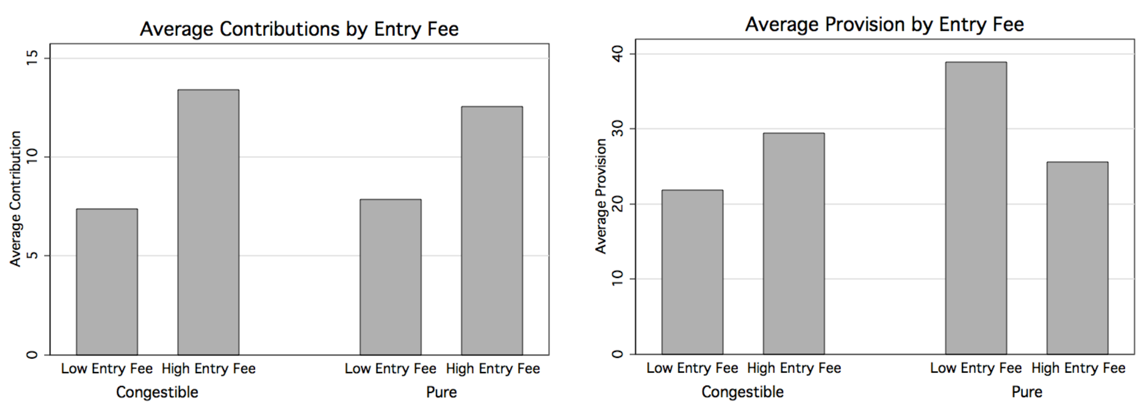

Figure 2.9: Per-capita Contributions and Local Provision by Entry Fee

2.7 A Note on Subject Pool Differences

While all the subjects in the pure public good sessions were Caltech students, subjects were drawn from three different pools in the congestible public good sessions. The subjects in the first three congestion sessions were Caltech students; in the second two sessions they were Cambridge, MA area residents (including students and non-students); in the final two sessions, participation was restricted to Harvard University students.

Across the CPG sessions, the public good contributions of Caltech students were the most responsive to differences in MPCR, followed by Harvard students, and the population that included non-students was the least responsive. All subjects in the PPG sessions were Caltech students and were no more responsive to differences in MPCR (which were primarily between-subjects) than were the Cambridge populations in the CPG sessions.

Due to the different subject pools and these noted differences in behavior, there is legitimate concern in comparing results from the congestible public good sessions conducted at both Harvard and Caltech to those from the pure public good sessions that were conducted entirely at Caltech, and attributing any differences solely to the rivalry of the public good. To address this concern, the PPG session results are also compared to the three Caltech-only CPG sessions. The graphs from this chapter are also presented for the Caltech-only subjects in Appendix B. In every result concerning differences between pure public good and congestible public good environments presented in this chapter, the differences are even more pronounced when only Caltech subjects are considered.

2.8 Conclusion

The pattern of those who impose negative externalities perpetually chasing those who impose positive externalities is a fundamental dynamic of community development and group formation.

This dynamic is borne out in the local neighborhoods of many cities, as artists and others with strong preferences for cultural and aesthetic amenities enter and rejuvenate commercial or depressed areas, only to attract further gentrification and eventually find themselves priced out of their new homes. Similarly, trendsetters are forever on the run from both conformists and marketers. Karni and Schmeidler (1990), for instance, show that social consumption preferences can lead to the cyclical nature of fads. Finally, the dynamic of chasing has also been observed in social dilemmas games, in which cooperators tend to be the first to exit uncooperative groups or partnerships and will be followed by free-riders in the absence of strict boundary rules (Ehrhart and Keser, 1999; Ahn, Isaac, and Salmon, 2008 and 2009).

In the experiments reported in this chapter, I find clear evidence of this pattern in a population of agents with heterogeneous preferences for public good consumption, even when those responsible for the congestion receive little benefit from movement and locating near others, and when there are significant barriers to entry. Further, while sensitivity to congestion does drive a portion of the flight from crowded locations, the dynamic often persists in the absence of payoff congestion. Movement continues even after a strong Nash stable partition has been reached and forward-looking agents have no incentive to coordinate on another location.

This suggests that this chasing dynamic is fundamental and intrinsic, rather than driven purely by congestion or payoff-based incentives. Even when efficiency would have a society pooling its resources into a single community, resentment or unwillingness to be around free-riders suggests that achieving stable groups and communities may be dependent on requiring equal contributions from all members.

Chapter 3

Local Institutions and the Dynamics of Community Sorting

3.1 Introduction

The ability of individuals to move between communities, groups, and organizations is fundamental. Mobility allows us to choose our friends and neighbors, to enter the locations that best satisfy our preferences, and to select the policies to which we must adhere. Americans are a particularly mobile population, with nearly fifteen percent of residents moving to a new location every year,[1] and how individuals choose their communities is a fundamental question. At the same time, one of the most important roles of local communities is to provide public goods and services, such as roads, parks, schools, libraries, police and fire protection, and so forth. Residents typically vary in their demand for these services, and how to provide them efficiently in light of this heterogeneity is a central problem of public economics.

The aim of this chapter is use laboratory experiments to study how populations with highly divergent preferences for public good provision sort themselves into local communities and to test the relative success of various institutions in promoting efficient local public good provision when residents are able to move between locations.

In 1956, Charles Tiebout suggested that mobility can lead to efficient public good provision. He introduced the idea of local public goods, which were excludable geographically, and proposed a market-based solution to the problem of efficient public expenditures at the local level. Tiebout's proposal was not presented, and likely not intended, as a descriptive model of residential choice and

[1] U.S. Census Data, 2000.

public finance, but as an innovative "conceptual solution" to the problem of demand revelation.[2] His paper was written in direct response to Musgrave (1939) and Samuelson (1954), who independently concluded that efficient provision of public goods through a decentralized pricing mechanism was impossible: Since residents who did not contribute to the financing of the public good could not be excluded from consuming it, they had incentives to under-pay, or strategically under-report their true demand, and to free-ride off of their neighbors.

Local public goods, on the other hand, allowed for spatial exclusion – since they were available only to those living within a jurisdiction, anyone wishing to consume the local public good would have to move into the community and pay the associated local taxes. If residents were able to move freely between jurisdictions then, rather than having to truthfully report their preferences within a community, Tiebout proposed that they would instead "vote with their feet" and relocate to the community that perfectly matched their needs. In doing so, households would reveal their true preferences and could thus be taxed according to their demand. Therefore, efficient public good expenditures could be achieved at the local level.

However, it is unclear whether the ability to vote with one's feet does in fact lead to optimal public goods provision. Since the inability to measure a household's true demand for public goods is the central motivation for Tiebout's proposal, it is perhaps unsurprising that attempts to directly test whether migration patterns are driven by preferences have proven difficult and that the evidence has often been varied and inconclusive. But public goods preferences can be readily generated in laboratory experiments by adjusting the payoffs that subjects receive from the outcome of a public goods game, and the dynamics of mobility and community formation may then be observed in a controlled environment. In addition, experiments can test the effectiveness of various institutions in facilitating efficient provision that would otherwise be very costly to assess in the field.

In this chapter, I conduct experiments to test elements of Tiebout's proposition. These experiments are not intended as a precise depiction of local public finance and residential choice in all its complexity, but, rather, as an attempt to gain insight into the fundamental mechanism and processes that Tiebout envisioned by studying movement decisions within a simple environment.

I consider whether mobility is, in itself, sufficient for achieving optimal public good provision, analyze the dynamics that may prevent optimality from being reached, and, given these dynamics,

[2] Tiebout (1956), p. 424. Oates (2006) provides a discussion of whether Tiebout intended his paper as a descriptive theory or purely as a clever thought experiment.

assess which institutions may be most successful in facilitating efficient self-organization. I find that the system dynamics are crucial for determining whether a population arrives at an efficient allocation and that an institution's success depends on its susceptibility to coordination failure.

This chapter considers a simple environment with three natural properties. First, the population has heterogeneous preferences for the public good: There are those who greatly benefit from the public good provided within their community, and those who benefit very little. Second, efficient public good provision is hindered by institutional design limitations. The preferences of the agents are unobservable to others, and so a single community cannot charge different prices to different preference types. Finally, there are multiple locations and agents have full mobility between them.

A voluntary provision mechanism, which allows residents to contribute different amounts within the same community and is therefore susceptible to free-riding, is compared with three different provision mechanisms requiring all residents to make the same local contributions. How the subjects' contributions are determined depends on the institution governing their experimental session.

Under the first institution, each location is associated with a different fixed, posted tax rate that remains the same for the duration of the experiment, and all subjects must contribute this amount in each period that they reside there. Among the locations are those offering the optimal tax rates for each of the preference types. Similarly, under the second institution, each location is associated with a fixed, posted total contribution level and all subjects must contribute an equal share of this amount. The final institution enables the communities to choose their own local taxes. In each period, the location's current members vote on the tax rate, the median voter's preference is implemented, and all residents are required to contribute this amount.

These latter three institutions generate the same unique strong Nash equilibrium in which agents separate and consolidate by preference type, and consume their optimal tax-provision pair. The first two reflect Tiebout's assumption that there exist a large number of available communities, representing a complete range of expenditure packages that are "more or less set" (Tiebout, 1956, p. 418). The voting institution incorporates a simple form of local governance that is responsive to the preferences of the current population.

Overall, I find that efficiency varies greatly across institutions. The means by which local contributions are determined influences both whether subjects reach an optimal partition across communities and whether they provide the optimal level of the public good for their community. While the existence of communities with fixed taxes or expenditures lead to moderate improvements in efficiency relative to the voluntary contributions equilibrium, these institutions still fall short of facilitating efficient public good provision. Only when subjects are able to vote on the local tax policy of the communities that they join do each of the preference types reach their optimal allocation.

I find that voluntary contribution communities are highly unstable. When subjects are able to contribute any amount they wish to the public good in their community, mobility is actually detrimental to efficiency. In this environment, the Nash equilibrium would have all subjects residing together in a single community, with free-riding causing the public good to be provided at approximately one-quarter of the optimal level. I find that the subjects instead waste their resources by forming multiple communities and diffusing their contributions across locations. The subjects continually move between locations throughout the experimental session, causing these locations to experience fluctuations in the local provision levels.

Even though the high demanders benefit most from being in larger communities where the public good is provided, they are typically the ones to initiate movement. The higher demanders often exit larger communities with declining provision in favor of smaller, less profitable ones, suggesting that residents may be unwilling to remain in communities where others are contributing less than they are.

Additionally, movement is associated with lower payoffs in the period the subject moves and frequent movers tend to earn less than other subjects, implying that movement is neither an immediate best response nor a successful strategy for increasing contributions and sustaining public good provision over the course of the experiment. Although the subjects in the voluntary contribution experiments converge toward the Nash equilibrium contribution levels, this chronic movement leads to efficiency significantly below that predicted under the Nash equilibrium for a single, fixed community.

Under all three institutions requiring all members of a community to make equal contributions, subjects successfully sort by type into the optimal partition of separate, homogeneous communities. The type of institution governing the experimental session determines the speed with which the population sorts, with subjects reaching the optimal partition twice as quickly when locations are associated with fixed tax rates than when the taxes are determined by member vote. However, once the subjects reach the sorted partition, movement is rare, leading to far greater stability than under the voluntary contributions institution and implying that the location where subjects of each preference type coordinate during the early periods determines where they will remain for the duration of the experiment.

When they are able to vote only with their feet, by moving between communities offering fixed taxes or provision levels, subjects often become stuck at local, inefficient equilibria such that they under- or over-provide the public good. Though they sort into separate, homogeneous communities, the subjects often fail to attain the optimal provision within these communities because they are unable to coordinate on the location offering the optimal tax-provision bundle for their type.

While the high demanders are more likely to move into less populated communities when the public good is provided voluntarily, this dynamic is reversed when the public good is provided through mandatory taxes. The high demanders benefit most from being around other taxpayers and rarely exit large communities with mandatory local taxes, even when public good provision differs from their optimum substantially, making them particularly susceptible to coordination failure. This suggests that the ability to vote with one's feet is not sufficient for achieving optimal outcomes. The existence of communities with optimally designed local tax policies does not guarantee that they will be entered and inertia, or the desire to be around others, can prevent optimality from being reached.

Under the voting institution, residents are able to vote both with their feet and with ballots. The subjects vote to enact their optimal tax rates, and the communities converge to the optimal outcomes for their populations. The ability to vote with their feet enables the subjects to sort by moving to the community that they like, while the ability to vote with their ballots enables them to then move the community to their liking once they have arrived.

This finding suggests that voting, or another mechanism that allows residents to internally influence community policy without needing to relocate, may be necessary for overcoming coordination failure and achieving optimal allocations. Although Tiebout did not address the question of local governance, these experimental results strongly suggest that both local politics and system dynamics may be essential for determining whether local public goods are provided efficiently.

The chapter proceeds as follows: Section 3.2 reviews theoretical extensions and empirical tests of Tiebout's hypothesis as well as previous experimental results on endogenous group formation; Section 3.3 sketches the simple Tiebout-style environment used in the experiments; Section 3.4

describes the experimental design; Sections 3.6 and 3.7 present the experimental results; and Section 3.8 concludes.

3.2 Local Public Goods, Community Sorting, and the Tiebout Hypothesis

The theoretical literature has since filled in and extended Tiebout's sparse framework, formalizing his insights while incorporating housing prices, land provision, spillovers and crowding, as well as considering income heterogeneity and redistribution, and analyzing the determination of public good supply and its political requirements. This literature suggests that sorting may be difficult to achieve and whether an efficient allocation is reached often depends on the specifics of the environment.

One approach has been to complete Tiebout's analogy of local public goods as private goods, by integrating the model into general equilibrium theory. This work has largely found that Tiebout's proposition holds only under highly restrictive conditions.[3] The general equilibrium interpretation is reflected in the experimental sessions in this chapter that have fixed local taxes or provision levels and offer agents a wide range of budget-balanced expenditure packages.

An alternative approach departs from Tiebout's assumptions by incorporating models of local governance and considers the simultaneity of selecting a community and voicing political preferences while there. These models have primarily focused on majority rule, and are captured by the voting institution considered in this chapter.[4] This literature strives to capture the highly complex process of residential choice, but often the resulting conclusions and equilibrium characterizations are dependent upon the particular features of the models.[5] The goal of this chapter is to strip away

[3] When the number of jurisdictions is fixed, often there does not exist an equilibrium that satisfies the First Welfare Theorem (for instance, Ellickson, 1979; Bewley, 1981). When allowing for the entry of entrepreneurial communities, approximate equilibria (ϵ-equilibria) may converge to Pareto optimality in large economies (see Wooders, 1999 for an overview).

[4] An exception is Kollman, Miller, and Page (1997), which considers a computational Tiebout model under democratic referenda, direct competition, and proportional representation institutions. They find that the institution that produces the worst outcomes in a fixed, single jurisdiction society is actually the most successful when agents can move between jurisdictions (and vice-versa), as the institutions that cause residents of heterogeneous communities to be least satisfied encourage exit and therefore promote sorting.

[5] Westhoff (1977) considers a majority voting rule by which residents select the level of public service expenditure within their community through the form of a tax rate, and establishes the existence of an equilibrium with separation by types. Rose-Ackerman (1979) adds divisible land markets and shows that equilibrium may not exist. Epple, Filimon, and Romer (1984/1993) introduce housing prices and characterize their equilibrium result with the property that communities populated by residents with the highest incomes also have the highest levels of public services and

this complexity, return to the simplified setting that Tiebout addressed, and to study the underlying dynamics of the residential sorting process in the absence of specific environmental factors.

There is also a vast empirical literature aimed at testing the implications of the Tiebout model within communities in the United States. Many studies have shown local sorting along demographic factors such as income, race, and education, as well as by political and cultural preferences.[6] However, the extent to which residents move in response to their preferences for public goods, sort into communities where other residents share their preferences, and consume their optimal package of local services, is far less clear (Dowding, John, and Biggs, 1994).

Consistent with Tiebout's assumptions, American cities vary greatly in public services provided and demanded.[7] While survey data have suggested that a household's decision to move is rarely based on public expenditure considerations,[8] there is also considerable evidence that public services (especially education quality) and tax rates are significant factors in neighborhood choice once a household has already decided to move.[9] However, the few direct tests of migration based on local policies and environmental impacts have produced conflicting conclusions.[10]

The difficulty in measuring public goods preferences and how they drive movement decisions suggests that laboratory experiments can play a significant role in understanding the mechanisms of residential choice and community sorting. The experiments in this chapter, which allow agents with different preferences to sort by local tax and provision policies, are the first of their kind, but build on recent experiments on voluntary public good provision in endogenously formed groups. Voluntary

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the highest housing prices. Other models determine public good provision through a wealth tax, either at the national or local level (Dunz, 1989; Nechyba, 1997). Konishi (1996) includes spillovers from other residents, as well as snob effects and demonstrates equilibrium existence with majority voting. Epple and Platt (1998) allow for preference heterogeneity, in addition to income variation, within this framework and find an equilibrium in which communities are heterogeneous along both income and preference dimensions while still satisfying the ascending bundles property. Pogodzinski and Sjoquist (1991) allow for differences in preferences, though not income, and find that the social choice rules within the jurisdictions determine the effect of production costs on capitalization. Others have shown that sorting can occur not only by the local policies, but also by community-wide values (Benabou, 1996a/b and Epple and Romano, 1998 address neighborhood and peer effects). Preferences over jurisdictional locale have also been incorporated, for instance by Cassidy, Epple, and Romer (1989), who assume that some locations are superior to others and by deBartolome and Ross (2003), who assume that location preference varies by income.

[6] See for instance: Costa and Kahn (2000) and Bishop (2008).

[7] Stein (1987) finds high variation in the bundles of services provided across communities. Gramlich and Rubinfeld (1982) find that variation in demand for public services is much lower within communities than throughout a wider population. Rhode and Strumpf (2003) found between-community disparities in local policies are on the decline.

[8] Rhode and Strumpf (2003).

[9] See for instance: Reschovsky (1979), Percy, Hawkins, and Maier (1995), and Fox, Herzog, and Schlottman (1989).

[10] For instance, a set of studies examining population changes in response to environmental impacts have found only marginal or no evidence of an effect on migration patterns (Been and Gupta, 1997; Cameron and McConnaha, 2006; Greenstone and Gallagher, 2008) while Banzhaf and Walsh (2008) find that increases in toxic air pollutants are associated with population decreases as well as exit of higher income households and/or entry of lower income households.

contributions experiments in fixed, exogenously assigned groups have consistently found that initial contributions are midway between optimal and Nash equilibrium levels, but that these contributions quickly decline and approach the theoretical equilibrium (Ledyard, 1995). Experiments that allow subjects to select their group in each period have shown that free-mobility is not sufficient to sustain contributions and, if movement is unrestricted, free-riders will chase cooperators from location to location (Ehrhart and Keser, 1999).

The experimental results presented in Chapter 2 show that, when subjects differ in the returns that they receive from the public good, there is a clear dynamic in which those who benefit the most from local provision found and develop groups. They are then followed by others even when entry fees are relatively large, provision declines, and the cycle restarts. This chasing phenomenon persists even when the public good is purely non-rivalrous, such that there is never monetary incentive to found a new group. This suggests that people are often unwilling to remain where others are contributing less than they are, and so group stability may be contingent upon requiring equal contributions from all members. This result is replicated in the experimental results of this chapter, but with one twist: With a non-linear payoff function, such that Nash equilibrium provision is greater than zero, the subjects' payoffs are lower than they would be if they were unable to move.

Implementation of formal boundary rules or other mechanisms that current members may use to control group composition have been highly successful in increasing and sustaining contributions, though subjects are sometimes prone to over-exclusion.[11] Finally, experiments have also shown that subjects will vote with their feet for institutions allowing them to punish free-riders (Gürerk, Irlenbusch, and Rockenbach, 2006).

3.3 Environment

I consider a basic Tiebout-style environment, in which residents may move between communities providing different quantities of the public good. In each time period, all agents simultaneously select their location, where they receive a payoff that is increasing over public good provision in the community and decreasing over the amount that they personally contribute toward provision.

There is a finite set of agents, $N = \{1, \ldots, n\}$, and of locations, $L = \{1, \ldots, k\}$.

[11] Ahn, Isaac, and Salmon, 2008/2009; Charness and Yang, 2010; Weber, 2006; Page, Putterman, and Unel, 2005.

A *state* $(\mathbf{l}, \mathbf{x})$ is an n-tuple of locations $\mathbf{l} = (l^1, \ldots l^n)$, where l^i is an integer between 1 and k, and an n-tuple of contributions $\mathbf{x} = (x^1, \ldots, x^n)$. In other words, l^i denotes where agent i resides, and x^i is agent i's contribution.

The feasible values of $\mathbf{x}$ follow one of two cases. In the first case, contributions are voluntary and, for all i, x^i may be any number greater than or equal to 0. In the second case, contributions are uniform for all members of a location, such that for any two agents i and j, $l^i = l^j$ implies that $x^i = x^j$. In this case, there is a mapping $t : L \Rightarrow \mathbf{R}^+$ such that $x^i = t(l^i)$. In other words, $t(l)$ describes the local tax associated with location l that all residents must contribute in each period that they reside there.

There exists a public good with three notable properties. First, the public good is purely non-rivalrous, such that it is not depleted by the presence of additional community members. Second, it is produced at constant returns to scale. Specifically, the public good provided is equal to the total contributions. Finally, the public good is local and there are no spillovers between communities: An agent's contributions finance the public good only within his location and an agent receives a return from a location's public good if and only if he resides there.

Let X^j be the quantity of public good provided in location j. Then,

$$X^j = \sum_{i|l^i=j} x^i \tag{3.1}$$

The non-rivalry of the public good is a departure from Tiebout's assumptions. He suggested production technology as the motivation for providing public goods at the local level and assumed that communities face a per-capita cost curve that is u-shaped over the number of residents, implying an optimal community size that is less than the total population.

These experiments consider a non-rivalrous public goods environment in order to study movement solely in response to preference differences, without the complication of crowding concerns that are particular to production technologies. In addition, if the population has highly divergent preferences and everyone within a location must pay a uniform local tax, then a pure public good in this environment need not imply that a population would prefer to cluster in a single location. The experimental design in this chapter has the property that preference types would prefer to separate when community members face a uniform tax policy. Finally, the pure public good environment gives subjects the best possible shot at being comparatively successful in the voluntary contributions case, when free-riding is the only obstacle to a society achieving the most efficient possible outcome by pooling its resources into a single community.

In each period, each agent i receives a payoff from residing in location l^i:

$$\pi^i(\mathbf{l}, \mathbf{x}) = A^i ln(X^{l^i}) - x^i \tag{3.2}$$

Agents differ only in the parameter A^i, which determines their marginal rate of substitution between the public good and private consumption.[12] It is easily shown that the best response of agent i is to contribute the exact amount necessary to bring the collective community contributions to A^i:

$$x^{*i} = max(0, A^i - \sum_{j|l^j=l^i, j\neq i} x^j) \tag{3.3}$$

This is the best response both myopically and in a game with a known, finite number of periods, as in the experimental design of this chapter (described in detail in the next section). Thus, when agents are able to voluntarily contribute any amount to the public good, in equilibrium each community's total provision will equal the maximum value of A represented in the community. However, the efficient level of provision for the community (which maximizes the aggregate payoffs of its residents) is equal to the *sum* of the parameters A in the community. Therefore, when contributions are voluntary, the public good is underprovided in equilibrium.

Under an institution with uniform tax policies, all residents of community j pay an equal tax, $t(j)$. In addition, let $n(j)$ denote the number of residents of community j. Then the payoff function in Equation 3.2 becomes:

$$\pi^i(\mathbf{l}, \mathbf{x}) = A^i ln(t(l^i) * n(l^i)) - t(l^i) \tag{3.4}$$

For any given number of residents, each agent has single peaked preferences over the community tax rates, such that i's utility is maximized at tax $t = A^i$. Thus, for each resident there is a trade-off between being in a large community and being in a community where the tax is close

[12] This is a modification of the Cobb-Douglas preference function that has several useful properties – in particular, that agents are strictly better off as the level of public good in their community increases, that each type of agent has a preferred tax policy, and that an agent's best-response is to contribute less than his preferred tax when contributions are voluntary.

to their ideal policy. When the values of A in the society diverge sufficiently, as in the experiments described in the following section, there does not exist any intermediate tax rate that would make all agents better off pooling their resources than they would be sorting by type and consuming at their optimal taxes in smaller communities.

In the experiments in this chapter, there are four agents for whom $A = 5$ (Low Types) and four agents for whom $A = 85$ (High Types). Figure 3.1 shows the payoff functions of each type over the tax rate, for communities of four agents (separate) and communities of eight agents (pooled). The range of taxes for which the High Types receive higher payoffs by pooling their resources in an eight-person community than by segregating in a four-person community with their optimal tax policy of 85 is: $t \in (19.72, 227.7)$. On the other hand, the Low Types would receive higher payoffs from pooling only if the larger community offered a tax in the range $t \in (1.16, 13.4)$. As these ranges do not overlap, there is no tax rate for which both types would receive higher payoffs by being in a single community than they would by separating.

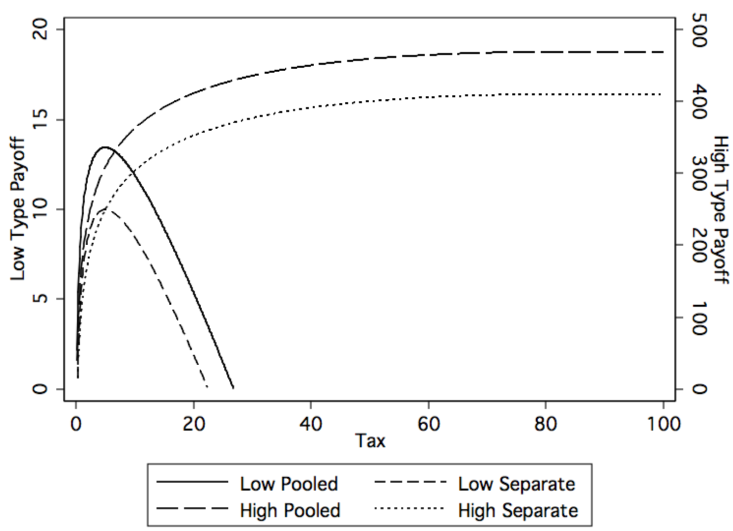


Figure 3.1: Payoff Functions for the Two Types in Communities of 8 (Pooled) or 4 (Separate) Agents

3.4 Experimental Design

All experimental sessions were conducted at the Harvard Decision Science Laboratory in Cambridge, Massachusetts. Participation was restricted to graduate and undergraduate students. Though most participants were Harvard University students, other local universities such as Boston University, Tufts, and Northeastern were also represented. Subjects participated in groups of sixteen people at a time, and interacted with seven anonymous others in the room using the experimental software z-Tree (Fischbacher, 2007).

Subjects played a twenty period repeated game. The number of periods was common knowledge. In each period, they first chose a location and then made a contribution to the local public good. There were six available locations, which remained the same for the duration of the experiment, and were labeled "Group 1" through "Group 6." Subjects received information on the previous outcomes in all of the locations, but not the location of specific others or their individual contributions. The method of determining the contribution the subjects made depended on the institution governing their session. The four institutions were Voluntary Contributions, Fixed Tax, Fixed Quantity, and Voting.

In the Voluntary Contributions *(VCM)* sessions, each subject could contribute however much they wished. The latter three institutions required all members of a community to make identical contributions.

Under the *Fixed Tax* institution, each of the locations was associated with a fixed, posted tax (t). Anyone who entered the location was required to contribute this amount in each period, for the duration of their time in that location. The provision quantity then depended on the number of residents who entered (i.e., t times the number of residents).

Under the *Fixed Quantity* institution, each location was associated with a fixed, posted provision quantity (X) that was provided in this location in every period in which it was populated. The per-capita taxes were then dependent upon the number of residents who entered (i.e., X divided by the number of residents). Among the available locations in the Fixed Tax and Fixed Quantity conditions were those offering the optimal bundles for each of the preference types in the experiment. These institutions are most similar to Tiebout's description of communities as offering public goods packages that remained fairly constant over time.

Finally, under the *Voting* institution, the location's current members voted on the local tax policy in each period. The median voter's preference was implemented and all members were then required to contribute this amount in the period.

A total of seventeen sessions were run: five sessions under the Voting institution and four under each of the other three institutions. Each session was populated by eight subjects. Four subjects in each session were randomly assigned to be "High Types," who greatly benefited from public good provision in their community, and four were "Low Types," who benefited very little. Subjects did not receive specific information on the payoffs of the other participants, but were aware that there was variation in the population.

At the start of each period, subjects simultaneously selected the location they wished to enter. They then submitted a contribution and received their payoff for the period. This payoff was given by Equation 3.2, in which $A = 85$ for High Types and $A = 5$ for Low Types.[13] Finally, they observed the outcomes of all locations over the previous three periods before making their next move. This included the number of residents and the subject's personal payoff from the location (in all conditions), along with any fixed policies associated with the locations (in the Fixed Tax and Fixed Quantity conditions), the previously enacted policies (in the Voting condition), or the total and personal contributions (in the Voluntary Contributions condition). Figure 3.2 shows the procedure of the stage game under each of these four conditions.

In the first period, all subjects, in all conditions, began in the same initial location. The policy of this location under the Fixed Tax and Fixed Quantity institutions was selected to be the same as the policy enacted in the Voting condition if all subjects voted for their ideal policy. Moving – selecting a different location than in the previous period – carried a cost of five experimental units.

A partition of agents is Nash stable if there does not exist any agent who would receive a higher payoff by unilaterally moving to a different location. A partition of agents is strong Nash stable if there does not exist any set of agents, all of whom would receive a weakly higher payoff and at least one of whom would receive a strictly higher payoff, by *coalitionally* moving to different locations.

Since the public good is pure, the state in which the entire population resides in a single location is strong Nash stable under Voluntary Contributions. However, under the Nash equilibrium contributions, this community under-provides the public good: the Low Types do not contribute anything and the High Types contribute 85 among the four of them. Thus the total provision level is equal to 85: less than one-quarter of the optimal level for the population.

The payoffs for the two types are sufficiently different that there exists a unique strong Nash

[13] Subjects were not presented with this equation directly. They were instead given payoff tables, showing the payoff they would receive for various combinations of total contributions made in their community and personal contributions. The experiment began only after all participants correctly answered a series of comprehension questions regarding the procedure and their payoffs.

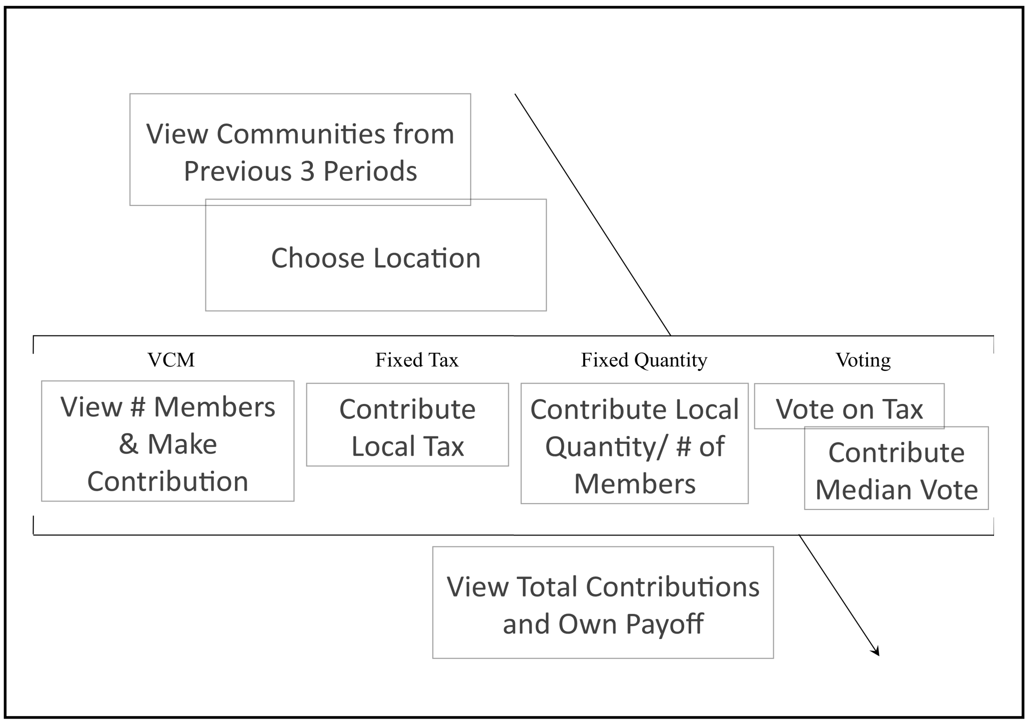


Figure 3.2: Experimental Procedure in Each Period under VCM, Fixed Tax, Fixed Quantity, and Voting

equilibrium under Fixed Tax, Fixed Quantity, and Voting in which the two types separate into two homogeneous communities where they consume the optimal tax-provision pair for their type. In this state, the Low Types are together in a location with $(t, X) = (5, 20)$ and the High Types are together in a location with $(t, X) = (85, 340)$.

However, under both Fixed Tax and Fixed Quantity, two forms of suboptimal Nash equilibria exist. In the first, the types separate and consolidate but are in locations where the tax policy differs from the optimal for that population. Though High Types would prefer to be in a community with $t = 85$, any state in which all four are together paying $t \in [8.7, 315]$ is Nash stable. Similarly, any state in which all four Low Types are together paying $t \in [0.5, 18.5]$ is Nash stable. The second form of suboptimal Nash stable states occur when the types are pooled in a single community with an intermediate tax policy. Any state in which all members are together in a community with tax $t \in [4, 23]$ is Nash stable, as no subject would wish to independently exit a community of seven others in favor of striking out on his own. Both of these are eliminated as equilibria under the Voting institution.

3.5 Ultimate Outcomes and Efficiency

This section examines the outcomes that the subjects reach by the end of their experimental session. The efficiency of the outcomes to which subjects converge vary greatly across institutions. When contributions are voluntary, subjects attain payoffs significantly below those of the Nash equilibrium. The subjects under both the Fixed Tax and Fixed Quantity institutions attain moderate payoffs, while the payoffs of those under the Voting institution nearly reach the strong Nash payoffs. Further investigation shows that subjects sort into homogeneous communities under all three of the tax institutions, and that these differences in efficiency are the result of subjects under the Fixed Tax and Fixed Quantity institutions providing a level of the public good that differs from their optimum.

3.5.1 Efficiency Convergence

I first compare efficiency convergence under the four institutions, relative to the baseline of the Nash equilibrium prediction under Voluntary Contributions, in which all subjects locate together but the public good is severely under-provided. The voluntary contribution Nash equilibrium is taken as the baseline since it is both the outcome that Tiebout was attempting to improve upon and the outcome to which standard public goods games tend to converge. The average efficiency over the final five periods of the twenty-period experiment under each institution is given in Figure 3.3.[14] The most efficient outcome is represented by the dashed line, but is achievable only when residents can solve the demand revelation problem within a single community. The strong Nash equilibrium is the highest feasible outcome when residents sort into multiple communities and is represented by the dotted line.

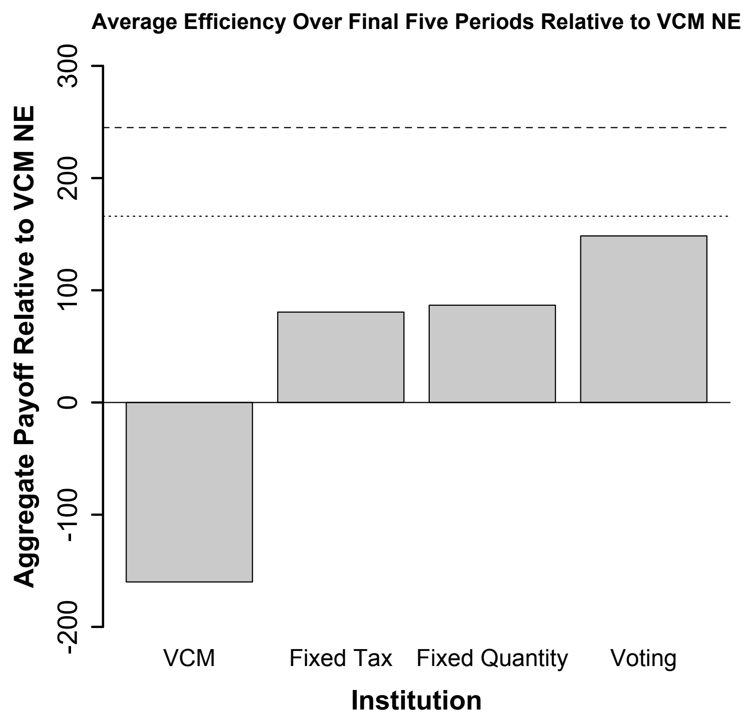


Figure 3.3: Average Efficiency under Each Institution

First, we see that the subjects achieve very low payoffs when contributions are voluntary, even relative to the Nash equilibrium prediction, suggesting that they are squandering their resources. Subjects may do worse than the Nash equilibrium outcome if they either locate in a single location but contribute less than the Nash equilibrium provision, or locate across multiple locations and diffuse their resources (or both). Further investigation into the cause of this inefficiency follows in the next section. Efficiency under both Fixed Tax and Fixed Quantity is significantly greater than the baseline, at 33% and 35% respectively – or approximately 50% of the strong Nash outcome.

[14]Efficiency is smoothed over the final five periods so as to avoid over- or under-emphasizing incidental deviations.

Finally, efficiency under Voting is significantly higher, and nearly reaches the strong Nash outcome. Thus, while the Fixed Tax and Fixed Quantity institutions lead to moderate improvements in efficiency relative to our baseline, they still fall short of facilitating efficient public good provision, and only under Voting do the subjects approach the optimal allocation.[15]

3.5.2 Sources of Inefficiency

There are two distinct causes of inefficiency in this environment: Subjects may fail to properly sort by type or, upon sorting, may fail to provide the optimal level of public good for their community.

I first look at whether subjects reach a sorted partition. Figure 3.4 shows the proportion of time, over the final five periods of the experiment, that the types are sorted into two separated, consolidated groups. A subject is sorted if he is in a location with at least two of the three others of his type, and with no more than one member of the other type.

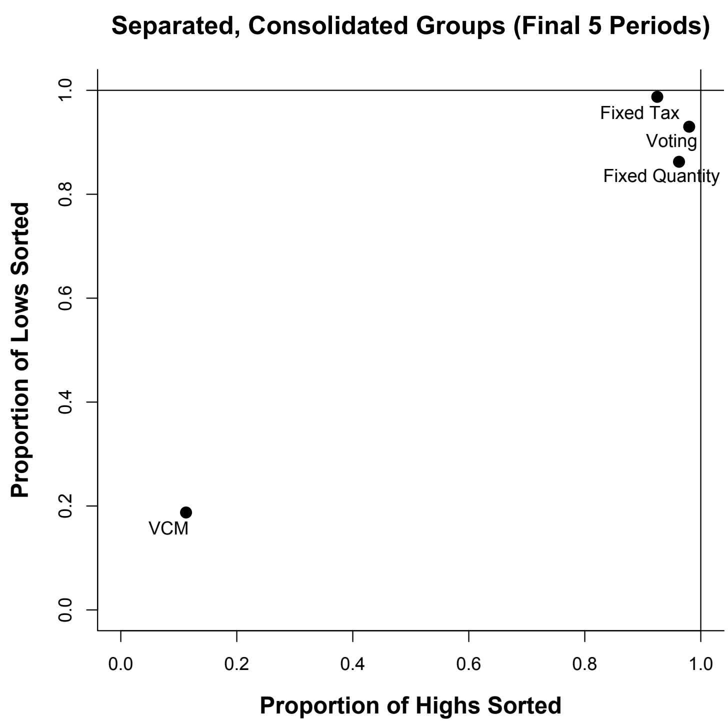


Figure 3.4: Sorting by Type in the Final Five Periods

[15]The effect of institution on efficiency is significant, VCM efficiency is significantly below zero, and Voting efficiency is significantly higher than Fixed Tax and Fixed Quantity efficiency, all at the .01 level.

For all three institutions under which community members must contribute equal amounts, subjects are highly successful in sorting into two homogeneous groups. Over the final five periods, subjects in these three conditions are sorted 94% of the time. While there is little difference in community composition by the end of the twenty-period sessions under Fixed Tax, Fixed Quantity, and Voting, the institutions do vary in how rapidly subjects sort. Subjects require an average of 2.5 periods to first reach a sorted partition under Fixed Tax, 3.6 periods under Fixed Quantity, 5.95 periods under Voting and 10.2 periods under VCM.

Although subjects are eventually well-sorted under all three tax institutions, the question remains as to whether they provide the optimal level of public goods for their type within these homogeneous communities. Unsurprisingly, contributions greatly differ from the optimal amounts when provision is voluntary. However, High Types under Fixed Tax and Fixed Quantity, as well as Low Types under Fixed Quantity, often deviate from their optimal contribution as well. Over the final five periods, High Types' contributions differ from their optimum by approximately 30% under both of these institutions, and Low Types' contributions differ from their optimum by 150% under Fixed Quantity. Finally, when subjects are able to vote for their local tax rate, contributions differ from optimal levels by 0.8% overall.

3.6 Dynamic Results

I next consider the dynamics under each of the four institutions that lead to these final outcomes. Although the subjects under the VCM institution contribute, on average, at the Nash equilibrium level, perpetual movement through locations leads to efficiency below that of the Nash equilibrium. Under the institutions requiring all members of a community to contribute the same amount, the High Types very rarely exit large communities with many tax-payers. In the Fixed Tax and Fixed Quantity sessions, this unwillingness to move into less-populated locations often results in the subjects becoming stuck at less efficient equilibria, in which public good provision differs from the optimum for their type. Finally, under the Voting institution, the communities converge to the optimal provision for their populations.

3.6.1 Voluntary Contributions

The top left panel of Figure 3.5 shows the average contribution over time for each of the two types under the VCM institution. This graph suggests that, although the subjects are free-riding, they are converging toward the equilibrium contribution level, and that the severe inefficiency we see in Figure 3.3 is therefore not driven by under-contribution relative to the Nash equilibrium level.

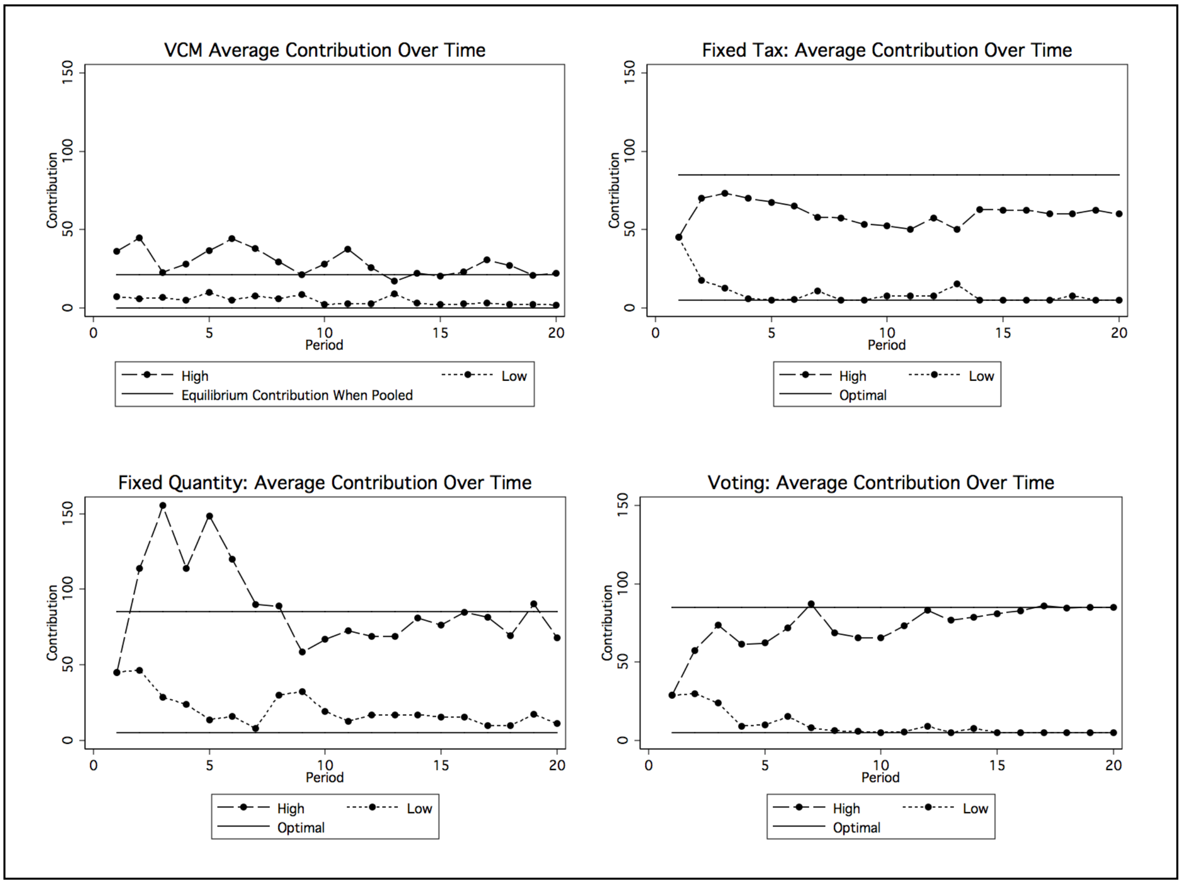


Figure 3.5: Average Contributions Over Time Under VCM, Fixed Tax, Fixed Quantity, and Voting

Although a partition with all members of the population in a single location is both efficient and strong Nash stable, subjects do exit the all-inclusive community and they continue to move over the course of the session. All of the subjects are together in a single location for only half of all periods. While movement significantly declines over time under all three institutions with local mandatory tax rates, there is no such stabilization under Voluntary Contributions and, toward the end of the session, movement occurs with more than twice the frequency of the other institutions.

Even though it is the High Types who benefit most from being in communities providing the public good, they are the ones who typically initiate this movement by exiting large communities in favor of previously empty locations. These dynamics are very similar to those previously found in Chapter 2, which considered a *linear*, pure public goods environment in which subjects with different returns from the public good could move between locations. There is a difference, however, in the efficiency relative to the Nash equilibrium. When payoffs are linear, no one contributes in equilibrium. But in an environment where public goods are provided in equilibrium, agents benefit from being in larger communities, and frequent movement may be harmful. Thus, in this environment, the ability to move leads to worse outcomes for the subjects than if they played the Nash equilibrium within a fixed group, and mobility is actually detrimental to efficiency.

Finally, we see that frequent movement is associated with lower payoffs. Table 3.1 presents fixed effects regressions of period-earnings on the subject's movement decision and contribution decision. Movement is associated with a large, immediate loss, though this is not significant when controlling for the size of the community that the subject enters. Table 3.2 presents OLS regression results of subjects' total payoffs on frequency of movement, average contribution and type. Those subjects who move frequently earn significantly less during the course of the experiment.

Earnings (Fixed Effects)	(1)	(2)
Move	-19.97*	-8.14
	($p < 0.001$)	($p = 0.186$)
Community Size	–	5.20*
	–	($p < 0.001$)
Contribution	-.48*	-.449*
	($p < 0.001$)	($p < 0.001$)
Intercept	187.95*	153.4*
	($p < 0.001$)	($p < 0.001$)
Observations	640	640

Table 3.1: Fixed Effects Regressions of Earnings on Movement

3.6.2 Fixed Tax and Fixed Quantity

The Fixed Tax and Fixed Quantity institutions are most similar to the environment envisioned by Tiebout: There exist many communities offering a wide range of exogenously determined local policies that remain constant over time. The residents, in turn, select the community whose tax-provision pair best suits them, but do not influence the local policies in their chosen community.

Total Payoffs (OLS)	
Moves	-88.28* ($p = 0.003$)
Contribution	1.53* ($p = .83$)
High Dummy	6512.3* ($p < 0.001$)
Intercept	479.02* ($p < 0.001$)
R^2	0.98
Observations	32

Table 3.2: OLS Regression of Total Profits on Number of Moves

While High Types are more likely to exit larger groups in favor of smaller ones under Voluntary Contributions, this dynamic is reversed when communities have mandatory local taxes. Rather than being attracted to areas populated by the contributing High Types, the Low Types now flee the taxes, while the High Types tend to be more attracted to populated areas (in particular: They are attracted to other taxpayers). The Low Types exit the all-inclusive group in their first opportunity 93.75% of the time under the Fixed Tax and Fixed Quantity institutions, while less than half of the High Types do so. The left panel of Figure 3.6 shows the average size of the community a subject exits, relative to the size of the community he enters, for each of the two types under both Voluntary Contributions and the exogenous tax policy institutions (Fixed Tax and Fixed Quantity). The right panel of Figure 3.6 shows how the likelihood that a High Type exits his community declines over the number of other High Types in the community, both when this community provides the optimal policy and when it does not. Although the High Types exit communities with policies that differ from their optimum more frequently, they rarely exit when two or three other High Types are present.

This unwillingness of High Types to exit larger communities causes them to be susceptible to a coordination failure where, though they consolidate into a location with other High Types, they fail to attain the optimal tax and provision levels for their type. Figure 3.5 shows the average contribution over time under Fixed Tax (top right panel) and under Fixed Quantity (bottom left panel).

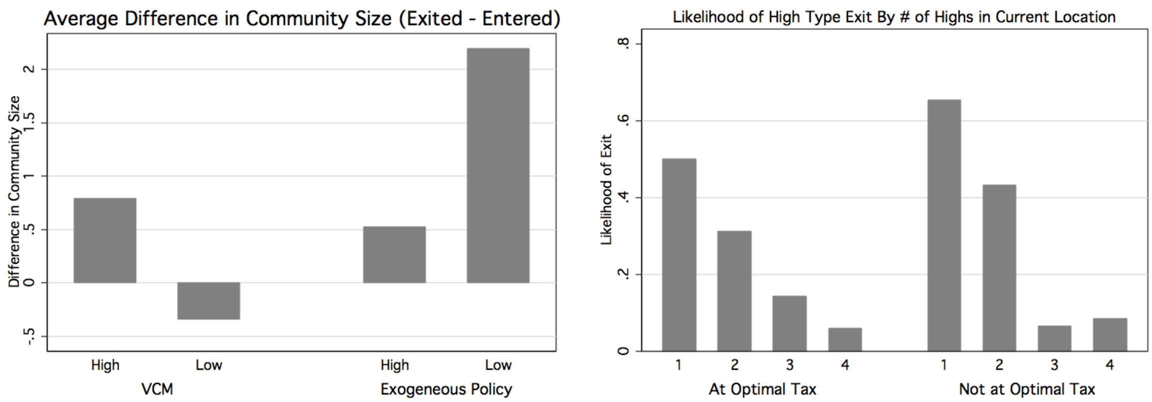


Figure 3.6: The Importance of Community Size in Movement Decisions of the High Types

3.6.3 Voting

While subjects under the Voting institution take longer to sort themselves into two homogeneous communities than under Fixed Tax or Fixed Quantity, once they coordinate they are less likely to move. Furthermore, 92.5% of subjects vote for their optimal tax policy by the end of the session, and so the optimal policies for each type are eventually implemented within the sorted communities. The bottom right panel of Figure 3.5 shows that the contributions of each type converge to their optimum under the Voting institution.

Thus mobility is most successful when communities have an internal process by which residents may adjust their local policies without being required to relocate. The ability to vote with one's feet allows types to separate and coordinate by moving to the community they like best. Subjects implementing their own local polices require only a few more periods to coordinate into separate, homogeneous communities than those choosing among locations with fixed policies. The ability to vote with one's ballot then allows the residents to adapt the community to their preferences, reducing the possibility that a community of like-minded residents fails to realize the policy best suited for them.

3.7 Conclusion

This chapter uses laboratory experiments to study the dynamics of movement and local public good provision in a simple Tiebout environment and to test the effectiveness of four different institutions in facilitating efficient public good provision. The results suggest that institutions determining the level of local public good provision within a community can greatly affect residents' ability to coordinate with those who share their preferences and to converge to an optimal outcome.

Voluntary contributions communities enable residents with different preferences to make different contributions, without the need to relocate or divide their resources over multiple communities, but are susceptible to the same free-riding and demand revelation problems that can plague public good provision at the federal level. This chapter finds that voluntary contributions communities are characterized by free-riding, instability, and inefficient movement and replicates the dynamics previously found in local pure linear public goods games with two types of agents. This suggests that these patterns and instability are robust to differences in the payoff function, with one distinction: When public goods are provided in equilibrium, this frequent movement may lead to efficiency significantly below equilibrium predictions, and mobility may actually be harmful to efficiency.

Taxes requiring all members of a community to make the same contribution to the local public good are highly successful at sorting subjects by preferences into consolidated, homogeneous communities. However, subjects often coordinate into, and remain in, communities offering suboptimal tax-provision bundles for their type. Inertia caused by the desire to be around others, for instance, as the result of community ties, suggests that mobility in itself is not sufficient for achieving an optimal allocation of public goods and that the existence of optimally designed policies is not sufficient for guaranteeing that communities offering these policies will be entered. (Potentially more concerning is the implication that new communities may then be entered only by the most extreme members of the society, whose preferences have not been satisfied elsewhere, and, if local policies cannot be adjusted when others follow, the society may wind up overly concentrated in communities with extreme policies.)

When subjects have an internal process for adapting the policies of the communities they have entered, the local communities converge to the optimal policies for their residents. While subjects require slightly longer to sort into homogeneous communities when fixed local policies are not provided, they are eventually just as successful at reaching an optimal partition and, when they can then vote on the local policy, residents converge toward consuming their optimal level of public goods.

Tiebout ended his discussion by asking whether local governments should have fixed expenditure policies (Tiebout, 1956, p.423). The results of these experiments suggest that, when agents have very different preferences, they will sort by preference type even when communities do not provide exogenous tax policies, and that local politics may be necessary for overcoming coordination problems, adjusting provision to the preferences of the residents, and reaching an efficient allocation.

Chapter 4

The Role of Institutions in the Partitioning of Heterogeneous Populations

4.1 Introduction

Populations with diverse preferences must often form and sustain heterogeneous groups to take advantage of increasing returns to scale and capture gains from pooling resources. For instance, individuals with differing ideologies often join together to form a single political party or coalition, and communities often build a single shared recreation facility even though residents may all prefer it to be located in their own neighborhood. This chapter uses laboratory experiments to study how agents partition themselves into groups when there are strong benefits to joining with others whose preferences for a group policy are not perfectly aligned with their own.

Overall, the experimental results suggest that the institution determining how group policies are chosen greatly affects whether agents reach optimal partitions. When group policies are fixed, such that they can vote only with their feet by moving between locations, subjects fully segregate by preference type. However, when mobility is combined with voting, such that agents may influence the policy of the group they join, most subjects succeed in forming groups of the optimal membership composition.

Two stability concepts are commonly considered in the literature concerning the partitioning of agents across communities, clubs, or other groups. The first corresponds to the Nash equilibrium, and a partition of agents is considered Nash stable if it is immune to unilateral deviations, such that no agent can gain by moving to a different group. These Nash stable partitions are typically numerous and inefficient. The second allows for coordinated movement, and thus corresponds to the strong Nash equilibrium.[1] Though such equilibria are Pareto efficient, they often do not exist. Moreover, the conditions for communication or competitive free-entry that would enable the system to converge to this equilibrium are fairly stringent and it is unclear whether an efficient stable partition may be reached by free-mobility, or whether all stable partitions will instead tend to be absorbing.

The goals of this chapter are: first, to provide a preliminary assessment of whether inefficient Nash stable states are, in fact, absorbing in a dynamic group formation game, or whether agents tend to reach efficient stable states when such exist; and second, to consider whether the means of establishing group policies determines into which stable partition agents sort themselves.

This chapter considers a simple experimental environment in which subjects can move freely between groups with various local policies. There are several available locations that remain fixed for the duration of the experiment and subjects play a dynamic game lasting for several periods. In each period, subjects simultaneously choose their location. They receive a payoff based on the number of other subjects who chose the same location and the group's policy on some unidimensional issue. The policy is simply a number in the [0,1] interval, and subjects are assigned symmetric, single-peaked preferences over the interval at the start of the experiment. This policy can be interpreted as any outcome that applies indiscriminately to all group members, such as the local tax rate in a community, the platform of a political party or organization, the location of a club facility, or the type of good consumed within a club. The agents thus face a trade-off between being in a group of optimal size versus being in a group where the policy is closest to their ideal. Here, the groups do not experience any congestion, and so the optimal group size is simply equal to the entire population. However, when agents have sufficiently divergent preferences and all members of a group are bound by the same local policy, they may receive higher payoffs by sorting into smaller groups with policies closer to their ideal.

How the group policy is determined varies by experimental session: In the *Fixed Policy* sessions, each location is associated with a fixed, posted policy, while in the *Voting* sessions, the policy is chosen in each period by member vote. In this environment, all Nash stable partitions will be *sorted*, in the sense that agents of similar types will locate in the same group. However, where

[1] This dichotomy originates with Tiebout (1956), which seemingly refers to both types of deviations without distinction. Within these broad classifications, the definitions vary as well, both with respect to whether agents can relocate only to extant groups, or are able to establish groups of their own, and whether agents can coalitionally relocate only alongside those in their previous group or they are able to coordinate with any agents in the population.

the dividing lines are drawn may be inefficient, such that some Nash stable partitions are Pareto dominated. In these experiments, the same set of Nash stable partitions exists in both the Fixed Policy and the Voting conditions. Additionally, the same unique strong Nash stable partition exists in both conditions and occurs when two groups form, each comprised of those whose ideal points fall along one-half of the [0,1] interval. In other words, the optimal outcome for the population requires the formation of groups with heterogeneous membership and an intermediate, compromise policy, but there exist other, less efficient, equilibrium partitions in which more groups form.

The literature on endogenous group formation began with work in both local public finance (Tiebout, 1956) and club formation (Buchanan, 1965), though in neither model does efficiency necessitate agents of different preference types joining together to form a stable group. In Buchanan's original model, all agents were identical and the balance of positive and negative externalities imposed by each implied a common and finite optimal group size. Tiebout, in contrast, considered a population with heterogeneous public good preferences, but also assumed an optimal group size that was small relative to the population, such that agents could select a community offering an expenditure package that precisely matched their preferences, assuring that homogeneous communities would form and, therefore, making compromise unnecessary and local governance irrelevant.

Following Westhoff (1977), both the local public finance literature and club formation literature have explored the tension between increasing returns to group size and preference heterogeneity. A common conclusion is that if there is a single parameter by which agents' preferences can be ordered along a single dimension (as is the case with the preferences assigned to subjects in the experiments in this chapter), then an efficient, stable partition exists in which agents of similar preferences cluster together.[2] However, there has been little work on the dynamics of group formation, and the conditions under which a population may reach an efficient partition remain largely unexplored. One exception is Arnold and Wooders (2005), which presents a dynamic group formation model in which agents who are myopically best-responding to the previous partition converge to the Nash equilibrium, and agents who are able to communicate converge to a strong Nash stable equilibrium if such a partition exists. In the absence of communication, all stable partitions are

[2]Westhoff (1977) first formalized Tiebout's model, while removing congestion and incorporating majority rule voting on local tax rates. He proved existence of a stable partition of agents into several communities where the median voter's will was enacted, and that each community in this partition represented an interval of agents. Greenberg and Weber (1986) assume that agents' preferences can be ranked by a unidimensional parameter and demonstrate existence of an equilibrium partition immune to coalition deviations by secession. Demange and Henriet (1991) incorporate a similar assumption in a market for a differentiated consumption good with free-entry and demonstrate that an optimal, stable configuration of consumers across firms exists. Demange (2005) provides a more thorough overview of this tension between increasing returns to group size and preference heterogeneity.

absorbing, and so the system will end up in the first stable partition reached.

Experimental work has yet to directly address these dynamics or equilibrium concepts and there have been few experimental studies considering optimal partitioning of agents into groups. An over-arching conclusion of these experiments is that social preferences may inhibit the formation of optimally sized groups. Several experiments that allow members to control the size of their group in a pure public goods game, in which additional members are beneficial, have found that subjects will often choose to expel, or approve the exit of, members from their group, or deny entry into their group.[3] Similarly, the results of Chapter 2 suggest that cooperative subjects will often exit efficient, strong Nash stable partitions to escape less cooperative subjects. Crosson, Orbell, and Arrow (2004) directly test subjects' ability to partition themselves into optimally sized groups by distributing complementary resources (playing cards) and allowing them to form groups to produce a club good (poker hand), which is then divided among the members. Though only three players were necessary to produce the good, few groups restricted their membership to the optimal size, choosing to instead allow additional members to join.

The experiments here follow a very similar setup to those presented in Chapter 3, but differ in a few ways. First, the payoffs that subjects receive are generalized to apply to settings beyond public good provision, so that agents have symmetric preferences over the policy space and all benefit equally from the addition of group members. Second, there are four preference types in each population, allowing for a variety of stable (and inefficient) partitions. Finally, the same set of partitions are stable in both conditions.

In both the environment considered here and that in the previous chapter, subjects can reach an inefficient outcome either by a) failing to sort into an optimal partition or b) attaining a policy that is not best for the group members. The ability to vote reduces the likelihood of the second, though not the first. The results in the previous chapter suggest that subjects are very successful at sorting themselves into homogeneous groups when there is no compromise policy on which those with different preferences would agree. However, when there are increasing returns to scale and agents have sufficiently similar preferences, the ability to sort into homogeneous groups may not

[3]Cinyabugma, Page, and Putterman (2005) and Maier-Rigaud, Martinsson, and Staffiero (2005) have found that expulsion is used frequently in public goods games. However, since the threat of expulsion also increases cooperation, subjects tend to earn more when expulsion is available. In contrast, Ahn, Isaac, and Salmon (2008) found that allowing subjects to control group size can suppress earnings in a pure public goods game. While restricted entry enables groups to sustain higher contribution rates, groups of cooperative subjects tend to earn less by being overly discerning in whom they allow to enter.

lead to optimal outcomes. Thus, it is important to check the robustness of efficient sorting to changes in the heterogeneity of membership composition under the efficient partition.

This chapter, therefore, expands the previous results by focusing on the partitioning of agents, rather than the efficiency of public good provision. In the experiments presented in Chapter 3, the ability to vote on local policies reduced the likelihood of subjects attaining a policy that was not best for its members. However, since voting does not necessarily eliminate the existence of less efficient Nash stable partitions, the parameter values here can be (and are) chosen such that identical Nash stable and strong Nash stable partitions exist under both the Fixed Policy and Voting institutions, allowing for a direct comparison of sorting under each institution.

The results in this chapter suggest that subjects who can vote only with their feet for group policies, by moving between locations offering fixed local policies, may often fail to partition themselves optimally. The subjects in the Fixed Policy sessions never succeed in reaching the optimal partition of two heterogeneous groups, and instead nearly all fully segregate into four homogeneous groups. This suggests that the existence of locations with fixed, posted policies facilitates the rapid sorting of agents by type into homogeneous groups, such as Tiebout envisioned, but may inhibit the formation of heterogeneous groups with compromise policies. Thus, fixing local policies may enable agents to successfully partition only when homogeneous groups are optimal, and may otherwise lead to over-segregation.

In stark contrast, subjects who are able to vote on their local policies, as well as move freely between groups, typically succeed in forming groups of optimal size and membership composition: The majority of subjects in the Voting sessions reach the strong Nash stable outcome by the end of the session. The prevalence of, or success in forming, heterogeneous groups in the Voting condition is a combination of the ability of larger groups to persist by internally adjusting local policy to changes in their membership composition and the ability to merge pre-existing groups by implementing compromise policies. This suggests that the ability of group members to influence local policy, without needing to relocate, is not only necessary for assuring that a group attains its optimal policy for a given membership composition once it has already sorted, but is also necessary for the population to reach the optimal formation.

The difference in outcomes between institutions occurs despite the equivalence in the set of Nash stable and strong Nash stable partitions under each. This suggests that the determination of local policy alters the system dynamics, and that how the population will partition cannot be assessed by considering the existence of stable states.

Overall, subjects tend to exit groups when they could have received higher payoffs elsewhere in the previous period, and unstable partitions rarely persist. Deviation from inefficient Nash stable partitions is equally rare in both conditions. However, when such deviations do occur, the population is far more likely to transition to the efficient partition when the subjects are able to vote on local policy. In the Fixed Policy condition, the only means by which subjects can build compromise groups is to establish new groups and hope to attract members. Such attempts are never successful, and the system quickly returns to the inefficient Nash stable partition. In the Voting condition, deviation from inefficient Nash stable partitions often prompts a transition to the efficient strong Nash stable partition, as existing groups are able to alter their policies internally, allowing compromise groups to form without requiring the formation of new groups.

4.2 Experimental Design

4.2.1 Setting

There is a finite set of agents $N = \{1, \dots n\}$ that differ only in a unidimensional preference parameter $\alpha \in [0, 1]$. Let $X = \{S_g\}_{g=1}^k$ be a partition of the set N into k groups such that $\cup_{g=1}^k S_g = N$ and, for all g, $h \in \{1 \dots k\}$, $S_g \cap S_h = \emptyset$.

A *state* $(X, \mathbf{t})$ is a partition X of the agents into k groups and a k-tuple of policies $\mathbf{t} = (t^1, \dots, t^k)$, where $t^g \in [0, 1]$ for all g. In other words, each agent is a member of exactly one group and each group is associated with a local policy that governs all members.

Let $S_X(i)$ be the group to which i belongs in partition X and $X(i)$ refer to its index. Agents have preferences over the size of their group, and over the policy space. For a given group size, each agent i has single-peaked preferences over t in [0,1], with payoffs maximized at α^i.

In particular, agent i receives a payoff from being a member of group $S_X(i)$:

$$\pi^i(X, \mathbf{t}) = |S_X(i)| - \gamma(\alpha^i - t^{X(i)})^2 \tag{4.1}$$

where $\gamma > 0$. This is a simple representation of the ubiquitous trade-off between being in an optimally-sized group (which, in the congestion-free environment considered here, is equal to

n) and being in a group where the local policies best matches one's ideal. This payoff function can be thought of as representing any environment in which all agents are bound by a single local policy over which they have single-peaked preferences. For instance, away from the extremes, this function is very similar to the payoffs that agents with Cobb-Douglas preferences for public good provision and private consumption have over a local tax rate and community size, though with the feature that agents of all values of α are equally willing to compromise.

4.2.2 Experimental Procedure

Fifteen experimental sessions were conducted at the Harvard Decision Science Laboratory in Cambridge, Massachusetts. Participation was restricted to undergraduate and graduate students. Subjects participated in groups of sixteen people at a time, and interacted with seven anonymous others in the laboratory using the experimental software z-Tree (Fischbacher, 2007). These experiments were conducted immediately following those in the previous chapter and the conditions in this experiment were randomized over the conditions that the subjects had previously experienced.

Subjects were randomly assigned different preferences over local policies, implemented through the value α in the payoff function 4.1. Two subjects were assigned to each of four different types, with $\alpha \in \{.15, .35, .65, .85\}$. The subjects played a repeated game that lasted for twenty periods. There were seven available locations, which remained fixed for the duration of the experiment and were labeled "Group 1" through "Group 7." At the beginning of each period, the subjects simultaneously chose a location. While making this choice, they were able to observe the number of members and the policy in each of the seven locations in each of the previous three periods. However, they did not receive any information on the identity of these subjects, their ideal policies, or the distribution of types in the population. After choosing their location, the subjects were told the number of others who chose the same location, and a local policy was implemented for everyone in the group. Finally, they received the payoff given in equation 4.1, where γ, the parameter specifying the trade-off between group size and policy, was set equal to 60, for reasons described in the following section.

Subjects were in one of two conditions, and how their group policy was determined depended on the condition of their experimental session. In the *Fixed Policy* sessions, each location was associated with a different fixed, posted policy. Among these locations were those offering the ideal policies for each of the four types as well as the three "compromise" policies that were midway between each of the types' ideals. In the *Voting* sessions, the groups' current members voted on their policy in each period, with the median voter's preference implemented. Seven sessions were run for the Fixed Policy condition (n = 56) and eight sessions were run for the Voting condition (n = 64). The experimental procedure for each period, under each condition, is summarized in Figure 4.1.

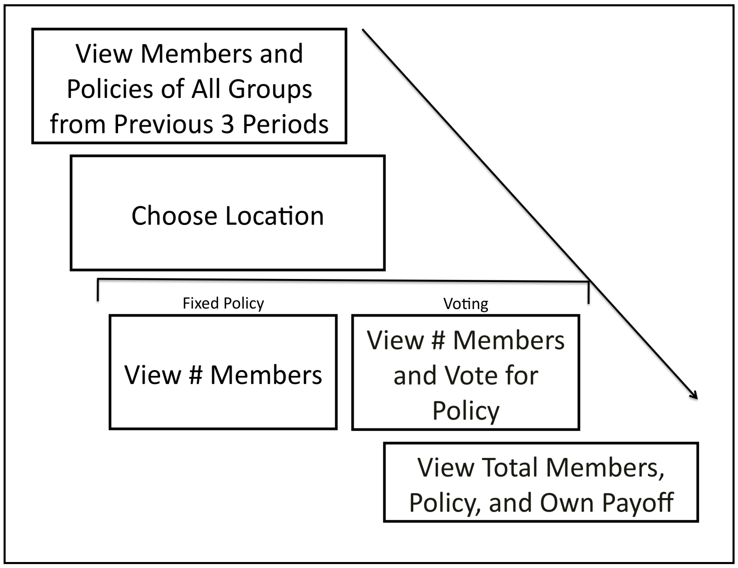


Figure 4.1: Experimental Procedure in Each Period

In the first period, the subjects were initially assigned to a single group of all eight participants. In the Fixed Policy sessions, the policy in this initial location was 0.5, which is the policy that would be enacted in the Voting sessions if all subjects voted for their ideal policy. In subsequent periods, subject were free to choose whichever group they wished. However moving – choosing a different location than in the previous period – carried a small moving cost of 0.3 experimental units.

4.2.3 Stability

A partition of subjects is *Nash stable* if no subject can receive higher payoffs by unilaterally relocating to a different group. A partition is *strong Nash stable* if there is no set of agents who can receive higher payoffs by collectively relocating.

There exist the same five Nash stable partitions in both the Fixed Policy and the Voting sessions. These partitions are depicted graphically in 4.2. The boxes labeled from 1 through 7 represent the seven locations, and the black boxes stacked above them depict the agents of each type at that location (with the value of α assigned to the subject written in the box). The numerical range in black beneath each location shows the range of policies in each group for which the partition is Nash stable.

The first Nash stable partition is a *Segregated* partition in which each of the types are in their own separate group, with a policy close to their ideal. The second, *Center Pooled*, Nash stable partition has the two extreme types segregated in their own groups while the two moderate types form a single group with a policy close to the center. The third, *Strong Partition*, has agents forming two large groups with those whose preferences are similar, with a policy within or very close to the range of policies represented in the group. There are, of course, two other stable partitions (not pictured here) that are combinations of the Segregated and the Strong partitions, in which only those whose ideal points lie within the lower half of the [0,1] interval pool while those whose ideal points lie within the upper half segregate, and vice-versa. There is a unique strong Nash stable partition, which is the same under both the Fixed Policy and Voting conditions, and is identical to the Strong Partition, but with a slightly narrower range of supported policies. This is depicted in the lower right quadrant of Figure 4.2.

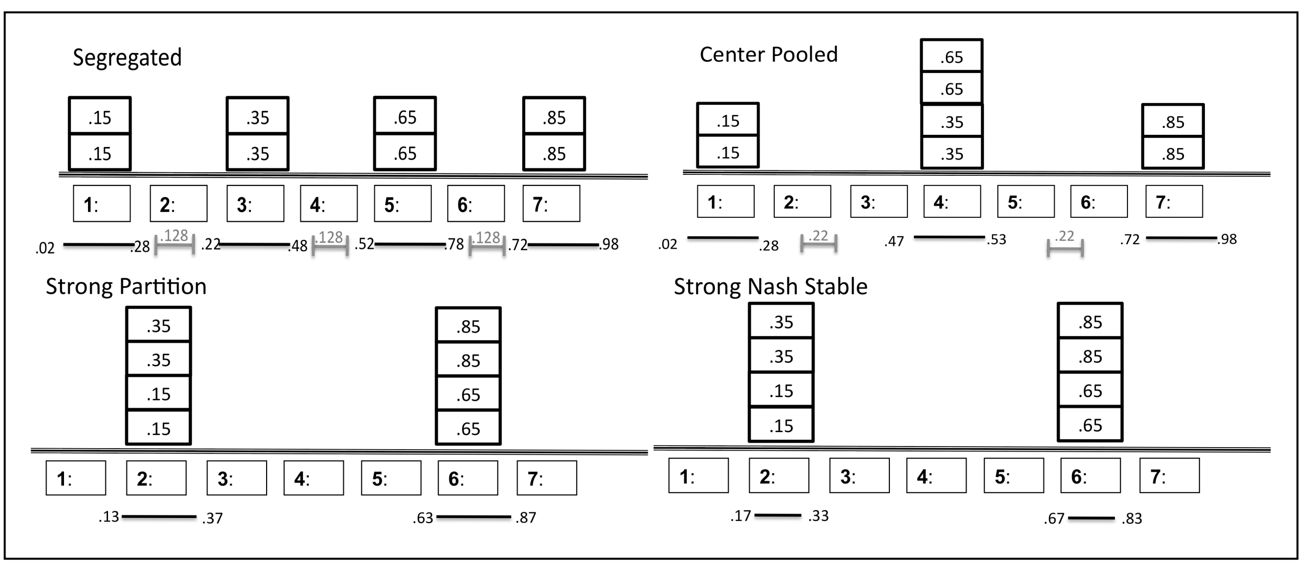


Figure 4.2: Forms of Nash Stable and Strong Nash Stable Partitions

Note that, though the set of Nash stable partitions are identical under both the Fixed Policy and Voting conditions for these parameter values, this need not hold generally. For instance, consider a similar environment with eight agents for whom $\gamma = 45$ rather than 60, and α values of $.05, .15, .2, .35, .65, .8, .85$, and $.95$, respectively. The state in which the three agents with the lowest ideal points are in a group with policy .05, the three agents with the highest ideal points are in a group with policy .95, and the two most moderate agents are in a group with policy .5 is Nash stable under a Fixed Policy institution (with an infinite array of available locations). In fact, it is the state at which the system would arrive if all agents began in a single group with a center policy and myopically best-responded. However, if the agents in this partition voted, then each of the extreme groups would enact the preferred policy of the median voter, and the two agents with moderate preferences would do better by joining them. Therefore, this is an example of a partition that is Nash stable in the Fixed Policy condition but not in the Voting condition.

4.3 Results: Final Outcomes

4.3.1 Efficiency Convergence

We first examine the efficiency of the outcomes to which the subjects converge in each condition. Subjects receive higher payoffs when they are able to vote on their local policies. The left panel of Figure 4.3 shows the average aggregate (session-wide) payoffs over the final five periods of the twenty period experiment under the Fixed Policy and Voting conditions. The dashed line shows the payoff under the Strong Nash state (the Nash stable state with the highest aggregate payoffs) while the dotted line shows the payoff under the Segregated partition (the Nash stable state with the lowest aggregate payoffs). Aggregate payoffs in the Voting condition are 45% of the way from the least efficient stable state to the most efficient stable outcome, while the aggregate payoffs in the Fixed Policy condition are slightly (though not significantly) less than those in the least efficient stable outcome. This suggests that the subjects either are not reaching a stable partition or are at one of the least efficient partitions, with some deviations.

Different stable partitions can benefit certain types. The right panel of Figure 4.3 shows the average payoffs for each of the four types in both the Fixed Policy and the Voting conditions, averaged over the final five periods. The per-period payoffs are higher for all types by the end of the experiment for the subjects in the Voting sessions.[4] There is no significant difference in payoffs

[4]Payoffs are significantly higher in the Voting condition for the duration of the experiment following the initial period, as well as over the final five periods. Additionally, payoffs are higher for each of the four types in the Voting condition, though the difference is not significant for the $\alpha = .85$ type (p = .15, collapsing within subjects).

between those with extreme versus moderate preferences, in either condition.

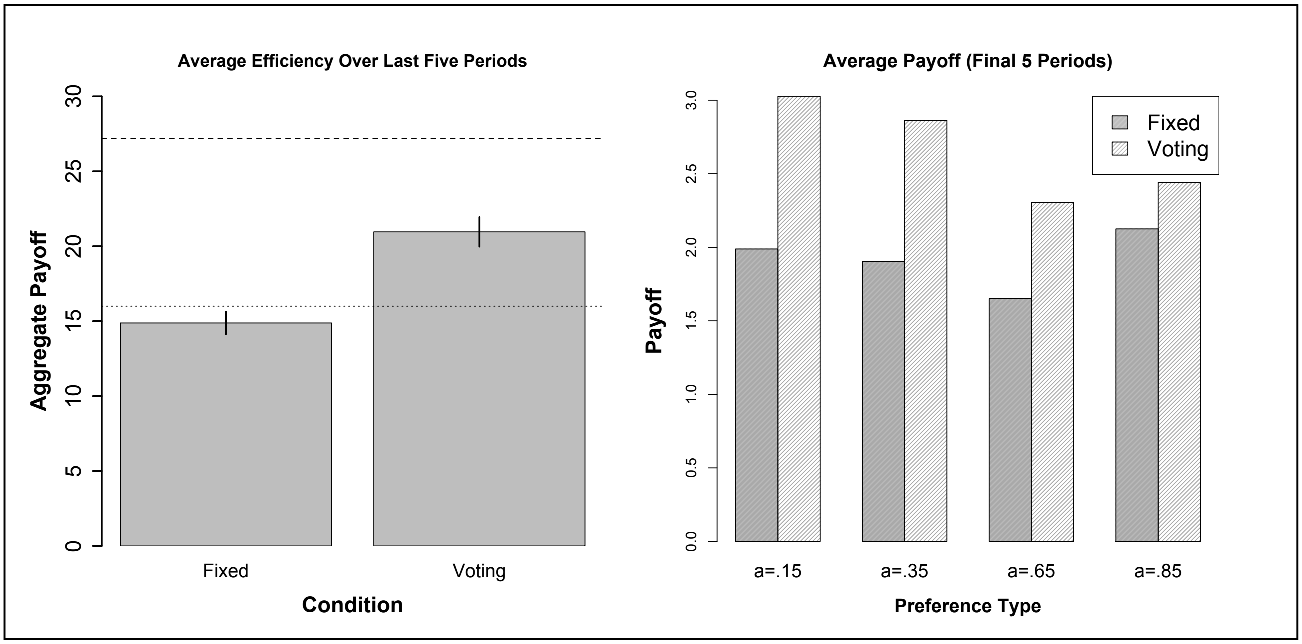


Figure 4.3: The Average Efficiency in Each of the Final Five Periods and the Average Payoff for Each Type

4.3.2 Group Features

We next examine the source of this difference by considering the features of the groups in existence at the end of the experimental session in each condition. Overall, the subjects in the Voting condition tend to sort into much larger groups with local policies further from their ideal.

The left panel of Figure 4.4 shows the frequency with which subjects are in groups of each size by the end of the experimental session. In the Fixed Policy condition, subjects are in a group with only one other member over three-quarters of the time, while subjects in the Voting condition are most typically in a group of four. Specifically, subjects are much more likely to be segregated in the Fixed Policy condition. The subjects are in the same group as the other subject of the same preference type 85% of the time in the Fixed Policy condition and 94% of the time in the Voting condition (over the final five periods), but are with subjects of other types only 16% of the time in the Fixed Policy condition, in comparison to over 60% of the time in the Voting condition.

Within these segregated groups, the subjects in the Fixed Policy conditions attain policies that are closer to their ideal than the subjects in the Voting condition do. In particular, subjects

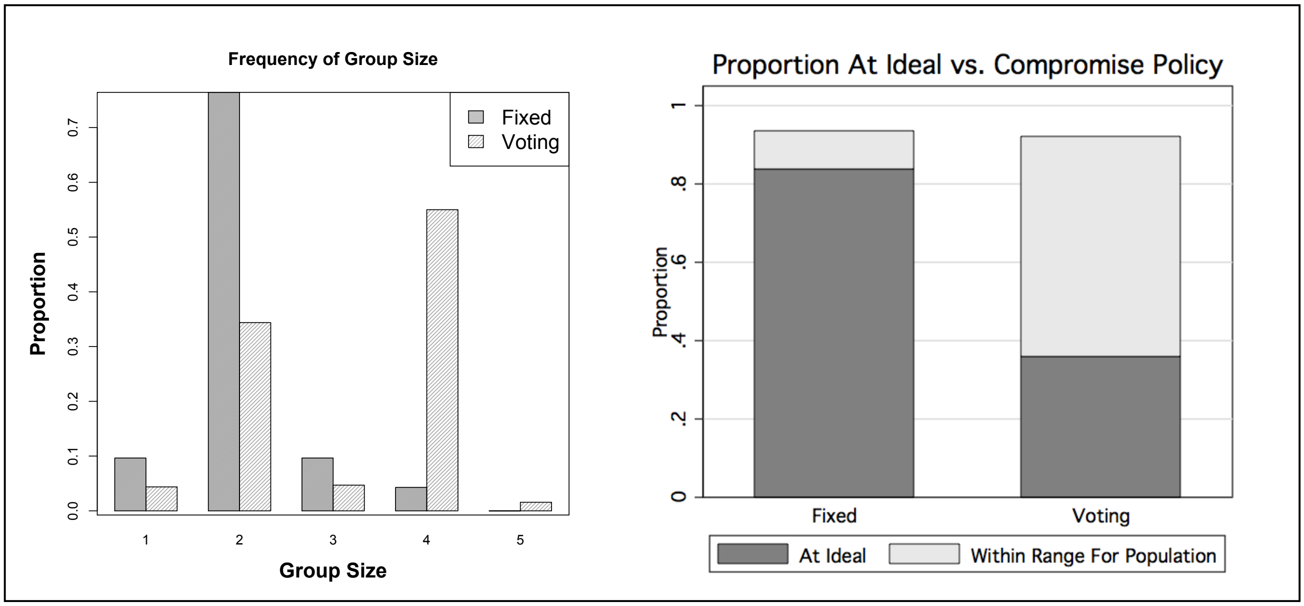


Figure 4.4: Histogram of Group Sizes in the Final Five Periods and the Proportion of Subjects Who Achieve Their Ideal Policy or a Policy Within the Range of Preferences for Their Group

in the Fixed Policy condition experience policies that differ from their ideal by only .02, while the average difference in the Voting condition is .07.[5] The right panel of Figure 4.4 shows that subjects in the Fixed Policy condition experience their ideal policy 84% of the time as opposed to 36% for those in the Voting condition (dark gray bars). However, experiencing a policy within the range of preferences represented in the group is equally likely in both conditions, and occurs upwards of 92% of the time (light gray bars). This suggests that deviations from the subjects ideal policies in the Voting condition are driven primarily by willingness to compromise, rather than by (either voting or sorting) error.

4.3.3 Final Partitions

Subjects in both conditions typically reach one of the five stable partitions. The left panel of Figure 4.5 shows the stability at the individual level. Subjects in both conditions typically cannot achieve higher payoffs by unilaterally relocating (the gray bars show the proportion of subjects who do not have a better unilateral move). Moreover, more than half of the subjects in the Voting condition also could not achieve higher payoffs even by collectively relocating (the black bars show

[5]This difference is significant at $p < .001$. Interestingly, there is no significant difference between the two conditions in deviation from ideal policy for the type $\alpha = .65$. This again highlights the possibility of sorting into groups with a policy far from the optimal for the group members.

the proportion of subjects who do not have a better coalitional move).

The right panel of Figure 4.5 shows the proportion of time during the final five periods that the subjects spend in a partition that is compatible with each of the three classifications of stable partitions (as described in Figure 4.2), or none of the above. Considering the frequency of each partition at the individual level, as opposed to whether the system as a whole reaches the partition, is useful both since asymmetric stable partitions exist (such that half of the population is segregated while the other half is in the strong partition), and since, in this case, individual deviations do not require that the whole system be classified as unstable. These classifications are not necessarily mutually exclusive, since the segregation of those with more extreme preferences is compatible with both the Segregated and the Center Pooled partitions. Plotting those with extreme preferences and those with moderate preferences on separate axes makes it clear that the Center Pooled partition is never reached in the final five periods. The right panel of Figure 4.5 suggests that subjects in the Fixed Policy condition typically converge to the fully segregated partition, while the subjects in the Voting condition are more likely to converge to the strong Nash stable partition.[6]

4.4 Results: Overall Dynamics

4.4.1 Persistence of Unstable and Stable States

To begin to understand the dynamics of group formation, it is important to first of all assess whether Nash stable states are, in fact, absorbing, particularly in comparison with strong Nash stable states. If subjects always myopically best-respond, then, starting from the initial state in these experiments, we would expect them to reach the Center Pooled partition. However, Figure 4.5 shows that the system is never in such a partition by the end of the experimental session. Figure 4.6 addresses the persistence from one period to the next of partitions stable, strong stable, or unstable.

The left panel of Figure 4.6 shows the likelihood that a subject remains in a location given that there is a better unilateral move available to him (system is not in a stable state), that there

[6]This graph uses the strictest definition of compatibility with a partition, which is why the proportion of subjects whose location is not compatible with any stable partition in the graph on the right of Figure 4.5 is slightly greater than the proportion of subjects without a better move in the graph on the left side of Figure 4.5. For instance, if the two subjects for whom $\alpha = .15$ are in a group with one of the subjects for whom $\alpha = .35$ where the policy $= .15$, while the other $\alpha = .35$ subject is separate, none of these subjects are in a partition compatible with any of these stable partitions. However, it may be stable for the two $\alpha = .15$ subjects.

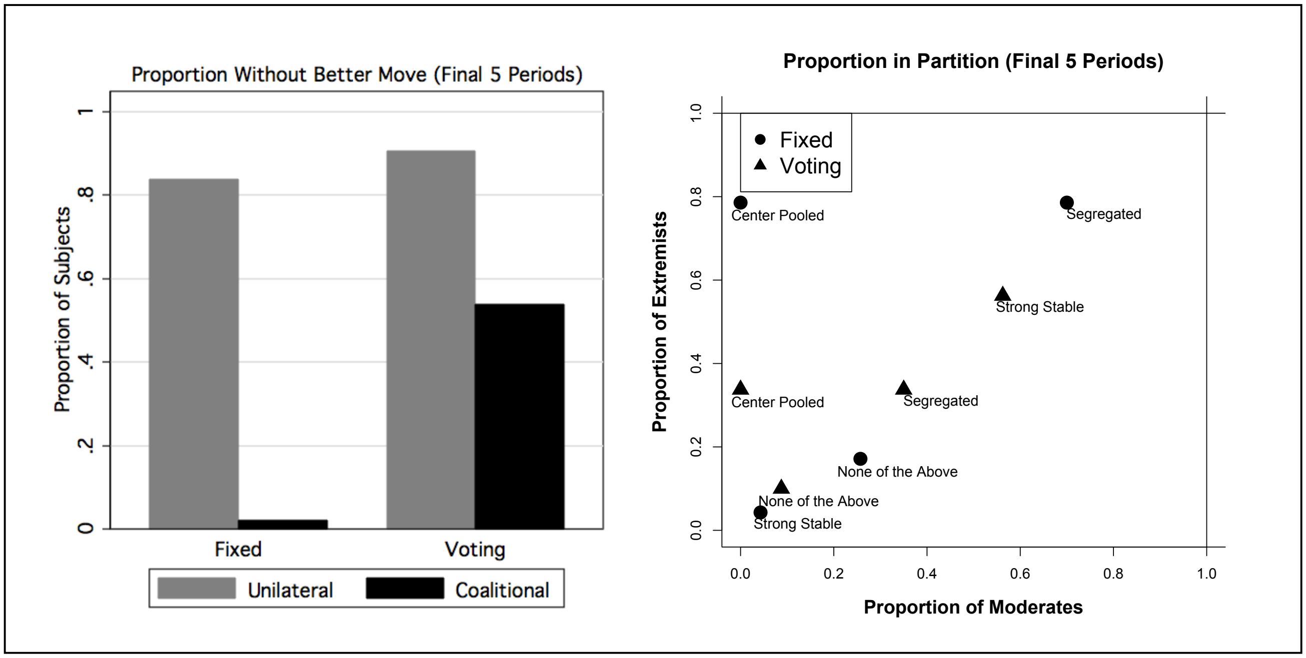


Figure 4.5: Proportion of Subjects Without a Better Unilateral or Coalitional Move and the Proportion of Subjects in a Location Compatible With Each Type of Partition

is only a better coalitional move available to him (if true for all agents: system is in a Nash stable state), or neither (if true for all agents: system is in a strong Nash stable state). Overall, the subjects tend to exit when they have a profitable unilateral move: in this case, they exit 60% of the time in the Fixed Policy condition and 50% of the time in the Voting Condition.[7] When subjects have only a better coalitional move, or when they could not do better even by collectively relocating, movement occurs in eight to nine percent of opportunities. Subjects are slightly less likely to remain when they have only a better coalitional move as when they have no better coalitional move. (In the Fixed Policy condition, subjects appear to often exit when they can do no better by collectively relocating. However, all of these opportunities occur in the first period and the system never reaches a strong stable state.)

The right panel of Figure 4.6 shows this persistence at the system level: In particular, the likelihood that the system remains in the same state from one period to the next, given its stability classification. Nash stable states persist into the next period 82% of the time in the Fixed Policy condition and 89% of the time in the Voting condition. However, the rarity with which the system is a strong Nash stable state (zero observations for the Fixed Policy condition and five observations

[7]This difference is significant at p = .02 in two-tailed t-test. After the first period, the greater likelihood of exiting in the Fixed Policy condition is significant only at the p = .07 level in a one-tailed t-test.

for the Voting sessions) does not allow us to address at the systemic level whether such states are more likely to be absorbing.

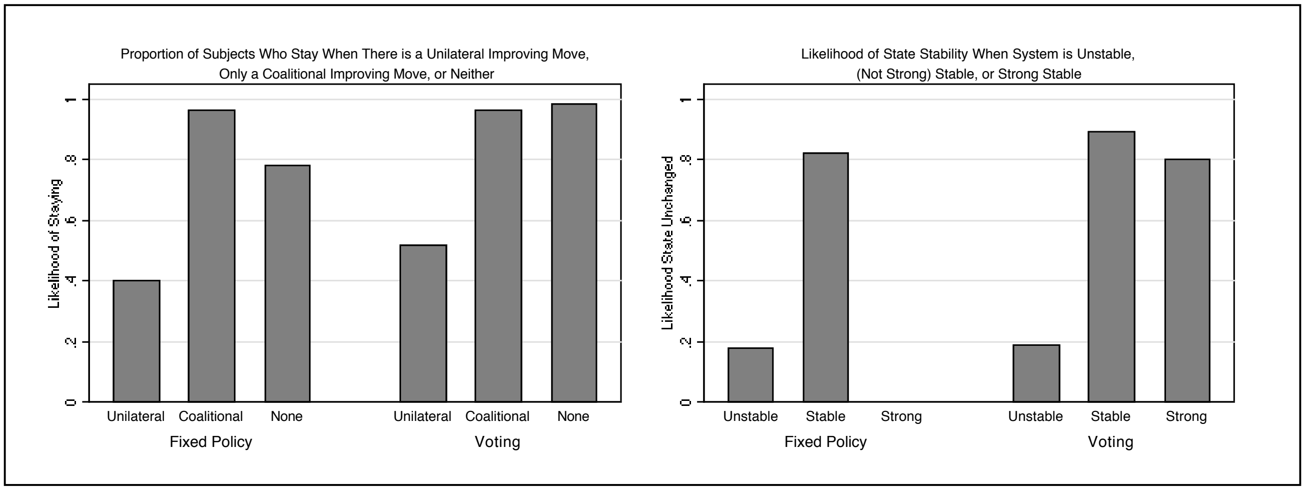


Figure 4.6: Likelihood of a Subject Remaining in a Group Given the Types of Moves Available and the Likelihood of a State Persisting Given the Systems Stability

The left panel of Figure 4.7 shows how the likelihood that a subject exits a group depends both on the number of members (horizontal axis) and the distance of the groups policy from his ideal point (vertical axis). The darker colors represent greater likelihood of remaining in the group. Given that the subjects move, they most frequently select the group where the policy in the previous period was the closest to their ideal or, in the Voting condition, a previously empty location where they can set the policy upon entering. The right panel of Figure 4.7 shows the likelihood that subjects choose the largest group, the group with the policy closest to their ideal, the group in which they would have received the highest payoff in the previous period, or, since there is significant overlap, at least one of the previous criteria.

4.4.2 Transitions Between Stable States

The rarity of movement when subjects reach stable states suggests that initial sorting dynamics along with the process by which the system transitions from one stable state to another are critical for understanding where the population ends up. Figure 4.8 shows the partition classification over time for each experimental session, given that the system is in a Nash stable state. For each session and period, the classification of those for whom $\alpha < .5$ is shown to the left and the classification of those for whom $\alpha > .5$ is shown directly next to it. The Center Pooled partitions are common

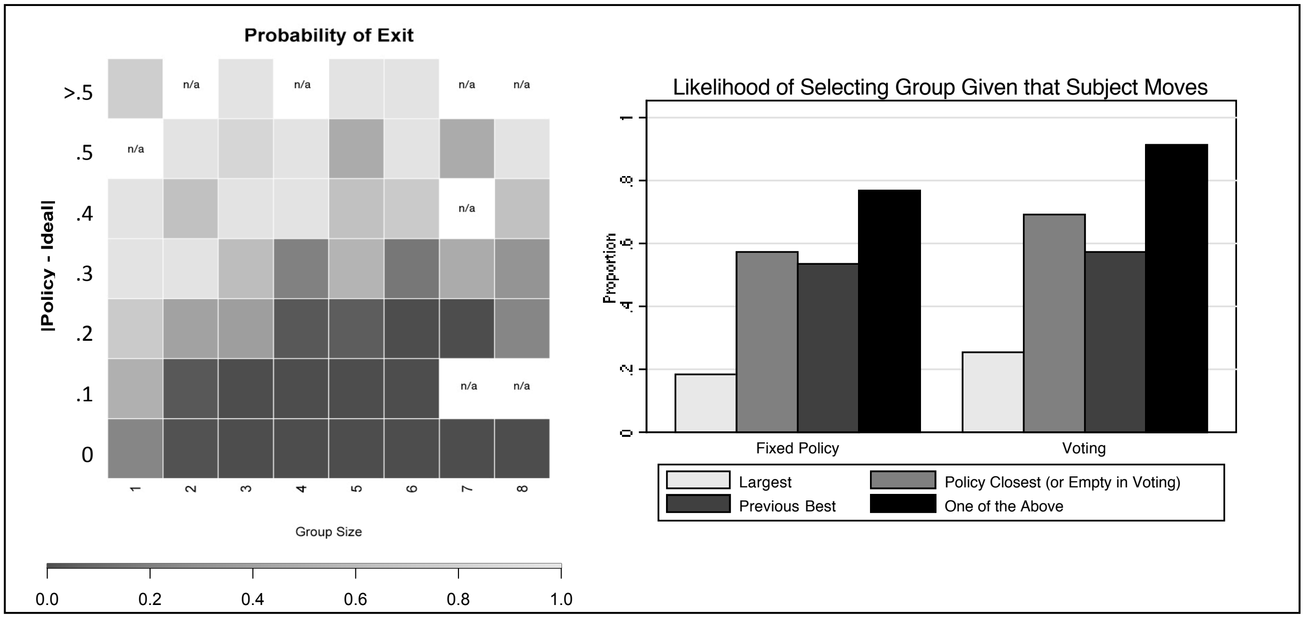


Figure 4.7: Probability Subjects Exit Groups By Group Size and Difference in Policy from Ideal and the Group Selection of Subjects Who Exit

early in the Fixed Policy condition, but are not sustained and, although the system moves in and out of Nash stable states, larger groups are not formed. By contrast, the Strong Partition tends to form later in the Voting sessions, following a few periods in which the system is not in a Nash stable state.

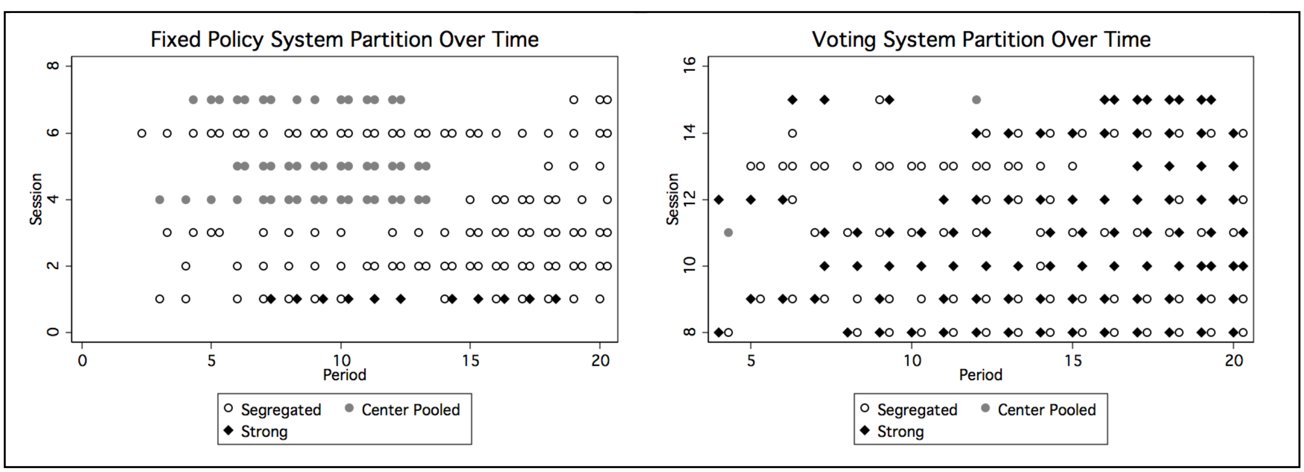


Figure 4.8: Classifications of System Partition Over Time, by Experimental Session

Thus far the dynamics have appeared similar in the Fixed Policy and the Voting conditions, and the questions of how the dynamics are changed when subjects are able to vote, and why they eventually reach different stable partitions, remain. Figure 4.9 shows the frequency with which subjects are in groups of each size (horizontal axis) and with policies that differ from their own ideal (vertical axis). The lighter colors represent more frequent occurrences. These graphs clearly show that subjects in the Fixed Policy condition are far more likely to be segregated in a group of two at their ideal point, while subjects in the Voting session are more commonly in a group of four further from their ideal, but they also provide insight into how the subjects in the Voting condition succeed in forming these larger groups.

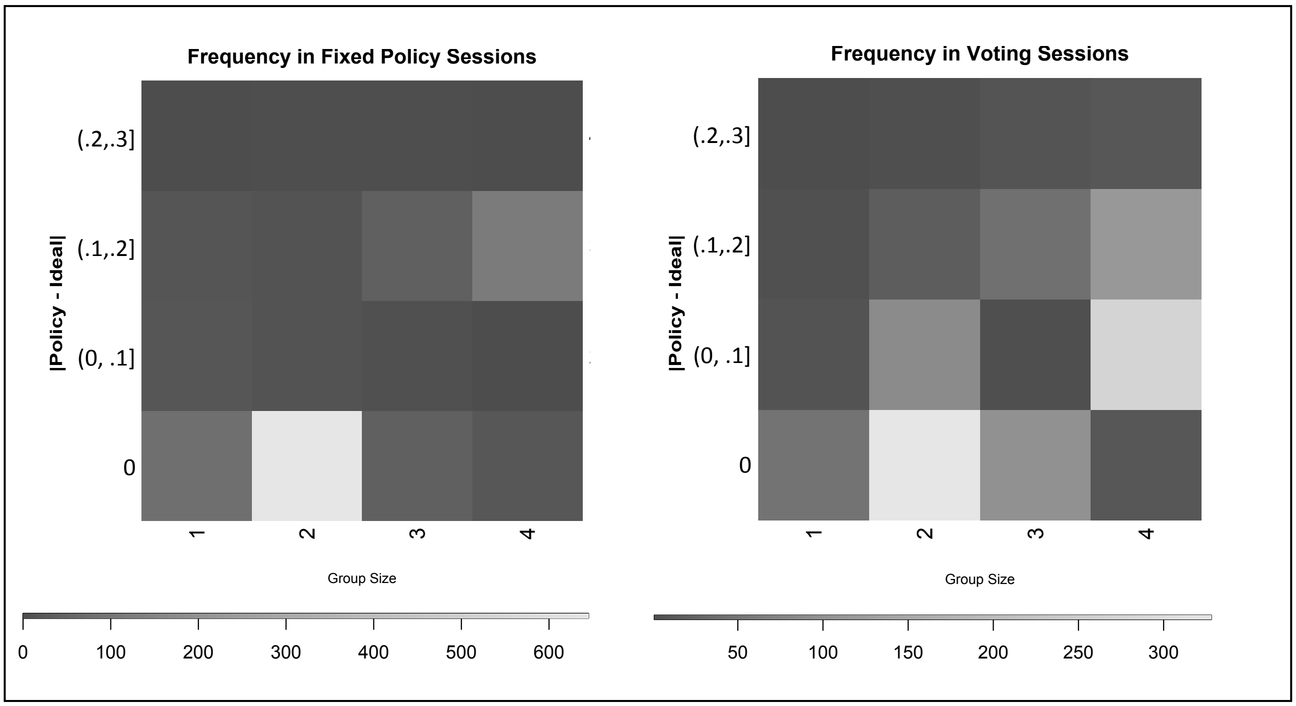


Figure 4.9: Frequency Heatmaps of the Likelihood of Subject in a Group of Various Sizes and Policies Different from Ideal

The prevalence of heterogeneous groups in the Voting condition is caused both by the persistence of the initial, large group and the success in building groups with compromise policies.

First, the initial group is far less likely to deteriorate in the Voting condition. In the Fixed Policy condition, nearly all of those with extreme preferences and 40% of those with moderate preferences exit in the initial group in the first period. As this is not a myopic best-response for the moderates, this suggests that the existence of groups with their posted ideal policy is driving initial exit and segregation by providing a clear signal of which group to choose. In the Voting condition, less than half of those with extreme preferences and only 12.5% of moderates exit initially. Unless this exit is perfectly symmetric, the distribution of preferences remaining within the group tips toward one side of the [0,1] interval: in 88% of Voting sessions, the initial group implements a policy favoring those on one side of the spectrum by the second period. In half of the Voting sessions, all four of the subjects whose ideal points fall on that side of the interval remain in the group for the duration of the session, while no subjects in the Fixed Policy condition remain in the initial group by the end of the session.

However, the persistence of the initial group does not account for the majority of four-member groups in existence at the end of the Voting sessions. Perhaps more important, as it does not depend on initial conditions, is the relative success of subjects in building up compromise groups after they have already scattered and segregated.

In the Fixed Policy condition, the only means by which subjects can initiate a transition from two segregated groups to a unified group with an intermediate policy is to move into the compromise location alone and hope to be eventually followed by the other three neighboring subjects. Such signaling, or attempts to found a compromise group, occurs in ten instances in the Fixed Policy condition when the subjects were previously in a fully segregated partition. Though the founders remain in the compromise location for an average of 2.3 periods following their move, none succeed in attracting the other members, and they eventually return to the segregated partition. The strategy of founding a compromise group is used only once in the Voting condition, and also fails. However, there is a different strategy available to those attempting to build a compromise group when policies are determined by group vote that is not viable when local policies are fixed: invasion.

If the local policies are fixed, then even if both agents of the same preference type are able to coordinate and invade another group, they will not be able to influence the local policy and will therefore end up receiving lower payoffs than in the Segregated partition. Thus founding a new compromise group, and requiring all four members on each half of the [0,1] interval to relocate, is the only viable means of moving the system from the Segregated partition to the Strong partition. The invasion strategy is attempted only three times in the Fixed Policy sessions, and, though a group of four forms once, it is at a location with an extreme policy, and the larger group is sustained only temporarily.

Though an invader in the Voting condition initially receives a lower payoff by moving in with two others of a different type, if his partner joins him quickly then the invading pair can influence the groups policy and move it closer to their own ideal. This strategy is attempted in seven instances in the Voting condition and is successful all but once. Moreover, invasion of a segregated group is sometimes encouraged by its members voting for a policy that differs from their ideal. Such an event is shown in the lighter gray square in the (2,2) position in Figure 4.9, while invasion by a third member is shown in the light gray squares diagonal to it. This suggests that whether the system reaches a strong Nash stable state may depend, not only on the existence of other stable partitions, but on the number of agents who must relocate in order for the system to transition from one stable state to another.

4.5 Conclusion

The results in this chapter suggest that the ability to vote with one's feet may not be sufficient for a population to reach an optimal partition when there are gains to be made from agents pooling resources with those who have similar preferences. While the existence of locations with fixed, posted policies enables the rapid sorting of subjects by type, the formation of homogeneous, segregated groups may not always be optimal. In that case, the saliency of locations offering a subject's ideal policy leads to initial over-movement and segregation, and the inability of newcomers to influence local policy deters the formation of compromise groups.

When subjects are able to vote on group policy, as well as move freely between groups, they most commonly succeed in forming larger heterogeneous groups of like-minded, though not identical, individuals and reaching optimal partitions. The ability of groups to internally adjust their policies in response to changes in membership composition enables subjects both to sustain larger groups and to expand pre-existing groups by implementing compromise policies. This ability to transition to the strong Nash partition without needing to establish new groups enables subjects to avoid being stuck in less efficient stable partitions.

These results suggest that the determination of local policy is critical for understanding whether diverse populations are likely to succeed in partitioning themselves optimally across groups. It appears that mobility in itself is not sufficient for reaching optimal partitions, and that additional mechanisms, such as a means of signaling or the ability to internally adjust local policies to the preferences of the current population, may also be necessary to enable groups to combine their resources efficiently. Furthermore, this difference between institutions occurs despite the equivalence in the set of equilibria under each. This suggests that institutional and environmental features alter the dynamics in ways that cannot be fully captured by considering stability concepts alone, and that additional laboratory experiments are necessary for understanding how agents sort themselves by preferences.

Appendix A

Chapter 2 Results for Caltech Subjects Only

Included in this section are the graphs from Chapter 2 for only those subjects in the congestion sessions who were Caltech students.

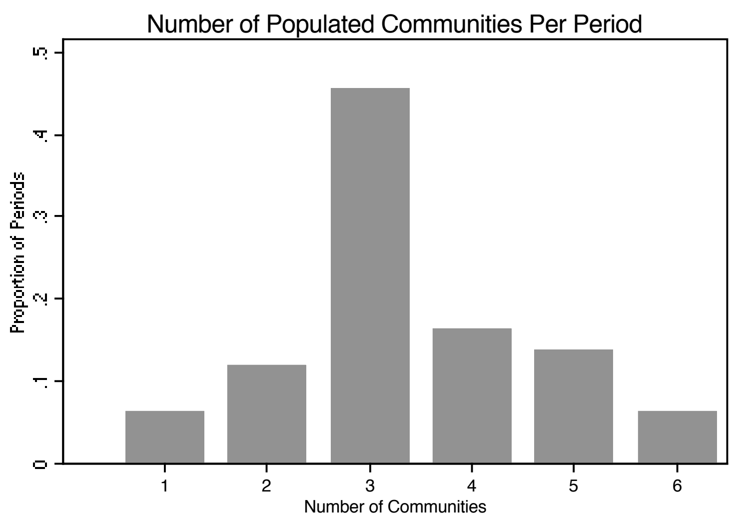


Figure A.1: Histogram of Populated Communities

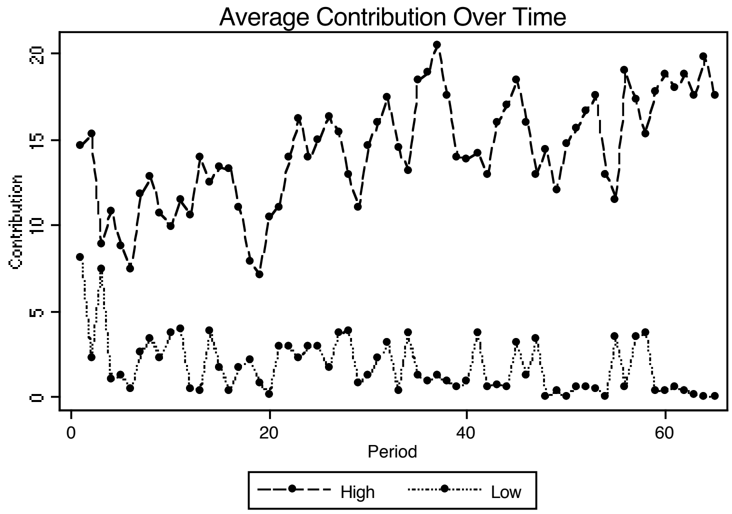


Figure A.2: Average Contribution Over Time

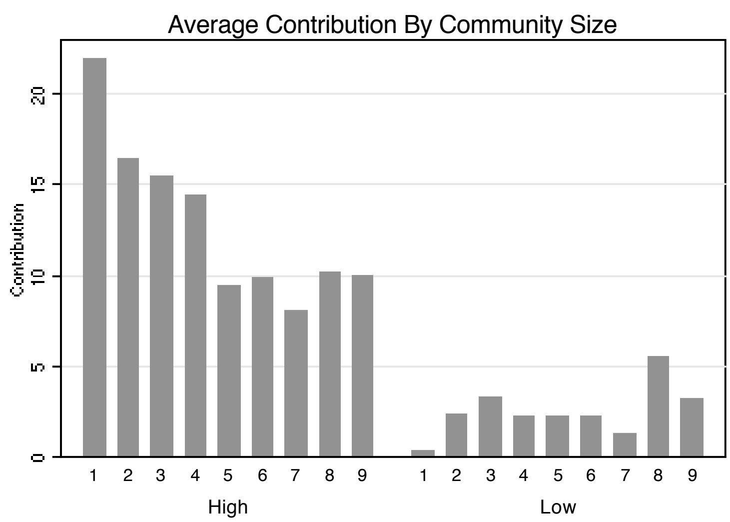


Figure A.3: Average Contribution by Community Size

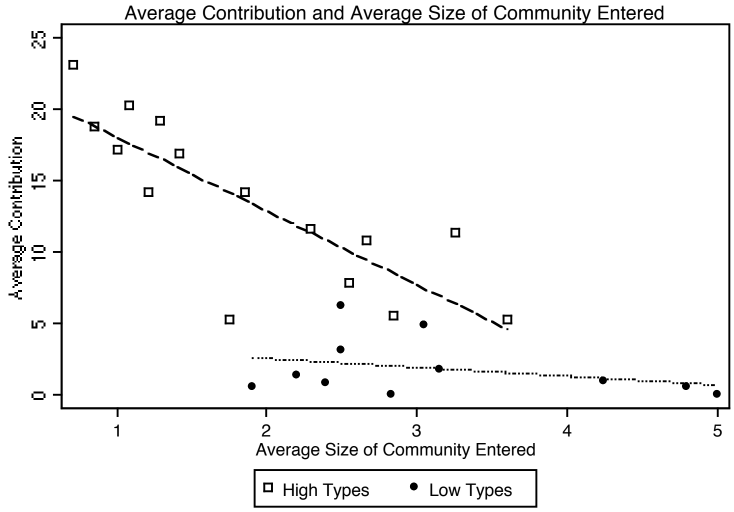


Figure A.4: Average Contribution and Average Size of Community Entered

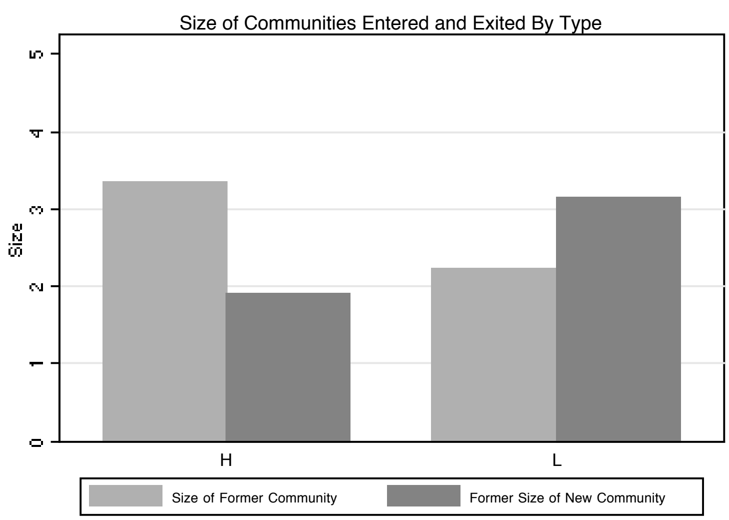


Figure A.5: Average Size of Communities Entered and Exited

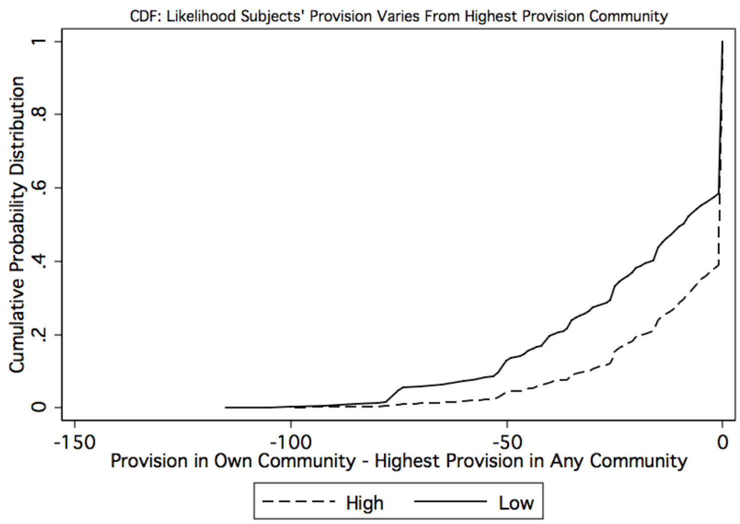


Figure A.6: Likelihood Subjects Are in a Community with Inferior Provision Levels

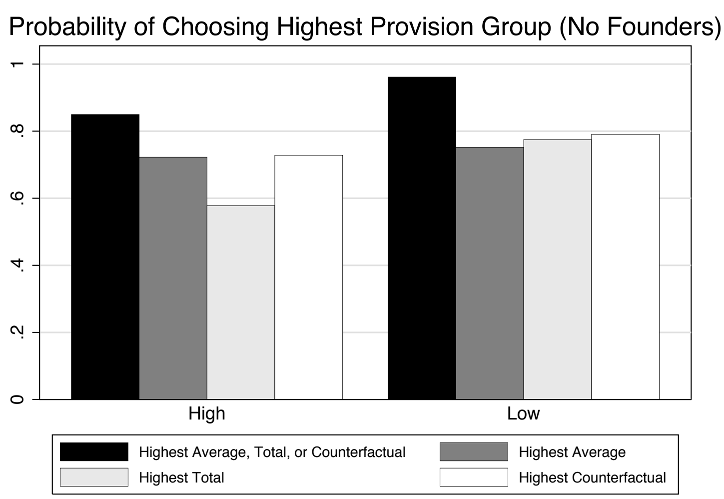


Figure A.7: Probability Movers Enter Highest Provision Community

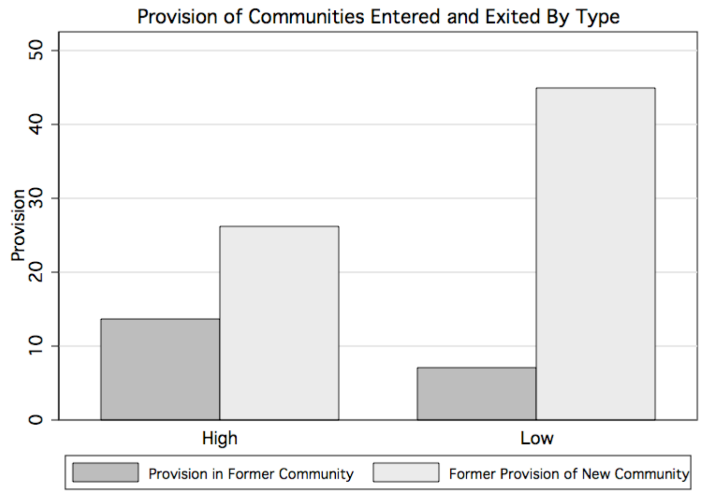


Figure A.8: Provision of Communities Entered and Exited

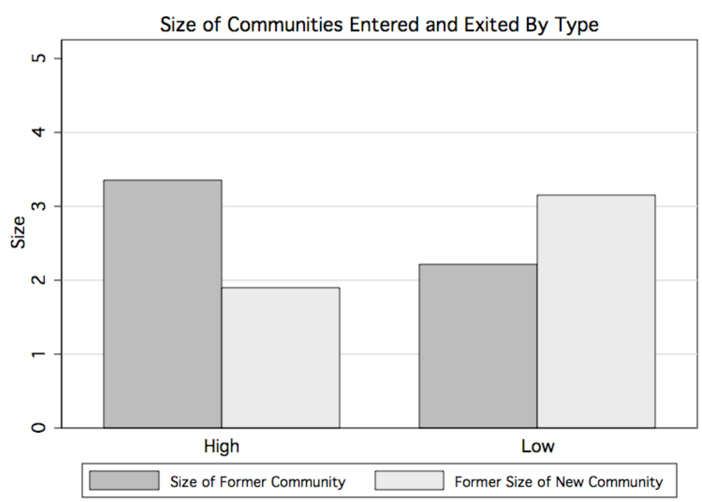


Figure A.9: Size of Communities Entered and Exited

Appendix B

Chapter 2 Instructions

Included in this section are samples of the instruction sheets used in the Chapter 2 experiments for the Low Types.

There are 9 participants in this experiment, which will last for several periods. In each period, you will be in a *group* with other participants. For the first period, we will randomly form 3 groups of 3 people each. In subsequent periods, you will choose which group you wish to belong to.

Once the groups are formed, each person will receive an endowment of 25 tokens in each period and will make choices regarding individual and group allocations. The choice is how many tokens to allocate to the *group account* and how many to allocate to one's *private account*. Each token allocated to one's private account pays one token to that individual, independent of the group size. Each token allocated to your group account, either by you or another group member, pays an amount less than one token to each member of the group, and may depend on the number of people in the group.

In a few minutes you will receive a table (similar to Figure 1 below) showing your personal marginal return from the group account. These values may vary for different participants. Please keep this information private and refrain from speaking to other participants until the experiment has ended.

Figure 1: EXAMPLE

Group Members:	1	2	3	4	5	6	7	8	9
Your Marginal Return:	1	0.661	0.485	0.400	0.352	0.323	0.304	0.293	0.286

The following is an example based on the values in Figure 1. If, for instance, you are a member of a four-person group and the total number of tokens contributed to the group account this period is 10, then you will receive a payoff from the group account equal to Total Contributions in My Group * My Marginal Return for a Four-Person Group = 10*0.4=4 tokens. For every additional token invested in the group account, you will receive an additional return of 0.4, while whoever makes the additional contribution will have one unit less available for his/her private account. Also note that in this example the total return for *all* members increases with group size and so for the same amount of tokens allocated by each person to the group account, larger groups will earn more money.

The experiment will progress as follows: In the first period, each person is initially assigned to a three-person group. You will choose how many of your 25 tokens you wish to allocate to your group's account. After each period, you will see a screen such as that below, showing your group's total contribution to its group account, your contribution, the average contribution of the others, and your payoff for the period.

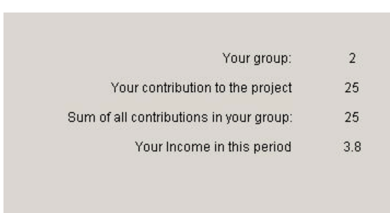
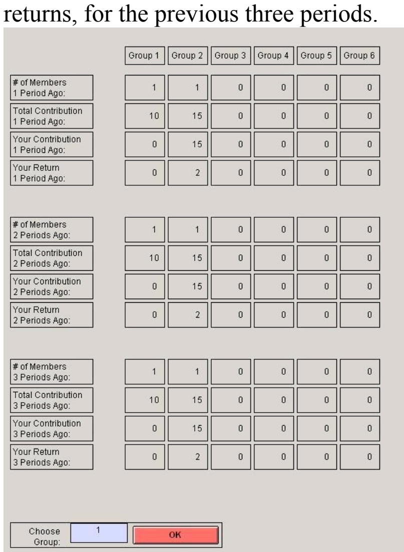


Figure B.1: Chapter 2 Instructions Page 1

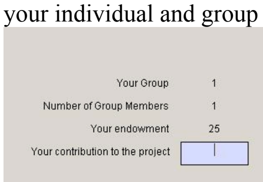
From the second period on, there will be six available groups and each period will be divided into two stages:
In *the first stage*, each participant decides whether to stay in his/her current group or to switch to one of the other groups. Switching into one of the original three groups carries a cost of 5 tokens and switching into Group 4, 5, or 6 carries a cost 15 tokens. While making your decision, you will a screen such as that in the figure below, containing the sizes and total contributions of all groups, as well as your personal contributions and returns, for the previous three periods.



	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
# of Members 1 Period Ago:	1	1	0	0	0	0
Total Contribution 1 Period Ago:	10	15	0	0	0	0
Your Contribution 1 Period Ago:	0	15	0	0	0	0
Your Return 1 Period Ago:	0	2	0	0	0	0
# of Members 2 Periods Ago:	1	1	0	0	0	0
Total Contribution 2 Periods Ago:	10	15	0	0	0	0
Your Contribution 2 Periods Ago:	0	15	0	0	0	0
Your Return 2 Periods Ago:	0	2	0	0	0	0
# of Members 3 Periods Ago:	1	1	0	0	0	0
Total Contribution 3 Periods Ago:	10	15	0	0	0	0
Your Contribution 3 Periods Ago:	0	15	0	0	0	0
Your Return 3 Periods Ago:	0	2	0	0	0	0

Choose Group: 1 OK

In the *second stage*, you will see a screen such as that in the figure below, showing the size of the group you are in, and you will choose how to allocate the 25 tokens between your individual and group accounts.



Your Group	1
Number of Group Members	1
Your endowment	25
Your contribution to the project	

Figure B.2: Chapter 2 Instructions Page 2

Listed below are your marginal returns for each possible group size:

Group Members:	1	2	3	4	5	6	7	8	9
Your Marginal Return:	.15	.15	.15	.15	.15	.15	.15	.15	.15

Please take a minute to answer the following questions:

1. **If you are in a group by yourself and you contribute 25 tokens to the group account, what is your return from the group account?**

2. **You move from Group 2 to Group 3, which has 5 members. You contribute 10 tokens to the group account and 15 to your private account. The contributions to the group account total 45. What is your total payoff for this period?**

Figure B.3: Chapter 2 Instructions: MPCR and Quiz

Appendix C

Chapter 3 Instructions

Included in this section are sample instructions sheets and payoff tables used in the Chapter 3 experiments for the VCM, Fixed Tax, Fixed Quantity, and Voting conditions.

Hello and welcome to our experiment!

In this experiment, you will be asked to make a series of choices on the computer. There will be 20 periods and in each period you will choose which *group* you wish to belong to. The payment you receive depends on the actions of you and your fellow group members, so it is important that you fully understand the instructions. If you have questions at any point, please press the "Push for Assistance" button below your screen.

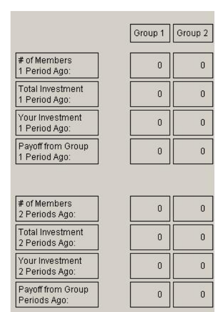
You will participate with 7 other people in this room. There are six available groups which you may join, and at the start of each period, everyone will simultaneously select their group for that period. You will then make an investment in your group. The more that has been invested in your group – by you or by the other group members – the higher your payoff will be, but whoever makes the investment must pay for it.

Your investment may be any amount, from 0 up to 1000 tokens. The chart beside your computer gives examples of what your payoff for the period would be for various amounts that *you personally* invest in the group (the columns listed along the top) and the *total* invested in your group (the rows listed along the left). These values may vary for different participants.

For example, say that you are in a group with two other people. They collectively invest 40 tokens and you personally invest 20 tokens, so that the total investment in your group is 60. What would your payoff be in this period? You personally invested 20 tokens, so look in the column marked 20. The investments in your group total 60, so look in the row marked 60. Your payoff in this period would have been 328.

There are six available groups which you may join. You will be assigned to a group for the first period. After that, at the start of each period, everyone will simultaneously select their group for that period At the start of each period, everyone will simultaneously select their group for that period. You are free to select a different group in the next period. The available groups will be the same for the duration of the experiment. If you move to a different group, you must pay a cost of 5 units, which will be deducted from your payoff at the end of the period.

Each period will proceed as follows. First, you will see a screen such as that in the figure to the right, showing the available groups, along with the number of people in each group and total investments in each group, in each of the previous three periods. You will also see your personal payoff from your group from the previous three periods (not including any moving costs you may have incurred). Once you have chosen your group, you will see a screen indicating how many members are in the group in that period and will enter your investment. You'll then see the total investments made and your payoff for the period.



At the end of the experiment, we will add up your payoffs from all periods and you will receive 1 USD for every 600 units.

Figure C.1: Chapter 3 VCM Instructions Page 1

Please take a moment to answer the following practice questions.

1. You are in a group by yourself or in which the other members do not invest. What is your payoff if you invest:

    0 tokens?
    5 tokens?
    85 tokens?

2. You move into a new group this period. The other members of your group invest 155 and you invest 5, for a total of 160. What is your payoff for this period? Don't forget to subtract the cost of moving.

Please notify the experimenter if you have any questions or once you have finished, so we can check your answers.

Figure C.2: Chapter 3 VCM Instructions Page 2

I Submit:	0	5	10	20	30	40	45	50	60	70	80	85	90	100	150	200	250	300	340	360	400	450	500
My Group Submits:																							
0	0.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	136.8	131.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	195.7	190.7	185.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20	254.6	249.6	244.6	234.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
30	289.1	284.1	279.1	269.1	259.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
40	313.6	308.6	303.6	293.6	283.6	273.6	268.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
45	323.6	318.6	313.6	303.6	293.6	283.6	278.6	273.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
50	332.5	327.5	322.5	312.5	302.5	292.5	287.5	282.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
60	348.0	343.0	338.0	328.0	318.0	308.0	303.0	298.0	288.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
70	361.1	356.1	351.1	341.1	331.1	321.1	316.1	311.1	301.1	291.1	-	-	-	-	-	-	-	-	-	-	-	-	-
80	372.5	367.5	362.5	352.5	342.5	332.5	327.5	322.5	312.5	302.5	292.5	-	-	-	-	-	-	-	-	-	-	-	-
85	377.6	372.6	367.6	357.6	347.6	337.6	332.6	327.6	317.6	307.6	297.6	292.6	-	-	-	-	-	-	-	-	-	-	-
90	382.5	377.5	372.5	362.5	352.5	342.5	337.5	332.5	322.5	312.5	302.5	297.5	292.5	-	-	-	-	-	-	-	-	-	-
100	391.4	386.4	381.4	371.4	361.4	351.4	346.4	341.4	331.4	321.4	311.4	306.4	301.4	291.4	-	-	-	-	-	-	-	-	-
120	406.9	401.9	396.9	386.9	376.9	366.9	361.9	356.9	346.9	336.9	326.9	321.9	316.9	306.9	-	-	-	-	-	-	-	-	-
140	420.0	415.0	410.0	400.0	390.0	380.0	375.0	370.0	360.0	350.0	340.0	335.0	330.0	320.0	-	-	-	-	-	-	-	-	-
160	431.4	426.4	421.4	411.4	401.4	391.4	386.4	381.4	371.4	361.4	351.4	346.4	341.4	331.4	281.4	-	-	-	-	-	-	-	-
180	441.4	436.4	431.4	421.4	411.4	401.4	396.4	391.4	381.4	371.4	361.4	356.4	351.4	341.4	291.4	-	-	-	-	-	-	-	-
200	450.4	445.4	440.4	430.4	420.4	410.4	405.4	400.4	390.4	380.4	370.4	365.4	360.4	350.4	300.4	250.4	-	-	-	-	-	-	-
220	458.5	453.5	448.5	438.5	428.5	418.5	413.5	408.5	398.5	388.5	378.5	373.5	368.5	358.5	308.5	258.5	-	-	-	-	-	-	-
240	465.9	460.9	455.9	445.9	435.9	425.9	420.9	415.9	405.9	395.9	385.9	380.9	375.9	365.9	315.9	265.9	-	-	-	-	-	-	-
260	472.7	467.7	462.7	452.7	442.7	432.7	427.7	422.7	412.7	402.7	392.7	387.7	382.7	372.7	322.7	272.7	222.7	-	-	-	-	-	-
280	479.0	474.0	469.0	459.0	449.0	439.0	434.0	429.0	419.0	409.0	399.0	394.0	389.0	379.0	329.0	279.0	229.0	-	-	-	-	-	-
300	484.8	479.8	474.8	464.8	454.8	444.8	439.8	434.8	424.8	414.8	404.8	399.8	394.8	384.8	334.8	284.8	234.8	184.8	-	-	-	-	-
320	490.3	485.3	480.3	470.3	460.3	450.3	445.3	440.3	430.3	420.3	410.3	405.3	400.3	390.3	340.3	290.3	240.3	190.3	-	-	-	-	-
340	495.5	490.5	485.5	475.5	465.5	455.5	450.5	445.5	435.5	425.5	415.5	410.5	405.5	395.5	345.5	295.5	245.5	195.5	155.5	-	-	-	-
360	500.3	495.3	490.3	480.3	470.3	460.3	455.3	450.3	440.3	430.3	420.3	415.3	410.3	400.3	350.3	300.3	250.3	200.3	160.3	140.3	-	-	-
380	504.9	499.9	494.9	484.9	474.9	464.9	459.9	454.9	444.9	434.9	424.9	419.9	414.9	404.9	354.9	304.9	254.9	204.9	164.9	144.9	-	-	-
400	509.3	504.3	499.3	489.3	479.3	469.3	464.3	459.3	449.3	439.3	429.3	424.3	419.3	409.3	359.3	309.3	259.3	209.3	169.3	149.3	109.3	-	-
420	513.4	508.4	503.4	493.4	483.4	473.4	468.4	463.4	453.4	443.4	433.4	428.4	423.4	413.4	363.4	313.4	263.4	213.4	173.4	153.4	113.4	-	-
440	517.4	512.4	507.4	497.4	487.4	477.4	472.4	467.4	457.4	447.4	437.4	432.4	427.4	417.4	367.4	317.4	267.4	217.4	177.4	157.4	117.4	-	-
460	521.2	516.2	511.2	501.2	491.2	481.2	476.2	471.2	461.2	451.2	441.2	436.2	431.2	421.2	371.2	321.2	271.2	221.2	181.2	161.2	121.2	71.2	-
480	524.8	519.8	514.8	504.8	494.8	484.8	479.8	474.8	464.8	454.8	444.8	439.8	434.8	424.8	374.8	324.8	274.8	224.8	184.8	164.8	124.8	74.8	-
500	528.2	523.2	518.2	508.2	498.2	488.2	483.2	478.2	468.2	458.2	448.2	443.2	438.2	428.2	378.2	328.2	278.2	228.2	188.2	168.2	128.2	78.2	28.2

Figure C.3: Chapter 3 VCM Payoff Table

Hello and welcome to our experiment!

In this experiment, you will be asked to make a series of choices on the computer. There will be 20 periods and in each period you will choose which *group* you wish to belong to. The payment you receive depends on the actions of you and your fellow group members, so it is important that you fully understand the instructions. If you have questions at any point, please press the "Push for Assistance" button below your screen.

You will participate with 7 other people in this room. There are six available groups which you may join, and at the start of each period, everyone will simultaneously select their group for that period. You will then make an investment in your group. The more that has been invested in your group – by you or by the other group members – the higher your payoff will be, but whoever makes the investment must pay for it.

Each of the six groups has its own *fixed policy* regarding how many tokens *must* invested by *each* group member. If you join the group you must invest this amount. For instance, assume that you and two others choose to join a group with an investment policy of 20 tokens. You must each then invest 20 tokens in group that period, so the total group investment is 20*3 =60.

The table below provides the payoffs you'd receive from being in groups with various investment policies and numbers of members. These values may vary for different participants.

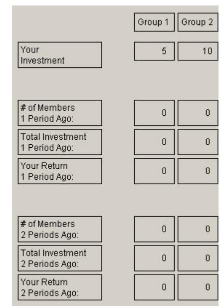
Policy:	**0**	**1**	**5**	**10**	**20**	**30**	**45**	**60**	**75**	**85**	**90**	**100**	**200**
Number of Members:													
1 Member	0	-1	132	186	235	259	279	288	292.0	292.6	292.5	291.4	250
2 Members	0	58	191	245	294	318	337	347	350.9	351.5	351.4	350.4	309
3 Members	0	92	225	279	328	352	372	381	385.4	386.0	385.9	384.8	344
4 Members	0	117	250	304	352	377	396	406	409.8	410.5	410.3	409.3	368
5 Members	0	136	269	323	371	396	415	425	428.8	429.4	429.3	428.2	387
6 Members	0	151	284	338	387	411	431	440	444.3	444.9	444.8	443.7	403
7 Members	0	164	297	351	400	425	444	453	457.4	458.0	457.9	456.8	416
8 Members	0	176	309	362	411	436	455	465	468.7	469.4	469.2	468.2	427

So in the example above, what your payoff be for the period? Your group has a twenty token investment policy, so look in the column marked 20. You are in a group with two others, so look in the row marked "3 Members." Your payoff in this period would have been: 328.

You will be assigned to a group for the first period. After that, at the start of each period, everyone will simultaneously select their group for that period. You are free to select a different group in the next period. The available groups and the policies associated with them will be the same for the duration of the experiment. If you

Figure C.4: Chapter 3 Fixed Tax Instructions Page 1 move to a different group, you must pay a cost of 5 tokens, which will be deducted from your payoff at the end of the period.

Each period will proceed as follows. First, you will see a screen such as that in the figure to the right, showing the available groups and the policies associated with them, along with the number of people in each group and total investments in each group, in each of the previous three periods. You will also see your personal payoff from your group from the previous three periods (not including any moving costs you may have incurred). Once you have chosen your group, you will see a screen indicating how many members are in your group in that period and will enter your investment. Your required investment will be displayed and you must enter this exact amount into the box beneath it for the experiment to proceed. You'll then see the total investments made and your payoff for the period.



At the end of the experiment, we will add up your payoffs from all periods and you will receive 1 USD for every 600 units.

Please take a moment to answer the following practice questions.

1. You select a group with an investment policy of 25 tokens. How many tokens must you invest this period?

2. You are in a group by yourself. What is your payoff if you invest:
    - 0 tokens?
    - 5 tokens?
    - 85 tokens?

3. You move into a new group this period, and the investment policy is 20 tokens. What is your payoff for this period if there is one other group member? If there are 3 other group members? Don't forget to subtract the cost of moving.

4. For any given number of members, which group policy gives you the highest payoff?

Please notify the experimenter if you have any questions or once you have finished, so we can check your answers.

Figure C.5: Chapter 3 Fixed Tax Instructions Page 2

Hello and welcome to our experiment!

In this experiment, you will be asked to make a series of choices on the computer. There will be 20 periods and in each period you will choose which *group* you wish to belong to. The payment you receive depends on the actions of you and your fellow group members, so it is important that you fully understand the instructions. If you have questions at any point, please press the "Push for Assistance" button below your screen.

You will participate with 7 other people in this room. There are six available groups which you may join, and at the start of each period, everyone will simultaneously select their group for that period. You will then make an investment in your group. The more that has been invested in your group – by you or by the other group members – the higher your payoff will be, but whoever makes the investment must pay for it.

Each of the six groups has its own *fixed policy* regarding how many tokens (in *total*) *must* invested by the group. If you join the group, you must invest your share of this amount. For instance, assume that you and two others choose to join a group with an investment policy of 60 tokens. You must each then invest 60/3 = 20 tokens in group that period, so that the total group investment is 60.

The table below provides the payoffs you'd receive from being in groups with various investment policies and numbers of members. These values may vary for different participants.

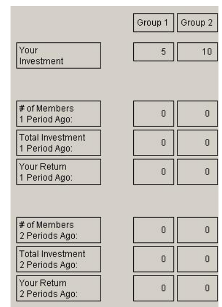
Policy:	**0**	**5**	**10**	**20**	**50**	**60**	**100**	**200**	**300**	**340**	**360**	**500**	**680**
Number of Members:													
1 Member	0	132	186	235	283	288	291	250	184.8	155.5	140.3	28	-126
2 Members	0	134	191	245	308	318	341	350	334.8	325.5	320.3	278	214
3 Members	0	135	192	248	316	328	358	384	384.8	382.1	380.3	362	328
4 Members	0	136	193	250	320	333	366	400	409.8	410.5	410.3	403	384
5 Members	0	136	194	251	323	336	371	410	424.8	427.5	428.3	428	418
6 Members	0	136	194	251	324	338	375	417	434.8	438.8	440.3	445	441
7 Members	0	136	194	252	325	339	377	422	442.0	446.9	448.9	457	457
8 Members	0	136	194	252	326	341	379	425	447.3	453.0	455.3	466	469

So in the example above, what your payoff be for the period? Your group has a sixty token investment policy, so look in the column marked 60. You are in a group with two others, so look in the row marked "3 Members." Your payoff in this period would have been: 328.

You will be assigned to a group for the first period. After that, at the start of each period, everyone will simultaneously select their group for that period. You are free to select a different group in the next period. The available groups and the policies associated with them will be the same for the duration of the experiment. If you move to a different group, you must pay a cost of 5 tokens, which will be deducted from your payoff at the end of the period.

Figure C.6: Chapter 3 Fixed Quantity Instructions Page 1

Each period will proceed as follows. First, you will see a screen such as that in the figure to the right, showing the available groups and the policies associated with them, along with the number of people in each group and total investments in each group, in each of the previous three periods. You will also see your personal payoff from your group from the previous three periods (not including any moving costs you may have incurred). Once you have chosen your group, you will see a screen indicating how many members are in your group in that period and will enter your investment. Your required investment will be displayed and you must enter this exact amount into the box beneath it for the experiment to proceed. You'll then see the total investments made and your payoff for the period.



At the end of the experiment, we will add up your payoffs from all periods and you will receive 1 USD for every 600 units.

Please take a moment to answer the following practice questions.

1. You select a group with an investment policy of 25 tokens. How many total tokens must your group invest this period?

2. You are in a group by yourself. What is your payoff if you invest

    0 tokens?
    5 tokens?
    85 tokens?

3. You move into a new group this period, and the investment policy is 200 tokens. What is your payoff for this period if there is one other group member? If there are 3 other group members? Don't forget to subtract the cost of moving.

Please notify the experimenter if you have any questions or once you have finished, so we can check your answers.

Figure C.7: Chapter 3 Fixed Quantity Instructions Page 2

Hello and welcome to our experiment!

In this experiment, you will be asked to make a series of choices on the computer. There will be 20 periods and in each period you will choose which *group* you wish to belong to. The payment you receive depends on the actions of you and your fellow group members, so it is important that you fully understand the instructions. If you have questions at any point, please press the "Push for Assistance" button below your screen.

You will participate with 7 other people in this room. There are six available groups which you may join, and at the start of each period, everyone will simultaneously select their group for that period. You will then make an investment in your group. The more that has been invested in your group – by you or by the other group members – the higher your payoff will be, but whoever makes the investment must pay for it.

In each period, each of the six groups will choose its own *policy* regarding how many tokens *must* invested by *each* group member in that period. This policy will be voted on by the group's current members in each period, with the median number selected as the group's policy. Everyone must invest the amount chosen by their group. For instance, assume that you are in a group with two others and your group chooses an investment policy of 20 tokens. You must each then invest 20 tokens in group that period, so the total group investment is 20*3 =60.

The table below provides the payoffs you'd receive from being in groups with various investment policies and numbers of members. These values may vary for different participants.

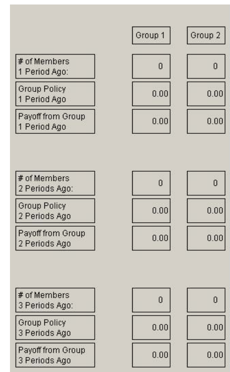
Policy:	**0**	**1**	**5**	**10**	**20**	**30**	**45**	**60**	**75**	**85**	**90**	**100**	**200**
Number of Members:													
1 Member	0	-1	132	186	235	259	279	288	292.0	292.6	292.5	291.4	250
2 Members	0	58	191	245	294	318	337	347	350.9	351.5	351.4	350.4	309
3 Members	0	92	225	279	328	352	372	381	385.4	386.0	385.9	384.8	344
4 Members	0	117	250	304	352	377	396	406	409.8	410.5	410.3	409.3	368
5 Members	0	136	269	323	371	396	415	425	428.8	429.4	429.3	428.2	387
6 Members	0	151	284	338	387	411	431	440	444.3	444.9	444.8	443.7	403
7 Members	0	164	297	351	400	425	444	453	457.4	458.0	457.9	456.8	416
8 Members	0	176	309	362	411	436	455	465	468.7	469.4	469.2	468.2	427

So in the example above, what your payoff be for the period? Your group has a 20 token investment policy, so look in the column marked "20." You are in a group with two others, so look in the row marked "3 Members." Your payoff in this period would have been: 328.

Each group will choose its policy by voting. Once everyone has selected their group for the period, you and your group members will each submit a vote for the group's policy. The median vote will be implemented: for groups with an odd number of members, the middle-most vote is implemented and for groups with an even number of members, the average of the two middle-most votes is implemented.

Figure C.8: Chapter 3 Voting Instructions Page 1

In the first period, you will be assigned to a group. After that, at the start of each period, everyone will simultaneously select their group for that period. You are free to select a different group in the next period. The available groups will be the same for the duration of the experiment. If you move to a different group, you must pay a cost of 5 tokens, which will be deducted from your payoff at the end of the period.



Each period will proceed as follows. First, you will see a screen such as that in the figure to the right, showing the available groups, along with the number of people in each group, and the policy and total investments in each group, in each of the previous three periods. You will also see your personal payoff from your group from the previous three periods (not including any moving costs you may have incurred). Once you have chosen your group, you will see a screen indicating how many members are in your group in that period and will enter your vote. The group's vote will then be displayed as your required investment and you must enter this exact amount into the box beneath it for the experiment to proceed. You'll then see the total investments made and your payoff for the period.

At the end of the experiment, we will add up your payoffs from all periods and you will receive approximately 1 USD for every 600 units.

Please take a moment to answer the following practice questions.

1. Your group implements an investment policy of 25 tokens. How many tokens must you invest this period?

2. You are in a group by yourself. What is your payoff if you invest:

    0 tokens?
    5 tokens?
    85 tokens?

3. You move into a new group this period, and the investment policy is 20 tokens. What is your payoff for this period if there is one other group member? If there are 3 other group members? Don't forget to subtract the cost of moving.

4. For any given number of members, which group policy gives you the highest payoff?

Please notify the experimenter if you have any questions or once you have finished, so we can check your answers.

Figure C.9: Chapter 3 Voting Instructions Page 2

Appendix D

Chapter 4 Instructions

Included in this section are sample instructions used in the Chapter 4 experiments for the Fixed Policy and Voting conditions.

There are eight participants in this experiment, which will last for 20 periods. At the start of each period, you will choose which *group* you wish to belong to, and you will receive a payoff from your choice and the choice of others. Specifically, your payoff depends on the number of group members and the group's policy.

Each group is associated with a policy. Your ideal policy is: .15. Different participants may have different ideal policies.

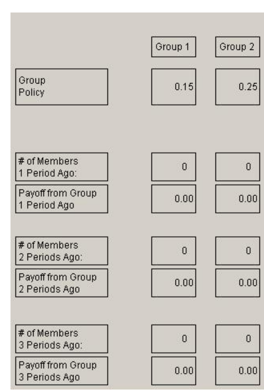
Your payoff is higher:

1. The closer your group policy is to your ideal policy.
2. The more people there are in your group.

The table below shows your payoff for various group policies and for numbers of group members.

Policy:	**0.05**	**0.10**	**0.15**	**0.25**	**0.35**	**0.45**	**0.50**	**0.55**	**0.65**	**0.75**	**0.85**	**0.90**	**0.95**
Number of Members:													
1 Member	0.4	0.9	1.0	0.4	-1.4	-4.4	-6.4	-8.6	-14.0	-20.6	-28.4	-32.8	-37.4
2 Members	1.4	1.9	2.0	1.4	-0.4	-3.4	-5.4	-7.6	-13.0	-19.6	-27.4	-31.8	-36.4
3 Members	2.4	2.9	3.0	2.4	0.6	-2.4	-4.4	-6.6	-12.0	-18.6	-26.4	-30.8	-35.4
4 Members	3.4	3.9	4.0	3.4	1.6	-1.4	-3.4	-5.6	-11.0	-17.6	-25.4	-29.8	-34.4
5 Members	4.4	4.9	5.0	4.4	2.6	-0.4	-2.4	-4.6	-10.0	-16.6	-24.4	-28.8	-33.4
6 Members	5.4	5.9	6.0	5.4	3.6	0.6	-1.4	-3.6	-9.0	-15.6	-23.4	-27.8	-32.4
7 Members	6.4	6.9	7.0	6.4	4.6	1.6	-0.3	-2.6	-8.0	-14.6	-22.4	-26.8	-31.4
8 Members	7.4	7.9	8.0	7.4	5.6	2.6	0.7	-1.6	-7.0	-13.6	-21.4	-25.8	-30.4

There are seven available groups in this experiment, each associated with a fixed policy. In the first period, you will be assigned to a group. From the second period on, at the start of each period, you will see a screen, such as that in the figure below, showing the groups and the policies associated with each, and the number of members in each group in the previous three periods. You will also see the payoffs that you've received from the group in the previous three periods. You will then make your group choice by entering the number of the group you wish to join. All participants make their group choice in each period and do so simultaneously.



If you *switch groups* – choose a different group from the one you belonged to in the previous period – you will pay a cost of .3 units, which will be subtracted from your payoff for that period. At the end of the experiment, we will add up your payoffs from all periods and you will receive 1 USD for every 10 experimental units.

Figure D.1: Chapter 4 Fixed Policy Instructions Page 1

Your ideal policy: .15.

Please take a minute to answer the following practice questions.

Practice Questions

1. For a given number of members, which group policy gives you the highest payoff?

2. You are in a group with policy .35. Three other participants are in the group this period as well, for a total of four members. What is your payoff for the period?

3. You enter a different group, which has a policy of .15. Two other participants are in the group, for a total of 3 members. What is your payoff for the period? Don't forget to subtract the cost of moving.

Figure D.2: Chapter 4 Fixed Policy Instructions Page 2

There are eight participants in this experiment, which will last for 20 periods. At the start of each period, you will choose which *group* you wish to belong to, and you will receive a payoff from your choice and the choice of others. Specifically, your payoff depends on the number of group members and the group's policy.

Each group is associated with a policy. Your ideal policy is: .15. Different participants may have different ideal policies.

Your payoff is higher:

1. The closer your group policy is to your ideal policy.
2. The more people there are in your group.

The table below shows your payoff for various group policies and for numbers of group members.

Policy:	**0.05**	**0.10**	**0.15**	**0.25**	**0.35**	**0.45**	**0.50**	**0.55**	**0.65**	**0.75**	**0.85**	**0.90**	**0.95**
Number of Members:													
1 Member	0.4	0.9	1.0	0.4	-1.4	-4.4	-6.4	-8.6	-14.0	-20.6	-28.4	-32.8	-37.4
2 Members	1.4	1.9	2.0	1.4	-0.4	-3.4	-5.4	-7.6	-13.0	-19.6	-27.4	-31.8	-36.4
3 Members	2.4	2.9	3.0	2.4	0.6	-2.4	-4.4	-6.6	-12.0	-18.6	-26.4	-30.8	-35.4
4 Members	3.4	3.9	4.0	3.4	1.6	-1.4	-3.4	-5.6	-11.0	-17.6	-25.4	-29.8	-34.4
5 Members	4.4	4.9	5.0	4.4	2.6	-0.4	-2.4	-4.6	-10.0	-16.6	-24.4	-28.8	-33.4
6 Members	5.4	5.9	6.0	5.4	3.6	0.6	-1.4	-3.6	-9.0	-15.6	-23.4	-27.8	-32.4
7 Members	6.4	6.9	7.0	6.4	4.6	1.6	-0.3	-2.6	-8.0	-14.6	-22.4	-26.8	-31.4
8 Members	7.4	7.9	8.0	7.4	5.6	2.6	0.7	-1.6	-7.0	-13.6	-21.4	-25.8	-30.4

There are seven available groups in this experiment. In each period, the policy implemented in each group depends on the composition of its members in that period: the median ideal policy represented in the group becomes the group's policy.

In the first period, you will be assigned to a group. From the second period on, at the start of each period, you will see a screen, such as that in the figure below, showing the groups and the number of members in each group, along with their policy, in the previous three periods. You will also see the payoffs that you've received from the group in the previous three periods. You will then make your group choice by entering the number of the group you wish to join. All participants make their group choice in each period and do so simultaneously.

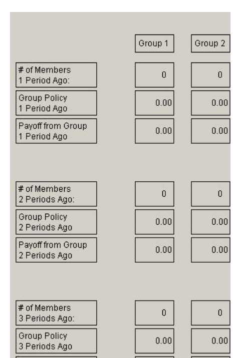


Figure D.3: Chapter 4 Voting Instructions Page 1

Once everyone has selected their group for the period, the group's policy will be chosen. This is will be the median ideal policy in the group: for groups with an odd number of members, the middle-most ideal policy is implemented and for groups with an even number of members, the average of the two middle-most ideal policies is implemented.

If you *switch groups* – choose a different group from the one you belonged to in the previous period – you will pay a cost of .3 units, which will be subtracted from your payoff for that period. At the end of the experiment, we will add up your payoffs from all periods and you will receive 1 USD for every 10 experimental units.

Your ideal policy: .15.

Please take a minute to answer the following practice questions.

Practice Questions

1. For a given number of members, which group policy gives you the highest payoff?

2. You are in a group with policy .35. Three other participants are in the group this period as well, for a total of four members. What is your payoff for the period?

3. You enter a different group, which has a policy of .15. Two other participants are in the group, for a total of 3 members. What is your payoff for the period? Don't forget to subtract the cost of moving.

Figure D.4: Chapter 4 Voting Instructions Page 2

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