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Conformity and Networks in a Simulated Society

by

Matthew Sudak

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Conformity and Networks in a Simulated Society" submitted by Matthew Sudak in partial fulfillment of the requirements for the degree of Master of Arts.

B. C. Eaton

Supervisor, Dr. Curtis B. Eaton, Department of Economics

John H. Ellard

Dr. John Ellard, Department of Psychology

Dr. Robert Oxoby, Department of Economics

September 17, 2003

Date

Abstract

Conformity induced by social pressure has been investigated at length by social psychologists and economists. However, few studies in either field have looked explicitly at how the structure of networks that characterize our social relationships affects conformist outcomes. This paper develops an economic model of conformist behavior over a binary choice that specifies explicitly the structure of social networks in a model society. The influence of network characteristics is then explored using computer simulations. The key finding of this work is that networks matter: not only does a broad range of network characteristics have an effect on social outcomes, but network characteristics can be more important than any other model parameters in determining the presence and nature of conformity in the model society.

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Introduction

The social pressures under which we humans make many of our decisions result in curious and often perplexing social scenarios. Consider the young schoolchild who refuses to wear a particular shirt to school, for fear of being ridiculed. That same shirt, however, is a perfectly acceptable wardrobe choice at home, playing in the backyard with the neighborhood kids, or on a family shopping trip. The underlying preferences of the child with regard to the shirt in question do not change in each of the separate outings. However, these underlying preferences can be influenced or modified by the social context in which the child, and his shirt, is placed. There may be a particular social situation at school that means wearing the green sweatshirt with purple polka dots will be an invitation for people to point and laugh. Due to social pressure, this particular article of clothing might not be worn to school.

Governments that are highly susceptible to the influence of public opinion rule our democratic societies. Individuals, quite aware of this, often form closely-knit lobby groups that are able to very effectively promote their agenda on the local or national level. These associations are often composed of a relatively small number of committed people, and yet they can be highly successful in moving national policy issues. However, it is not just governments that are responsible for the success of these small groups: society itself is equally adept at adapting to accommodate the requests of these committed organizations. There are two key ways through which lobby groups can so successfully press their agenda. First, it is through the direct lobbying of government. The second way, more firmly sociological in nature, involves disseminating their views through society in the hopes of "converting" individual citizens to their cause, or at the very least pressuring them enough to prevent their vocal opposition. Through either government intervention or the remolding of public opinion, special interest groups have often been able to ultimately push through policies that may appear quite unfavorable to the general citizen. What is also interesting is the fanatical devotion to their cause that the members of many of these groups have. On most issues their commitment to one side of a particular debate is far greater than the commitment of the public at large to either side of the issue, which explains their disproportionate power.

A dinner party presents another example of this type of social scenario—one that undoubtedly many of us have ourselves experienced.[1] Guests arrive at a party. People mingle, people talk, people eat. However, at some point in time, somebody wants to leave. For the sake of argument suppose this person has had enough talking, enough mingling, and quite enough food, yet the party has hardly just begun. Perhaps they are in a hurry to get home and finish some overdue work, or they have children who await their return and require their attention. Regardless, they want to leave. Given that it is quite early into the party to be getting up and exiting, the person has an interesting choice. They could simply leave now, thus satisfying their personal desire to go home. This seemingly simple choice nests within a complex series of reactions. Leaving early could bring about the scorn of the other partygoers. They could talk about you behind your back, commenting on the rudeness of the abrupt and early departure. They may not invite you to their next party. There is thus a social cost to leaving, which arises because you would flout whatever the socially accepted convention for staying at a social

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[1] A similar anecdote is used to illustrate preference falsification by Timur Kuran in his book *Private Truths, Public Lies*. 3.

gathering is. Ultimately, you may very well decide to stay a little longer, eat a little more, talk a little more, and mingle a little more—all the time being thoroughly miserable.

Another instance of social pressure that is readily visible in most Western countries today is political correctness. At its core, political correctness is a society-wide and socially expected form of self-censorship, which limits the debate and discussion or the viewpoints acceptable for public expression on certain issues, or in some instances, precludes the discussion of those issues altogether. Some examples—which are provided here for the purpose of context, not to begin an ideological or political discussion—would include issues of women's rights and minority discrimination that have led to numerous affirmative action programs and policies. A negative discussion of affirmative hiring practices in some workplaces would be deemed politically incorrect, even if that discussion were motivated not by any underlying hatred, grudge, or malicious intent, but sincere concern for the social optimality of the policy under consideration. Similarly, discussions on subjects such as native land rights and immigration policies are shrouded in a veil of political correctness that often prevents their rational evaluation. One reason why political correctness is such an interesting example of social pressure is that it arises largely apart from any legislative, regulatory or judicial direction from the government. However, even without the presence of explicit coercive penalties, the punishments inflicted upon individuals deemed to be politically incorrect can be significant, ranging from the loss of face to the loss of job.

It should be noted that there are many who would argue that political correctness is in fact a positive development in the Western world. Advocates of minority rights, multiculturalism and women's rights have all used political correctness to further their policy goals. The argument is that some level of political correctness in a society can have two very positive results. First, it can help prevent the "tyranny of the majority" from oppressing a minority. By instilling a form of self-censorship on society many issues or policies that might be aimed at depriving some sub-segment of the population of their "rights" due to discrimination will never even reach the drawing board. And second, proponents have argued that political correctness can result in a greater level of tolerance and sensitivity towards certain groups or people (more on the counterpoint to this debate later). The discussion of the merits of political correctness raises a serious question which one should at least discuss, if not answer definitively, as part of an introduction to conformity: is social pressure welfare-enhancing?

Social pressure and convention can be highly productive instruments, in the sense that they can increase individual and social welfare. Abstracting from the example of political correctness, let us consider the case of traffic.[2] Unlike some other countries, the left-handed nature of traffic in Great Britain evolved naturally—the government through law, decree or statute did not order it. Over time, people began to adhere to a social precedent. There was pressure on an individual to conform to this. The pressure came not only from social forces, although these are the forces of most interest to us. Individuals were also acting in their own self-interest since they were much more likely to get where they were going quickly and in one piece by blending in on the appropriate side of the road with people traveling in the same direction, rather than fighting oncoming traffic. The pressure was also a result of the social will to travel harmoniously

[2] Discussed in: Young, H. Peyton. 1996. "The Economics of Convention". *The Journal of Economic Perspectives*. Vol. 10, 2. 105-122.

in the proper directions. That is, other travelers would likely not take too kindly to someone who would flout the established, accepted, and now self-enforcing convention, since such behavior would impede their own progress. If we consider the social pressure to conform to a particular way of action in this situation, we can easily deduce that there are large productivity and efficiency gains—consequently welfare gains—for society. People can now get to where they are going faster. There are less arguments and accidents. People can spend more time working, less time getting to work. Etcetera. This is an example of social pressure acting to create a socially positive, welfare-enhancing outcome, albeit in conjunction with standard utility-maximizing behavior. In fact, this scenario would likely conform to even the most stringent of the economic welfare measures: the Pareto criterion. The benefits of an organized and efficient system of transportation accrue to all members of society. The travelers who use the transport routes are better off, as mentioned above, as are the many businesses, households and individuals whose livelihoods or activities depend on travel. Social pressure can have a modifying effect on individual behavior in a way that is welfare—and Pareto—improving.

However, not all social pressure is so benevolent. There is a distinction to be made between the social pressure that led to the convention above, and social pressure that modifies social behavior in social settings. As an extreme example, consider a government that has instituted a policy of hate against a group of its citizens. What is necessary for such a policy to succeed in isolating and oppressing the target group of people? Interestingly enough, it is not social consensus that is necessary, but a lack of social opposition. That is to say, the government only needs a small group of determined backers to implement the policy if the rest of society either does not care enough or is unwilling or afraid to express their opposition to the policy. Ultimately, the rest of society may fall in line: whether they initially believed in the policy or not, at the end they march in unity to the beat of the drums due to the strong social pressure exerted by what is perhaps a very influential—and certainly a very well organized—minority. The lack of concrete social opposition in this situation means that there is nobody left to speak against the government policies. This scenario brings to mind the words of Martin Niemoller, a Protestant pastor arrested by the Nazi regime in the late 1930's:

> First they came for the Jews. I was silent. I was not a Jew. Then they came for the Communists. I was silent. I was not a Communist. Then they came for the trade unionists. I was silent. I was not a trade unionist. Then they came for me. There was no one left to speak for me.[3]

The example of Niemoller is meant to add gravity to the discussion of social pressure. While in today's world we often desire to understand social pressure and its effects—such as conformity and preference falsification—we easily forget that social pressure can be a powerful tool of social control, and induced conformity within a society one of the key weapons in the arsenal of dictators and tyrants.

Returning to our earlier example of the dinner party, we recall that guests have arrived and are enjoying themselves to various degrees. But as the party draws on, it can be expected that people are less and less enthralled by the conversation or the food, and more and more willing to leave. However, people may feel compelled by social pressure not to make the first move for the door. It would be impolite not to stay a certain period

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[3] Encyclopedia of the Holocaust. 1990. "Niemoller, Martin". New York: Macmillan. Can be viewed at: http://motlc.wiesenthal.com/text/x00/xm0076.html

of time, whatever is customary. How does such a decision to stay affect social welfare? It is likely that people who wish to leave want to do so because their outside option will yield them higher utility than the continuation of the party. This may cease to be the case when one considers the social consequences of leaving. But unless we assume that there is some productive benefit to society of people staying at a party when they really want to leave, or that social conformity to custom is in and of itself productive, then the social pressure acts as a distorting influence which moves us away from a socially optimal allocation of our time and resources. Naturally, it is quite possible to construe a scenario in which the additional utility from the party for the people who stay is so great that the social pressure is in effect a productive mechanism. It is equally possible to postulate the opposite. The incongruence between private preferences in a private setting and individual action in a social setting illustrates again the disconnect between individual preferences and social outcomes.

One should not fall into the trap of ignoring the utility benefits of socializing. Being part of a social group, and having a respectable position within the social setting, is an important and utility-enhancing behavior for most individuals. However, "socializing" and giving in to "social pressure" are two different things. Conformity to a set of social rules or conventions may in fact be necessary to guarantee or facilitate acceptance into a social order. But the utility roots of conformity are difficult to enunciate: do we conform because that makes us happy, or do we only do so to gain acceptance into a social group? Why do people in a group expect conformity from us? Is it because they gain some intrinsic and personal utility from seeing us forced to act a particular way, or is it because they feel it makes the group stronger and creates some sort of interpersonal bond? Again, these are all questions that are difficult to answer succinctly, although we will deal with them to some degree when we present an overview on the social psychological literature dealing with the subject of conformity. What is clear is that there are forms of social pressure that have clear benefits—such is the case of traffic illustrated above. What, though, are the aggregate effects of social pressure on society? In reality, this is an empirical question. One could imagine that if all members of society, rather than expending time and energy either conforming with social pressures or forcing others to conform, would make an alternate use of their time, we *could* be better off.

We can return now to our earlier example of political correctness as a form of social pressure. Political correctness, at its core, prevents people from openly or actively expressing their true opinions when these are incongruent with some "socially accepted" view on an issue and it leads to "preference falsification". Can such preference falsification have socially beneficial consequences? While we have presented some of the arguments of proponents of political correctness above, others have argued that political correctness does far more harm than good. As early as 1869, John Stuart Mill stated that:

> The peculiar evil of silencing the expression of an opinion is, that it is robbing the human race; posterity as well as the existing generation; those who dissent from the opinion, still more than those who hold it. If the opinion is right, they are deprived of the opportunity of exchanging error for truth: if wrong, they lose, what is almost as great a benefit, the

> clearer perception and livelier impression of truth, produced by its collision with error.[4]

According to Mill, anything that stifles the expression of opinion—true or otherwise—is adversely affecting social welfare not only in the present, but also in future generations.

When we observe social instances of conformity in society it is often difficult to determine exactly the source or rationale for the conformist behavior. At times, what may appear as conformity due to social pressure—which is the type of conformity we are concerned with in this paper—may in fact be the result of other factors. An example of this can be found in a recent comedy skit of the Canadian comedy group "Just For Laughs". The setting was a busy downtown park in some North American city—one of the little corner-pieces of greenery that often dot our metropolitan centers. As people walked in the park, perhaps returning from their lunch breaks, or just taking a few minutes to relax, a mass of five or six actors would suddenly run in a panic through the park in one direction, looking over their shoulders in complete fear. A curious thing would happen: complete strangers, out for a leisurely stroll, would join in the stampede, running from what quickly became some unimaginable horror, coaxing other strangers to join in. Soon enough—it only took about five seconds to get the stampede going—the park is empty of people, as some fifteen-odd individuals have fled, running for their lives. From an initial state where each individual in the park was simply doing whatever he or she wanted (at least for the immediate moment), a small shock brought the system to a completely conformed position where nobody was left walking in the park. There are two different interpretations of what happened here. One is that individuals felt a social pressure to conform to some mode of action. However, an equally possible explanation

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[4] Mill, J. S. 1998. *On Liberty and Other Essays.* Oxford: Oxford University Press. 21.

is that what we have described is not an instance of social pressure leading to conformity, but rather a case of asymmetric and imperfect information. As individuals we process informational cues from our environment, including those from the physical world we find ourselves in and cues that may come from other members of society. Since few of us would consider ourselves perfectly informed, and the costs of becoming perfectly informed are prohibitive (to say the least), we often use the behavior of others as a source of information. When we see a large and growing group of individuals frantically running through a park we may feel that they have better information than we do regarding potential dangers that may exist in the neighborhood. Given the limited cost of imitating the frantic flight and the potentially high costs of failing to flee if in fact danger is near, it is understandable that many people will choose to run rather than take a risk. So while it may in fact be the case that some individuals are somewhat motivated by a desire to blend in, and if everybody runs they probably will too even if they know it is safe, we see here an instance of conformity that is better explained through looking at individuals' information constraints. This example primarily serves to make the point that while conformity is a phenomenon that is readily observable, it is one whose motivations need to be carefully weighed. As in our earlier discussion of traffic conventions in Britain, the panicked flight in the park illustrates that social pressure is but one of the explanations for conformity, and that observed conformity can not be assumed to result from social pressure. Nevertheless, it is particularly on the specific form of conformity that does stem from social pressure—not from informational concerns or through independent utility maximization—that we seek to focus our debate.

The several examples provided above help illustrate some key factors which this paper seeks to examine. First, individual choice is not purely a reflection of individual preference regarding the matter at hand, but rather the cumulative result of individual preference and some form of social pressure, often leading to some level of social conformity. Social psychologist Elliot Aronson defines conformity as "a change in a person's behavior or opinions as a result of real or imagined pressure from a person or group of people," a definition which is both eloquent and instructive.[5]

Second, several of the above examples serve to introduce another interesting human behavior: preference falsification. That is, individuals will often not only change their decisions as a result of social pressure to do so, but can even make choices which are entirely contrary to their personal preferences. The factors and situations that influence the degree of preference falsification in society are of extreme importance.

A third aspect of conformity that is interesting to discuss deals with the exact structure of the social context in which decisions are made. That is to say, while various external agents in each situation surround the individual agent, we have failed to identify the individual's specific social relation to the agents around him. Are the people he is with his friends, his family, his coworkers or total strangers (as in the park)? In other words, how does an individual relate to all the other members of his or her society? The structure of individual social networks is of vital importance in understanding individual decision-making and in analyzing how the decisions of individual agents who are part of a larger society are interconnected. In terms of understanding conformity, a clear understanding of the entire social context in which individuals make their decisions is

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[5] Aronson, Elliot. 1999. *The Social Animal.* 8^{th} ed. New York: Worth.

vital, and that social context must take into account the nature of each individual's connectivity and relations with the rest of society.

The goal of this paper is to investigate the phenomenon of conformity and its relation to social pressure and individual preference, in the context of preference falsification and social network structure, by running experiments on a simulated society. While conformity is traditionally a subject treated in most depth by social psychologists, it has received increasing attention from economists interested in social and behavioral issues. Following the precedents set by previous economists, some of whose work will be detailed later, this paper seeks to bridge the interdisciplinary gap by using social psychological fundamentals to develop an economic model. The primary difference between this paper and the bulk of economic literature in this area is our use of the simulation framework to investigate a conformity model. There are several benefits to such an approach. Most importantly, it allows the researcher to run a series of interesting social experiments with an almost infinite number of parameterizations and formulations using the model framework—experiments that in traditional economic modeling approaches are less feasible, or offer less intuitive results, and which as social psychology experiments would be extremely difficult to control and execute. By running simulations using the basic model we develop we are able to immediately test the robustness of the model in entirely different social settings, and correlate these results with the research done to date by those in the economic and social psychological fields.

The approach that is followed here does not seek to develop a new psychological or social theory of conformity, nor will it lead to an invalidation of the key economic research in this field. It will however elucidate the issues surrounding conformity and allow us to test some of the theoretical propositions on which our leading theories are based. We also hope to show some of the potential inadequacies of current research in the field by demonstrating that network structures should not be taken for granted or abstracted from, as they can have as much influence on conformity as preferences themselves.

In preparation for the development of a simulation framework to look at the above issues we will present a brief overview of the social psychology research into conformity. Apart from serving as an introduction, that discussion will also allow us to describe the fundamental psychological assumptions and propositions on which our model of conformity rests. Another discussion will be presented to outline the existing attempts by economists to model conformity.

Literature Review

While economists and social psychologists have both investigated issues of conformity, it is the latter group that is responsible for the bulk of formal analysis in the field. Although economics as a field is predicated on fundamental assumptions about individual preferences, and the study of behavioral phenomena has been central to the discipline, it is in fact social psychology that presents us with the most formal and extensive literature on the subject. While issues of conformity may be important to economics, they are central to social psychology. To understand conformity in an economic context as it will be presented here it is vital to explore the literature on the subject in both fields: to develop a comprehensive and reasoned model that will allow for interesting simulation exercises it is important to lay out the basic social-psychological foundations of human behavior in social settings and under social pressure; to establish a robust and meaningful economic model it is necessary to understand the attempts to date of explaining conformity using the economist's toolkit.

Social Psychology

There are several competing theories in social psychology that attempt to explain human behavior, and in particular, the type of conformist behavior in which I am interested. I plan to—very briefly—outline the historical progression and development of these theories, as well as explain some of their most basic precepts. Before discussing conformity directly, it is useful to give some general background on the major theoretical attempts to explain how human actions and human beliefs and attitudes are linked. Social psychologists generally list three possible explanations for why the actions of people affect their attitudes and beliefs.[6]

The theory of self-preservation suggests that we decide how to act based on our desire to create certain impressions on those around us regarding ourselves. At the core of this theory is the idea that we care what others think about us. The reasons for our desire to impress others can be varied, including our wish for a particular social reward, material advantage, or a greater security in our social identity or group bonds.[7] Having acted in a particular way in order to make some desired impression, we then adapt our external beliefs and attitudes (how we act) to avoid looking hypocritical—we modify what we say and what we do so as to properly manage the impression we are trying to make. We do not however, change our underlying attitudes and opinions, but rather refrain from expressing them.

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[6] See Myers, David. 2002. *Social Psychology*. 7th ed. Boston: McGraw Hill. 147.
[7] Leary, M. 1994. *Self-Presentation: Impression Management and Interpersonal Behavior*. Pacific Groove: Brooks. 147.

Self-preservation theory does not explain why underlying attitudes and opinions can actually change over time, which is its major drawback. Lean Festinger's theory of cognitive dissonance, first postulated in 1957, and since revisited by Festinger and Carlsmith (1959) and later by Aronson (1960, 1990...) and many others, suggests that tension arises when an individual is faced with two different cognitions.[8] In particular, as Festinger writes,

> If a person held two cognitions that were psychologically inconsistency, he or she would experience dissonance and would attempt to reduce dissonance much as one would attempt to reduce hunger, thirst, or any drive.[9]

Dissonance theory primarily deals with discrepancies between our attitudes and our behaviors. When the two are not aligned we feel pressure to change one of these factors and eliminate the discrepancy. An interesting corollary of this theory is the insufficient justification effect: when the external justification for acting against one's own beliefs is small, there is pressure for internal justification to occur, so that an individual changes their actual opinions to justify their actions.[10] This effect was first explained in an experiment performed by Festinger and Carlsmith in 1959.[11]

Self-perception theory is the last of the major theories I will mention. Enunciated best by Bem in 1972, this theory argues that when we are unsure of our attitudes—that is,

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[8] Festinger, Leon. 1957. *A Theory of Cognitive Dissonance.* Evanston: Row/Peterson.; Festinger, L. and Carlsmith, J. 1959. "Cognitive Consequences of Forced Compliance". *Journal of Abnormal Social Psychology, 58.* 203-211.; Aronson, E. 1960. *The Cognitive and Behavioral Consequences of the Confirmation and Disconfirmation of Expectancies.* Working paper.; Aronson, E., Fried, C, and Stone, J. 1991. "AIDS Prevention and Dissonance: A New Twist on an Old Theory." *American Journal of Public Health, 81.* 1636-1638.

[9] Festinger, Leon. 1957. *A Theory of Cognitive Dissonance.* Evanston: Row/Peterson.

[10] Myers, David. 2002. *Social Psychology.* 7th ed. Boston: McGraw Hill. 149.

[11] Festinger, L. and Carlsmith, J. 1959. "Cognitive Consequences of Forced Compliance". *Journal of Abnormal Social Psychology, 58.* 203-211.

we do not really know what we think about a particular subject—we tend to infer our beliefs from our behavior and the circumstances under which that behavior is exhibited.[12] Therefore, our underlying beliefs about our own opinions are deduced from our own observation of how we act, much in the way that we deduce the opinions of others based on our observations of their actions.

While initially these two theories may seem to be irreconcilable—and indeed, the debate between Festinger's and Bem's explanations of attitude change has been a lively one—they are not necessarily so. Greenwald and others have argued that in fact, these two theories may both be, at least partially valid ways of interpreting human behavior.[13] While Bem's cognitive theory—which suggests that our opinion process is not a result of an interplay between motivation and cognition, as does dissonance theory—gained increasing ground through the seventies and into the nineties, increasingly scientists are looking for ways to reconcile the two approaches, driven largely by the fact that both theories generally predict the same behavioral and social outcomes in the same situations.[14]

I will not delve further into that debate, as the actual theories and their relative effectiveness in explaining social behavior are well beyond the scope of this paper. Their inclusion is valuable mostly as background to a slightly more detailed discussion of conformity. In the following examples of social psychological approaches to conformity

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[12] Bem, D. 1972. "Self-Perception Theory" In Berkowitz, L. (ed.) *Advances in Experimental Social Psychology*. Vol. 6. New York: Academic Press. 1-62.
[13] Greenwald, A. 1975. "On the Inconclusiveness of Crucial Cognitive Tests of Dissonance versus Self-Perception Theories." *Journal of Experimental Social Psychology, 11*. 490-499.; Greenwald, A., Banaji, M., Rudman, L., Farnham, S., Nosek, B., Rosier, M. 2000. "Prologue to a Unified Theory of Attitudes, Stereotypes , and Self-Concept". In Forgas, J. (Ed.) *Feeling and Thinking: The Role of Affect in Social Cognition and Behavior*. New York: Cambridge University Press. 335.
[14] See *ibid*, Greenwald.

I abstract from the more general psychological theories just discussed in order to present a simplified, though adequate for our purposes, view of conformity. The more advanced reader may also note that much of the conformity research described below is hardly leading-edge—for instance the Asch experiments that will be presented are almost five decades old. Nevertheless, these experiments are still useful in framing an economic discussion of conformity, and through their influence on more modern theories remain important today. Additionally, since cognitive dissonance and self-perception theory largely predict the same outcomes in similar social situations, which theory is specifically applied in each of the examples that follow will prove to be of limited importance in the modeling section of this paper, since much of my work will focus on social outcomes resulting from economic assumptions about individual behavior, and those assumptions will subsume and supercede any other psychological considerations.[15]

Social psychologists often look at human decisions as a trade-off between intrinsic values an individual may hold, and the desire to fit into a particular social order in a particular way which may require the modification of those intrinsic values (more on what is meant by "modification" later).[16] Conformity is but one of the possible responses of human beings to social pressure, with rebellion as its opposite, and indifference (non-conformity) intermediate between the two extremes. While Aronson's definition provided above is accurate, social psychologists have acknowledged the fact that not all instances of conformity are the same in terms of motivation, longevity and effect on the

[15] This becomes clearer later on. Generally I will not be dealing with the *why* of conformity. Having assumed that individuals *do* conform, and that their conformity is based on some economic axiom—as represented by their utility functions—I will then try and observe what a society with these assumptions placed upon it would do. Thus, *why* people actually value conformity and *why* it is in fact placed in their utility function becomes less important as the emphasis shifts to *how* that utility specification influences the conformity in society.

[16] An excellent introduction into the literature is provided by Elliot Aronson in his book *The Social Animal.* Many of his references have been used in writing this introduction.

individual. Herbert Kelman provided interpretation of the different types of conformist reactions to social pressure in the following trichotomy, which is widely used by social psychologists today.[17]

1. *Compliance* occurs when individuals modify their behavior as a result of influence from another person or group primarily in the hopes of achieving a favorable reaction from them.[18] Examples of this type of conformity or behavior modification include instances where individuals seek to avert punishment or receive reward in return for modifying their actions in a specific fashion. Thus, the child that does his homework only to avoid the scorn of his parents, or perhaps in order to receive reward from them, is said to be complying with his pressure. Drivers who do not speed simply because they fear getting a ticket are similarly complying with the influence of society as manifested in traffic laws. Kelman notes that behavioral changes falling into the compliance category are generally short-lived and somewhat superficial. That is to say, they disappear as soon as the social threat or social reward disappears. An individual who is motivated primarily by the desire for some sort of reward would not be expected to continue in an activity for which pressure was required to induce their participation once the prospect of the reward was removed. Similarly, if a person refrains from doing something they actually want to do purely for fear of punishment, it would be reasonable to expect that once this impediment to their action is removed they would engage in the activity without a second thought. While compliance can elicit very profound behavioral changes in human beings, these changes are not fundamental or long lasting: their longevity generally depends on the presence of the reward or punishment which induced them.

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[17] Kelman, Herbert. 1961. "Processes of Opinion Change". *Public Opinion Quarterly, 25*, 57-78.
[18] *Ibid.* 62.

2. *Identification* occurs when individuals adopt the behavior of others because this behavior is a way of strengthening their relationship with individuals whose friendship forms part of their own self-image.[19] Identification therefore occurs because people want to in some way emulate a particular group in society, or more specifically, they find some group of agents in society appealing and attractive to them for some reason—perhaps they are successful, or beautiful, or popular, or seem intelligent. This emulation however is not actually a result of admiration of whatever behavior the role-model is exhibiting, but rather since individuals want to strengthen their relationship to this so-called role model because that relationship is important in defining the person themselves. Thus, even in the absence of any form of explicit reward or punishment, we are able to incorporate behavioral changes which do not arise from any of our intrinsic preferences, but which are transferred to us through our interaction with members of society for whom we have a particular empathy. Identification and compliance are similar in that both cases involve individuals who accept social influence not because the content of the influence is itself somehow satisfying, but because accepting the influence has some ancillary benefit. Nevertheless, identification differs clearly from compliance since in the former there is no explicit reward or punishment associated with the adoption of any particular mode of behavior. Further, an individual who is complying with social influence is generally quite aware that his actions are not necessarily in accordance with his own preferences. An individual who is identifying is not cognizant of this because she actually believes the opinions and behaviors she has adopted are her own.

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[19] *Ibid.* 63.

3. *Internalization* occurs when individuals accede to social pressure because the pressure is congruent with their own value system.[20] Therefore, it is the specific content of the influence that is attractive to us. Internalization bears with it overtones of rationality, in that individuals who internalize are doing so because the new behavior they are adopting is either the best way to maximize their own values and preferences, or because the new behavior provides a logical solution to some problem or dilemma the individual encounters. However, Kelman cautions against equating rationality with internalization, since some forms of internalization are not innately rational, even though they may coincide with our particular values or outlook on the world. Thus, while the adoption of racist beliefs is not considered a rational behavior, if racism in and of itself is satisfying to us as a belief then it may be internalized. When social pressure is internalized it can become a permanent fixture in a person's value system that is very difficult to change and independent of the source of the initial influence.

Determining which of the above motivations are responsible for various displays of conformist behavior is often a difficult task, since conformity is often a culmination of two or even all three of them. Various additional considerations are necessary to adapt this model to real-life events, since a host of factors can modify the permanence of the above trichotomy. For instance, De Salvo, Kiesler and Zanna have shown that instances of compliance could lead to internalization of the behavior if individuals viewed the reward or punishment as a long-term or permanent presence.[21]

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[20] *Ibid.* 65.

[21] De Salvo, J., Kiesler, C., Zanna, M. 1966. "Deviation and Conformity: Opinion Change as a Function of Commitment, Attraction and Presence of a Deviate". *Journal of Personality and Social Psychology, 3*, 458-467.

Some of the most important early contributions to the theory of conformity come from Solomon Asch.[22] In the 1950's Asch ran a series of experiments to investigate the phenomena. He asked "How, and to what extent, do social forces constrain people's opinions and attitudes?"[23] In one experiment, Asch assembled a group of nine college students for a psychological experiment on visual judgment. The test subjects were asked to compare lengths of lines printed on two separate cards. On the first card was a single vertical reference line; on the second, three lines of various lengths. Subjects are required to choose the line on the second card that corresponds in length to the line on the reference card. The exercise is elementary: most individuals easily pick the correct line. However, Asch found that an interesting thing happens as the experiment progresses. The nine subjects all announce their answers (their choice of corresponding line), and for the first two trials everybody answers correctly. Consent in each trial is unanimous. On the third trial however, there is one dissenting vote. One of the test subjects has chosen a different line than the other eight subjects. The dissenter is quite surprised, and frankly unable to comprehend how the other eight people could make such a fundamental mistake. On the fourth trial again the same single voice of dissent is heard. As the experiment continues, the one dissenter is more and more amazed that he is actually seeing something so fundamentally different than everybody else. Eventually, his response becomes more uncertain, with long pauses before he finally announces his answer of dissent. What accounts for this glaring discrepancy? The fact is that eight of

[22] Asch, Solomon E. 1955. "Opinions and Social Pressure". *Scientific American.* Vol. 193, No. 5.; Asch, Solomon E. 1951. "Effects of Group Pressure Upon the Modification and Distortion of Judgment". In M. H. Guetzkow (Ed.), *Groups, Leadership and Men.* (117-190). Pittsburg: Carnegie.; Asch, Solomon E. 1956. "Studies of Independence and Conformity: A Minority of One Against a Unanimous Majority". *Psychological Monographs, 70.*

[23] Asch, Solomon E. 1955. "Opinions and Social Pressure". *Scientific American.* Vol. 193, No. 5.

the nine test subjects are agents of the experimenter who have been instructed to vote a particular way for each set of cards. In particular, they are told to unanimously agree on a line that is not in fact the correct match to the reference card, but not until the third and following trials. Thus it is only the dissenting voice that is actually freely choosing the correct line, which explains why it finds itself constantly in a minority of one. What is most surprising about Asch's experiments is that seventy-five percent of test subjects end up conforming to the (entirely incorrect) majority opinion, to varying degrees. The implications of his experiments are profound: if people are willing to conform even when faced with irrefutable visual proof that the majority of their fellow experimenters are incorrect, how much conformity must there be in our day-to-day decisions when proof is neither as available nor as clear? In fact, several researchers have shown that conformity increases in the presence of ambiguous informational cues.[24]

The individuals in the experiment described above conformed for a variety of reasons. Some cited the need to not "spoil" the experiment. Others simply decided they must be wrong. Some thought that it was the rest of the group who were innocently following the vote of the first member of the group who announced their choice, or that others were the victims of a strange optical illusion. Only twenty-five percent of people refused to conform to the majority viewpoint to some degree—an astonishingly low number.

Asch also conducted experiments to investigate the influence of different types of majorities on the degree of conformity. In particular, he created experiments to test whether the size of the majority or its unanimity were more relevant in producing

[24] Walker, E. L. and Heyns, R. W. 1967. *An Anatomy for Conformity*. Belmont: Brooks/Cole. Chapters 2 and 3; Allen, V. L. 1965. "Situational Factors in Conformity" in Berkowitz (ed.). *Advances in Experimental Social Psychology*. Vol. 2. New York: Academic Press. 133-176.

conformist behavior. His results indicate that in the presence of at least one "truthful partner" the effectiveness of the group pressure exerted by the majority is reduced by seventy-five percent. Further, Asch found that as a majority grows in size—from a majority of one person, to a majority of two people, and eventually to a unanimous majority minus the dissenter—the degree of conformity increases substantially, but only to a point. In particular, his experiments found that with a majority of three—the experiment had nine members—the dissenters tended to conform almost thirty-two percent more often than when the majority was only a one member majority. However, further increases in the size of the majority had only marginal effects on the conformity of the dissenting population.

At the conclusion of one paper, Asch echoes the sentiments of Locke when he makes reference to the productivity implications of conformity, which we have mentioned briefly in our introduction:

> Life in society requires consensus as an indispensable condition. But consensus, to be productive, requires that each individual contribute independently out of his experience and insight.[25]

Aronson, commenting on the Asch experiments, notes that it is highly intriguing that individuals in the experiments showed high levels of conformity even when there were no direct punishments or restrictions placed on individuality.[26] This illustrates that compliance was not the driving force behind the conformist behavior of the naïve test subjects, but rather, that their behavior was modified more for reasons of identification, and possibly internalization (say if the individual knew that they were a weak judge of

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[25] Asch, Solomon E. 1955. "Opinions and Social Pressure". *Scientific American.* Vol. 193, No. 5.
[26] Aronson, Elliot. 1999. *The Social Animal.* 8th ed. New York: Worth. 21.

lines, and generally thought it was better to defer to the observations of others with respect to these matters), or due to other considerations.

The basic Asch experiments have been modified, replicated and reproduced by a great number of researchers.[27] Deutsch and Gerard elaborated on the basic work of Asch to illustrate that public commitment to a particular point of view greatly decreased the probability that an individual would conform.[28] Bond and Smith, and several other researchers, have looked at how certain cultural differences can affect the levels of conformity.[29] They found that societies that share collectivist social values are much more likely to produce conforming naïve test subjects than societies which tend to value and expound individualism and uniqueness.[30] Other researchers have looked at conformity differences between the sexes (Maccoby and Jacklin, Eagly and Carli, Cooper, Javornisky)[31], and on differences in influence when majorities consist of different races (Schneider, Allport)[32].

Another line of conformity research in social psychology (indeed, also in economics, as will be detailed later) has dealt with informational issues. Leon Festinger argued that as individuals have less reliable information about what the proper course of

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[27] To be fair, some replications of the experiments have *failed* to illicit similar levels of conformity.
[28] Deutsch, M. and Gerard, H. 1955. "A Study of Normative and Informational Social Influence Upon Individual Judgment". *Journal of Abnormal and Social Psychology, 51.* 629-636.
[29] Bond, R. and Smith, P. 1996. "Culture and Conformity: A Meta-Analysis of Studies Using Asch's (1952, 1956) Line Judgment Task. *Psychological Bulletin, 119.* 111-137.
[30] Collectivist societies could be: China, Japan. Individualistic societies might be: United States, Canada.
[31] Maccoby, E. and Jacklin, C. 1974. *The Psychology of Sex Differences.* Stanford, CA: Stanford University Press. 268-272; Cooper, H. 1979. "Statistically Combining Independent Studies: A Meta-Analysis of Sex Differences in Conformity Research". *Journal of Personality and Social Psychology, 37.* 131-146; Eagly, A. and Carli, L. 1981. "Sex of Researchers and Sex-Typed Communications as Determinants of Sex Differences in Influenceability: A Meta-Analysis of Social Influence Studues". *Psychological Bulletin, 90.* 1-20; Javornisky, G. 1979. "Task Content and Sex Differences in Conformity". *Journal of Social Psychology, 108.* 213-220.
[32] Schneider, F. 1970. "Conforming Behavior of Black and White Children". *Journal of Personality and Social Psychology, 16.* 466-471; Allport, G. 1954. *The Nature of Prejudice.* Cambridge: Addison-Wesley. 13-14.

action is, they are more and more likely to rely on social cues in modeling their behavior. Asch's line judgment experiments had a clear informational element in the form of the line display cards, which could be easily referenced by all participants. However, in many (perhaps most) social situations there is no clear right answer against which we are able to judge the social pressure we are incurring. Consequently, we are more likely to rely on social pressure as a gauge for what is "right". This is interesting since if in the absence of non-social information we increasingly turn to our social peers for our informational needs, the effects of social pressure on conformity can be magnified. Mullen, Cooper and Driskell have conducted studies on jaywalking that indicate the validity of social signals.[33] In their experiments, it was found that jaywalking increased dramatically in the presence of a model jaywalker (somebody in league with the experimenters who would jaywalk). Thus, even in the absence of any specific social pressure to jaywalk, individuals used the existence of another individual as an informational cue on which they chose to model their own behavior. The study also found that individuals are much more likely to emulate some people than others. In particular, well-dressed jaywalkers were a more successful model—that is, they were more likely to be followed—than models dressed in shabby clothing. This result, which is echoed in numerous other social psychology experiments, supports the importance of credibility in determining the influence and permanence of social pressure and conformist behavior. Aronson and O'Leary conducted modeling experiments in a shower room, and observed water conservation practices in the presence of a water conserving model.[34]

[33] Mullen, B., Cooper, C., and Driskell, J. 1990. "Jaywalking as a Function of Model Behavior." *Personality and Social Psychology Bulletin, 16(2)*, 320-330.
[34] Aronson, E., and O'Leary, M. 1982-83. "The Relative Effectiveness of Models and Prompts on Energy Conservation: A Field Experiment in a Shower Room." *Journal of Environmental Systems, 12*, 219-224. In

Their results found that even with a single model, water conserving behavior increases by forty-three percent, and by sixty-two percent in the presence of two models.

Tyson and Kaplowitz identify three key propositions regarding the prevalence of conformity, which summarize our discussion above:

1. Conformity is lessened when individual behavior is not reported publicly.

2. Conformity increases as the ambiguity of informational cues increases.

3. Conformity increases when an individual is faced with a strong majority, and is highest when the individual is faced with unanimous opposition.[35]

Their study suggests that surveillance, unanimous or strong opposition, and stimulus ambiguity are in fact required to produce conformity. In their experiments they show that in the absence of at least one of these conditions there will be no marked tendency for individuals subjected to social pressure to conform to anything but their own private preferences.

This serves as a very brief overview of some key conformity literature from the field of social psychology. I doubt I have done the discipline justice, but the short introduction should be sufficient for our purposes.

Economics

While economists have not adopted Kelman's taxonomy in reference to their discussions of conformity and have largely abstracted from a specific discussion of identification and internalization, they have focused extensively on conformity explained

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particular, they were testing to see how often people would conform to the printed request in the shower room to conserve water by turning the shower off while soaping up. In the control group the showering practices of individuals were observed when there was no model present to show the water conservation behavior. In the test group an individual situated himself in the shower room and "demonstrated" the water conserving behavior.

[35] Tyson, H. and Kaplowitz, S. 1977. "Attitudinal Conformity and Anonymity". *Public Opinion Quarterly, 41, Issue 2.* 226-234.

as compliance. Compliance is quite central to the economic approach to many social problems and scenarios, as well as to the design of institutions to deal with issues such as crime and punishment. In fact, the idea that individuals will respond to rewards and punishments forms the foundation of much of economic thought. Most economic problems involve individual best responses or utility-maximizing decisions by economic agents who are seeking to either obtain a reward for their action or avoid a punishment. While this type of problem is often formulated in a monetary framework, the concepts are identical: more money or profit is a reward, less is a punishment.[36] As early as 1781 philosopher Jeremy Bentham had written,

> Nature has placed mankind under the governance of two sovereign masters, pain and pleasure...They govern us in all we do, in all we say, in all we think.[37]

Although Bentham was not an economist, his ideas are central to welfare economics and indeed to the entire economic way of thinking about the decision-making process and utility-maximizing behavior of individuals and the institutions they create.

The research output and depth from economists on the subject of conformity is much smaller than that from the social psychology field. While economists recognize the potential importance of cultural and social factors in influencing preferences and modifying behavior, the discipline has not developed many models that could easily incorporate the social and psychological intricacies of human decision-making into an

[36] Of course, it would be incorrect to say that all economics simplifies the reward/punishment axiom of human behavior to some monetary denominator, because it does not. In any case, since monetary values are but proxies for agent utility, the distinction for our purposes is not relevant.
[37] Bentham, Jeremy. 1781. An Introduction to the Principles and Morals of Legislation.

economic framework. There are however several excellent papers on the issue which are worth mentioning.

Steven Morris has done extensive research into political correctness, which itself is a form of conformity.[38] Morris notes that while political correctness can seem a perfectly rational form of behavior from the view of its practitioners—either those who espouse it to promote their agenda, or those who comply with it—it is a potentially wasteful exercise since it inhibits the effective and efficient transfer of reliable information between economic agents. Morris states that participation in politically correct activity results purely because of our desire to be perceived a particular way by our social peers. But that is not to say that individuals necessarily engage in conformist behavior simply to fit-in with some socially accepted norm. Rather, Morris argues that individuals attempt to fit in to the social norm for an extraneous reason: to protect their reputation and thereby the value of their opinions. The argument is that somebody who is politically incorrect increases their probability of being perceived as biased (racist, sexist, elitist, etcetera), thereby reducing the credibility of their opinions. Morris's model suggests that conforming to a politically correct mode of action can have significant negative social consequences if it leads to biasing of social information, and ultimately the implementation of sub-optimal social values and policies. However, Morris also notes that biased individuals—the racists and sexists in our society—by conforming to a politically correct mode of action, can in fact mitigate some of the welfare losses incurred when non-conformists change their views, and that ultimately the necessity to be politically correct decreases as the portion of extreme views in society decreases.

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[38] Morris, Steven. 2001. "Political Correctness". *Journal of Political Economy*. Vol. 109, 2.

Paralleling the developments in social psychology, several economists have argued that conformity can arise as a result of modeling behavior stemming from informational concerns. In particular, individuals often choose to conform to other modes of actions because they believe that other members of society, and in particular majorities, are better informed than they are themselves. John Conlisk explores this issue in depth, and finds that firms and individuals that optimize their decision-making are not necessarily guaranteed to outperform economic agents that simply imitate the decisions of others, the reasoning being that it is expensive for agents to design and employ an optimized decision-making process.[39] If the costs are sufficiently high, some economic agents will choose to forego their own optimization and follow the decisions of others in the hope that they may have optimized. If the agent actually manages to follow somebody who has optimized their decisions then that agent has an integral advantage on the optimizer, since they are able to make the same informed decision without actually having to expend the time and energy required for making that decision. Such behavior is an interesting explanation for the development of conformity. However, it does not incorporate any individual preferences over social parameters, since the decision to optimize is based not on a desire to fit-in or to comply with a socially accepted mode of action, but rather on a desire to avoid the costs associated with information gathering and optimized decision-making.

Bikhchandani, Hirshleifer and Welch follow a similar line of reasoning in explaining conformity.[40] They argue that conformist behavior can often be attributed to

[39] Conlisk, John. 1980. "Costly Optimizers Versus Cheap Imitators". *Journal of Economic Behavior and Organization, 1.* 275-93.
[40] Bikhchandani, S., Hirshleifer, D. and Welch, I. 1992. "A Theory of Fads, Fashion, Custom and Cultural Change as Informational Cascades". *J.P.E., 100.* 992-1026.

the presence of an information cascade, which occurs when individuals base their decisions on the observed decisions of others without any regard for their own private information. In fact, their model illustrates that individuals can rapidly converge to a single behavior even when circumstances or information change only very slightly. Information cascades explain large and very rapid shifts in public opinion and behavior because they facilitate a situation in which societal opinion tends towards a borderline where many individuals are only marginally sure in their choice of action. This leads to increased fragility as it only takes a small shock to create a cascade whereby many of the borderline individuals rapidly change their preferences, taking those more certain in their beliefs along for the ride. The authors also note that in social networks where information cascades are present, the value of the information being transmitted to other members of society decreases as people increasingly rely on the information of others without regard for their own information. When an information cascade is initiated, individuals who have not made their decision garner no valuable information from the economic agent sequentially preceding them in the decision-making—since this agent ignored whatever information assets they may have held personally—and increasingly unreliable information from the collective whole of individuals ahead of him or her.

Katz and Shapiro explain conformity by suggesting that there may exist significant positive externalities for agents who choose to coordinate their actions and conform.[41] Their research focuses on conformist technology adoption when the technology itself is more productive (utility-enhancing) to the agent who possesses it when the network of individuals who have adopted the same technology is larger. A

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[41] Katz, M. and Shapiro, C. 1986. "Technology Adoption in the Presence of Network Externalities". *J.P.E., 94*. 822-41.

prime example of this type of conformity is the widespread use of Microsoft Windows as an operating platform. The fact that the operating system is readily compatible with so many computers makes buying a Windows-based computing platform significantly more attractive to potential consumers than other operating platforms, even if they are superior in terms of product offering. Like Conlisk and others, Katz and Shapiro have abstracted from any sociological explanations of conformity, and focused on non-sociological circumstances that can lead to behavior homogeneity.

The coordination of decision-making in a society in the presence of a network externality is also investigated by Eaton and Krause, who note that when the benefits of the network externality are large members of society are much more likely to achieve relatively high levels of coordination.[42] Since network externalities imply that realized network benefits that each member of a society receives depend on the number of individuals within a society who make the same choice, conformist outcomes with high levels of coordination can in fact be welfare-enhancing. Depending on the degree of welfare benefit associated with the network externality, agents have different degrees of incentive to modify their behavior in a way that facilitates coordination. Eaton and Krause demonstrate that with sufficiently large network externalities their model has two terminal Pareto optimal states in which all agents make the same choice over a set of goods (understood in the general sense, these goods need not be physical but can include opinions and other social choices). What is interesting conceptually about their model is the trade-offs individuals make between following their own private preferences and maximizing utility by maximizing the benefit of the network externality. In effect, the

[42] Eaton, Curtis and Krause, David. 2001. "Coordination Cascades: Sequential Choice in the Presence of a Network Externality". Working paper.

network externality serves as a form of social pressure, and like in social scenarios we have discussed earlier, specific choices bear with them consequences that are determined by the actions of other members of society.

Eaton, Pendakur and Reed create a model of socializing in which individuals derive increasing utility from social encounters when these encounters are between individuals with increasing degrees of shared social experiences.[43] Therefore, individuals who have in common a large amount of experiences are expected to derive greater utility from their social encounters than if they did not have shared social experiences. Their model, which is explored using a series of simulations, suggests that in making their choices over a set of possible social experiences in which they can partake (for example, watching a movie, reading a book, or going for a walk), individuals will consider, apart from their private preferences over the set of activities, the potential for developing shared experiences with other members of society. One implication of such an individual choice problem is the potential for conformist behavior in society, as individuals will try to maximize the number of experiences they have in common. Examples of this include the rise of superstars and cultural domination. The superstar example is particularly illustrative: if individuals seek to find a set of common experiences so as to maximize the utility value of their social encounters, a society-wide coordination of experiences onto one particular individual, the superstar, will enable social actors to have an additional shared experience with others—apart from the weather.

Most of the economic literature discussed above abstracts from the direct modeling of social pressure by suggesting that there are external utility considerations

[43] Eaton, C., Pendakur, K., and Reed, C. 2002. "Socializing, Shared Experience and Popular Culture". Working paper available at www.econ.ucalgary.ca/eaton.htm.

which give rise to the social pressure, rather than purely sociological reasons which might suggest that conformity is itself a central question for individuals. They are thus able to ignore certain preference parameters when formulating agent utility functions, and do not need to specifically model any form of direct social pressure, nor analyze in what way that direct social pressure affects an individual's decision process. Another way of addressing the issue of conformity is to assume that social pressure is itself something which has direct utility consequences for individuals, and that conforming to or rebelling against social influence is directly associated with individual utility. For instance, Timur Kuran suggests that an individual's total utility is a sum of their intrinsic utility, reputational utility and expressive utility.[44] Intrinsic utility is that which a person obtains from a decision or an action, without considering the social context in which that decision will be viewed. Reputational utility derives from how people view and react to one's decision, while expressive utility represents the importance a person attaches to being able to follow their private preferences (intrinsic utility). For Kuran, the individual's problem is characterized by a tradeoff between intrinsic, reputational and expressive utility. (For illustration, the farther away a person's action is from their true private preference as a result of social pressure, the lower is that individual's expressive utility.) This framework incorporates several aspects of the conformity research in social psychology.

Douglas Bernheim also creates a model of conformity in which economic agents derive utility from intrinsic utility (consumption) as well as from status.[45] These two utility sources are often in conflict, since intrinsic utility can be positive for a given

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[44] Kuran, Timur. 1995. *Private Truth, Public Lies: The Social Consequences of Preference Falsification.* Cambridge: Harvard University Press.
[45] Bernheim, D. 1994. "A Theory of Conformity." *Journal of Political Economy, 102, 5.* 841-877.

consumption good (consider "consumption" as an expressed opinion) while the reputational utility from the same consumption bundle is negative. Information is imperfect in this model, which implies that status is not derived from your actual intrinsic preferences but from your actions that are an imperfect reflection of your private preferences. Bernheim's model finds that when status is sufficiently important to members of society there emerges a homogenous mode of behavior, regardless of the underlying preference structure of individual agents. The model also illustrates that different underlying preference distributions among society's citizens can lead to different levels of conformity and different conformist outcomes.

Economic studies of conformity as a response to network externalities or information asymmetries do not incorporate the key elements of social decision-making from the social psychology point of view, since they do not focus on conformity as a response purely to social pressure, which is the type of conformity with which we wish to specifically deal. While there have been models that deal with conformity in the more direct fashion, they largely abstract from a detailed discussion of network considerations, which we believe are an important factor when looking at conformist outcomes. Our model seeks to bridge the gap between these two approaches by adopting some of the network considerations which are central when conformity is seen as arising from network externality considerations, but also modeling individual decisions as explicitly related to acquiescing or resisting social influence. The result, I hope, is a model that explains conformity as a response to social pressure more fully, since it not only explicitly models individual choice based on certain social psychology principles, but also specifies in more detail the effects and importance of social network structure. In addition, few of the papers dealing with conformity have utilized extensive simulations as a method of exploring their models—a process adopted here.

The Model

In my model, individuals are called upon to express a preference for one of two policies or opinions, A or B. The policy choice can be as simple as that between two colors: given the choice of red or blue, some individuals will prefer red (choice A), others blue (choice B). Similarly, the choice can be between two political parties (NDP or Canadian Alliance), or between two breakfast cereals (Müsli or Bran). For clarity, an *expressed preference* is called a *vote*, and the vote of individual i is denoted by v_i: $v_i=0$ is a vote for policy A, and $v_i=1$ is a vote for policy B. The endogenous variables in my model are the votes or expressed preferences of the N individuals in society:

$$V = (v_1, v_2, \ldots, v_N)$$

Each individual i is described by four utility parameters:

$$\theta_i = (R_i, p_i, f_i, s_i)$$

Parameter R_i is a binary variable that indicates the individual's *private policy preference*: $R_i=0$ indicates a private preference for policy A, and $R_i=1$ a private preference for policy B. Parameter p_i, $0 \leq p_i \leq 1$, captures the strength of the individual's private preference, parameter f_i, $0 \leq f_i \leq 1$, captures the strength of the social pressure exerted on individual i by his friends, and parameter s_i, $0 \leq s_i \leq 1$, captures the strength of the social pressure exerted on individual i by society at large. For convenience, it is assumed that

$$p_i + f_i + s_i = 1$$

Individual i's preferences are captured in the following utility function

$$U_i(v_i, V_{-i}) = p_i R_i + f_i F_i + s_i S_i \qquad \text{if} \qquad v_i = 1$$

$$U_i(v_i, V_{-i}) = p_i(1-R_i) + f_i(1-F_i) + s_i(1-S_i) \qquad \text{if} \qquad v_i = 0$$

where F_i is the fraction of i's friends who vote for policy B and S_i is the fraction of society that votes for policy B.[46] Notice that p_i can now be interpreted as the weight the individual attaches to being true to her private preferences, f_i the weight she gives to the expressed preferences of her friends, and s_i the weight she gives to the expressed preferences of society at large. Individuals therefore determine their own votes based on the observed or expressed preferences, the votes, of the rest of society. Note that the private preferences of each individual are not observable by others.

Naturally, the individual chooses the vote that maximizes her utility. The utility functions above reduce to the following choice criterion:

If $p_iR_i + f_iF_i + s_iS_i > \frac{1}{2}$ then vote v_i=1.

If $p_iR_i + f_iF_i + s_iS_i < \frac{1}{2}$ then vote v_i=0.

If $p_iR_i + f_iF_i + s_iS_i = \frac{1}{2}$ then vote v_i=1 or v_i=0 randomly.

The randomness introduced in order to break ties is necessary to ensure that the voting results are not biased. This proves to be an important consideration in some of the experiments we perform.

We can now introduce several notions of equilibrium. Since all individuals vote concurrently based on the perceived preferences of others there exists a vector of votes, V^*, for which each v_i is a best response to each v_{-i}. This vector,

[46] The value of S_i is obtained by averaging the opinion of all members of society except individual i. Thus, friends are "double-counted". Their opinions influence the individual directly through F_i (weighted by f_i), and also indirectly because the friends also influence the average societal value of S_i. This is but one option for determining these values. The conceptual story told here is that while you are directly influenced by the opinions of your friends, those friends also each individually influence whatever is considered a "social norm". As a conceptual example consider how average opinions are measured in many (larger) societies: through opinion surveys. While your friends individually interact with you, they are also part of the larger social opinion as reflected in an opinion survey. While this discussion is not very relevant for very large social networks, it proves to be quite significant when networks are small, owing to the fact that in smaller networks your friends constitute a large portion of society.

$V^* = (v_1^*, v_2^*, \ldots, v_N^*)$

is said to be a static Nash equilibrium if, for all individuals i,

$U(v_i^*, v_{-i}^* ; \theta, \Phi) \geq U(v_i', v_{-i}^* ; \theta, \Phi)$

where v_i' is defined as the complementary vector to v_i^* such that,

$v_i' = (1 - v_i^*)$.

Further to the concept of the static equilibrium we introduce the idea of a cyclical Nash equilibrium, in which a series of recurring V* vectors are in each sequential iteration of the model the best response vectors for all individuals i. Therefore, if $V^{*1} \neq V^{*2}$ and V^{*1} is the vector of best responses to V^{*2}, and V^{*2} is the vector of best responses to V^{*1}, then the system is said to be in a two-stage cyclical equilibrium (V^{*1}, V^{*2}). In the generalized case, an x-cycle equilibrium occurs when each vector of votes V^{*t} is the best response to the sequentially preceding set of best response votes, V^{*t-1}, and the initial V^{*1} (when t=1) is the best response to the terminal point of the cycle, V^{*x}, where x denotes the length of the cycle. Note that in a cyclical equilibrium $V^{*t} \neq V^{*-t}$, since if this were the case we would simply have a static equilibrium.

The model as presented captures several important aspects of human behavior. First, individuals are rewarded (in terms of utility) for acting in accordance with their private preferences. This type of behavior has been explored at length by both economists and social psychologists, and has been described in our earlier discussion of the literature in both disciplines. The degree to which individuals will be motivated to act in accordance with their own preferences depends on the weight they assign to p_i.

Apart from considerations of purely private preferences individuals respond to signals they get from the rest of society in the form of votes. Namely, each person in society derives utility from voting in a similar fashion to his or her friends, as well as from "fitting-in" to the average societal view on an issue. The particular reason why an individual derives utility from conforming to the expressed preferences of others is not made explicit in the model. That is, we abstract from a detailed modeling of some of the phenomena described earlier such as compliance and identification.[47] For instance, it could be postulated within the confines of our model that individuals derive utility from conformity because non-conformity has attached to it certain negative social consequences—some sort of social punishment (as in compliance). Similarly, it is equally possible that the conformity is motivated by identification. The distinction for our purposes is not important. It is assumed that to varying degrees some or all of these motivations for conformity exist in each individual in society. What is important to note is that we are only dealing with conformity that arises as a result of social pressure, not conformity which is derived from informational issues. While this sort of generalization deprives our model of some explanatory power when discussing conformity, the general focus of this paper is conformity in society rather than the particular make-up or motivation for that conformity, other than the above distinction between conformity driven by social psychological considerations versus informational issues.

Clearly these simplifying assumptions deprive the model of some explanatory power. This is less visible from the practical point of view—that is, we can still see how people act given our preference assumptions—but it is more problematic from an explanatory point of view—*why* do people choose to conform. Having swept most of the social-psychological theories "under the carpet", by abstracting from a more detailed cognitive and motivational modeling of the individual decision process, one need bear in

[47] Note that internalization is less easily abstracted from. This issue is explained shortly.

mind that some of our conclusions require careful consideration in terms of their implications and their scope. Not differentiating between compliance and identification on the one hand, and internalization on the other, could be problematic since if certain opinions are internalized then we would expect the actual vector of private preferences to change. The model does not capture this effect. The implication for our results is that when they are interpreted we can not conclusively say whether they are showing us the effects of compliance and identification as a response to social pressure, or if they are illustrating some sort of feedback through internalization. This is a limit to our model's explanatory power—although the results are still important in a myriad of other ways.[48] In fact, there is no room for internalization as a response to social pressure in the model as it stands, since the actual private preference vector is static.[49]

Several preliminary observations can be made immediately from the model. It is clear that if the weight attached to private preferences is sufficiently high there is no preference falsification. In particular, if p_i>.50 for all i, then $v_i^*=R_i^*\ \forall i$. That is, all individuals are truth-tellers, and the system converges to a truth-telling equilibrium. Similarly we can observe that if individuals do not attach any weight to their private preferences, a conformist equilibrium in which all individuals express preference over the same policy (they vote the same) exists. Specifically, if p_i=0 for all i, then V=(1,1,1,1,...) and V=(0,0,0,0,...) are both Nash equilibriums. In the case where R_i=(1,1,1,1...) or R_i=(0,0,0,0...) these are potentially truth-telling equilibriums, although it is always true that at least one of the conformist equilibriums will involve a degree of preference falsification in that expressed preferences will not reflect private preferences.

48 Many thanks to John Ellard (University of Calgary), who helped clarify this, and other issues regarding the overlap of the economic model and social-psychological principles.
49 This is clearly one of the numerous interesting modifications that this model eagerly awaits.

Note that the influence exerted by the votes of an individual's friends and of society as a whole is not necessarily uniform in this model. This is an important consideration, allowing us to vary the individual's responsiveness to pressure that comes from different sources. For instance, this set-up would allow for a scenario where a small group of committed friends can "buck the trend" even in the face of unanimous opposition from the rest of society (although this particular example is not explored in the simulations). More generally, this dichotomy allows us to make one's friends more important than the votes of society as a whole.

The distinction between the influence of friends and of society sets the stage for a discussion of social networks: who are your friends? The social network present in the society which determines who is friends with who is assigned exogenously in the NxN matrix, Φ. More specifically, each individual has one of two relationships with every other individual in society: they are either friends, or they are strangers. In the network matrix friends are denoted by a 1, and strangers by a 0. We impose the restriction that all relationships are reciprocal. This implies that the network matrix is symmetric around the main diagonal: $\Phi = \Phi^T$. Note that for every society only one network matrix is necessary, since it incorporates the relationships of all members of society.

With the introduction of Φ our model now captures specific social networks in addition to the private preferences and utility parameters described above. Equilibrium votes are now determined endogenously based on a set of exogenous specifications: Θ, the collection of parameters R_i, p_i, f_i, s_i for each individual i; as well as Φ, the social network matrix. The role of the simulations in this thesis is to explore the comparative statics of Θ and Φ, in terms of their effects on conformity. In particular, how likely are the two conformist equilibriums in which all individuals vote the same, and how prevalent is truth-telling? Of interest is how much preference falsification occurs within the static and cyclical Nash equilibriums, and if certain equilibriums are more likely to occur than others. For instance, it is possible that for one parameterization of the system there exist multiple best response vectors V*. Will these multiple equilibriums occur with similar frequency? What is the probability associated with each particular equilibrium? The question is central, because knowing that some equilibrium could exist does not allow us to make strong statements about society unless we know how likely that equilibrium is to occur. These questions lead us to two sorts of comparative static exercise, where we manipulate the exogenous factors of the model and observe the effects the changes have on the make-up and existence of Nash equilibriums.

The first type of comparative static exercise deals with changes in Θ. This preference vector describes, for each individual, the weights they attach to the preferences of the other members of society as well as their own underlying private preferences. Both social psychologists and economists have studied how changes in underlying preferences and preference parameters affect social conformity. In fact, most of the literature in conformity deals with changes in these parameters. Investigations into Θ and its relation to social equilibrium can answer several interesting questions. As the weights attached to our private preferences increase, how rapidly does the level of conformity in society decrease, if at all? Are conformist outcomes driven by underlying private preferences or by the utility derived from conforming to our friends' and society's values? Different parameterizations obtained by varying Θ can also help us ensure the robustness and accuracy of our model by comparing our results to those of other researchers, in particular, those who have conducted actual social experiments.

The second type of comparative static deals with changes in the social network matrix, Φ. This area of conformity has been less well researched, and the economic modeling attempts of conformity largely ignore issues of network structure when conformity arises due to social pressure. It is my contention however that changes in the network parameter can have a profound impact on the conformity of outcomes we observe in society. The network parameter defines our social relations with other members of society. It identifies who our friends are, and therefore contributes to determining what sort of social pressure we will be making our decisions under. The explicit modeling of this network parameter allows us to manipulate important social variables such as the strength of social networks, the amount of social overlap between different individual's social networks, and the degree of social support or opposition that individuals might have in making their decisions. Investigating Φ can also help explain instances of localized conformity within a society, where individuals belonging to different social sub-networks tend to converge in their preferences even in the presence of social links to other social sub-networks (although this is not explored in-depth here).

Since individuals in our society determine their votes according to the observed votes of others an issue arises regarding initial conditions. In particular, we wish to find all of the possible equilibriums in a given society. How do we do this? In the first round of utility maximization informational signals received from others do not exist, since in the first time period nobody has yet voted. There are several ways that this issue can be dealt with. One is to assume that in the first round of voting everybody votes according to his or her actual private preferences. This would mean that after the first running of the vote function people would in effect not take into account other people because they would not have observed any vote coming from the rest of society. The first iteration of the model would be the first action of this nascent society. Going forward individuals could now observe the votes of others and would continue their maximization activity until Nash equilibrium was reached. There are however several drawbacks to this approach. Its applicability to real-life is limited, since there are few situations in society where we expect people not to falsify *any* of their preferences, while at the same time all members of society have a perfect view of those preferences. The assumption of perfect private preference information, which is implied by the above scenario, is a strong one, and one that I believe is unnecessary.

A more robust method of investigation would be to examine the best response dynamic for all possible initial conditions in society. This strategy involves applying the utility maximization exercise to all possible initial conditions a society may find itself in, and then observing which equilibriums each initial condition converges to. This best response dynamic is guaranteed to pick out all static equilibriums as well as all equilibrium cycles.[50] The set of all possible initial conditions is nothing more than the union of all possible voting scenarios. Thus, for a society of N people with a binary policy choice there are 2^N possible initial starting conditions. Utilizing all possible initial states as starting points for our society eliminates the complex requirement of choosing a

[50] This is not entirely accurate. In fact, in the case where there is tie-breaking our cycle may not pick out all *possible* equilibriums. Since votes, and thereby equilibriums, are decided with a degree of randomness, in the cases where this randomness exists not all equilibriums or equilibrium cycles may be found. This turns out to be only a minor drawback, for two reasons. First, tie-breaking is actually a fairly rare phenomenon in the simulations. Thus, this issue is does not permeate or bias most of the results significantly (there proves to be an exception in our simulations that follow). More importantly, since we are cognizant of this issue we can interpret our results accordingly, taking into account the effect of tie-breaking on social outcomes.

specific initial condition, and allows for one parameterization of the model to immediately be applied to all possible social scenarios (in terms of initial conditions). However, the introduction of this best response dynamic gives rise to many equilibrium possibilities for certain parameter values. In fact, in some instances the number of possible equilibriums approaches the number of possible initial states. This is discouraging because without further structure or assumptions we cannot say a lot about the model. Consequently, we make the assumption that for any given society all initial conditions are equally likely. This has the benefit of allowing us to associate probabilities with equilibrium possibilities, which in terms of analysis permits us to make much stronger statements regarding the prevalence of conformity and preference falsification in the model society. Such probabilities help us determine the basin of attraction for each of the possible equilibrium conditions, since they tell us how many initial starting conditions, on average, will converge to each particular equilibrium.

The Simulations

I have designed four sets of specific experiments to investigate the comparative static properties of our model. The first set of experiments, A, investigates some of the comparative statics associated with Θ. Experiments B through D focus on changes in the network matrix Φ. More detail on the design of each particular experiment is provided below.

Experiment A—A Discussion of θ

Since this is the first experiment being presented significant detail will be provided in order to introduce the reader to the methodology used in performing the simulations. In subsequent experiments the introduction will not be as lengthy.

A society of 10 people (N=10) is created. Individuals have private preferences defined by the following vector[51]:

$$R = \{R_1, R_2, \ldots R_{N=10}\} = \{1,1,1,1,1,0,0,0,0,0\}$$

Thus, individuals one through five prefer policy B and individuals six through ten policy A. Three further vectors are defined by the experimenter that define the weights individuals attach to private preferences, their friends votes and the votes of society as a whole, or p, f, and s, respectively. The values of p_i, f_i, and s_i are equal for all individuals i, implying that over the weight parameters preferences are homogenous, although private preferences are not, as above. As the baseline case we assume that[52]:

$$p = \{p_1, p_2, \ldots, p_{N=10}\} = \{.51, .51, \ldots\}$$

$$f = \{f_1, f_2, \ldots, f_{N=10}\} = \{.3675, .3675, \ldots\}$$

$$s = \{s_1, s_2, \ldots, s_{N=10}\} = \{.1225, .1225, \ldots\}$$

It is clear that in this scenario the private preferences of individuals will drive the results. In fact, this has already been discussed in our earlier modeling section. It is however a simple example, and therefore a good one to serve as an introduction into the simulation process. Note that after assigning the value of .51 for all p_i we split the remaining weight values (recall that $p_i+f_i+s_i = 1$) by assigning 75 percent to f and 25 percent to s. This entails an assumption regarding the relative importance of friends' opinions vis-à-vis the average opinion of society: the average votes of an individual's friends are three times as important as the average votes of society.

[51] This underlying preference vector is used throughout the simulations that follow, unless otherwise noted.
[52] These parameter weights are homogenous for all members of society throughout our experiments. Thus, we adopt the conventions that the above three vectors are abbreviated, respectively, as p=.51, f=.3675 and s=.1225. Since these parameters do not have the i subscript, they are vectors, not individual weights for one specific individual.

The network matrix Φ, which in this case is a ten-by-ten array of zeros and ones, is assigned randomly. In particular, I specify the probability that any two individuals are friends as .50, and we assign this probability the name y.[53] Further, if a person considers himself the friend of another, the other individual also considers himself that person's friend. In other words, the friendship relationship is reciprocal. This implies that Φ is necessarily symmetric around the main diagonal, and is in keeping with our earlier restrictions imposed on Φ.

An array of all possible initial conditions is constructed, which for this society is $2^{10} = 1024$. These are all the possible combinations of starting states for the society. Each individual is then asked the question: given a particular set of societal expressed preferences (one of the 1024 possibilities), and their preference parameters, how will they choose to vote? To answer each agent simply adheres to his individual choice criterion. Agents are asked this question concurrently, the votes are recorded, and society is now in a new state. If in this state the distribution of votes is identical to the initial condition, then we know the initial condition is an equilibrium. If after one application of the choice criterion at least one person changes their vote, then the system is not in equilibrium. In fact, we iterate the best response process until one of two things happens: either a static equilibrium is found (there is no change in the system from one iteration to

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[53] Note that the probability that two individuals are friends is
y=(probability j is a friend of i) + (probability i is a friend of j) – (probability i is a friend of j)(probability j is a friend of i).
This simplifies to
y=(probability j is a friend of i) + (1 – probability j is a friend of i)(probability i is a friend of j).
Since the probabilities for both individuals are equal, we can observe that the joint probability of two people being friends, y, is composed of the individual probabilities that the people are friends, x, as follows:
$y=x(2-x)$
When assigning the actual network Φ the value of x is used for each individual in the society, but this value is derived from the joint probability that two individuals are friends, y. We only specify the joint probability, y, throughout the paper.

the next), or a cyclical equilibrium emerges (there are changes to the state of the system in terms of votes, but these recur in a set pattern).[54] This process is applied to each of the 1024 possible initial conditions, and the resulting equilibriums are recorded. It is clear that the number of possible equilibriums is bounded: there must be at least one equilibrium (which would occur if each of the 1024 initial conditions converges to the same state), but there can be no more than 1024 equilibriums. The results are then tabulated and we observe how many initial conditions converged to each unique equilibrium. For instance, it could be the case that one particular equilibrium was the end-result for 1000 of the 1024 initial conditions. Since all initial conditions are equally likely, this allows us to make a probability statement that this society will converge to the equilibrium in question 97.6 percent of the time. This procedure allows us to distinguish between equilibriums that have a high basin of attraction (high probability of occurring), and those that have a smaller basin of attraction (lower probability of occurring). Notice that after running this simulation for all 1024 possible initial starting conditions we have, in summary, several results:

- One randomly generated social network, Φ.
- The number of unique static and cyclical equilibriums that could possibly emerge in this society.
- The probability associated with each of the above unique equilibriums.

A summary of these results is presented at the conclusion of each simulation in table form, although only the five most prevalent equilibriums are described (for brevity),

[54] Since in this best response dynamic there is no randomness, the system *must* eventually converge to one of the two types of equilibriums. While in theory an equilibrium cycle could be of length 1024, in which case it would take 2048 iterations to identify, in practice none of the simulations require more than 20 iterations to identify all the static (obviously) and cyclical equilibriums.

along with a summary of extreme equilibriums (stable truth-telling, full conformity, and full preference falsification). A less detailed but more practical summary of the (abridged) results is also provided in Table One—Simulation Summary Sheet.

Before running the baseline case simulation we make an additional modification to the procedure. Rather than running this experiment with just one randomly generated social network, we will run it with 1000 randomly generated social networks. While the y parameter will be the same for each, the random nature of creating the networks will ensure that few, if any, networks are the same—although there is nothing to prevent two identical networks from being randomly generated. The social network will be the only difference between the 1000 different trials. The results we have listed above will be modified as below:

- One thousand randomly generated social networks, Φ_a, where a indicates the number of the simulation to which the network belongs.
- The number of unique static and cyclical equilibriums that could possibly emerge in this society, over all 1000 simulations.
- The probability associated with each of the above unique equilibriums, as an average over all 1000 simulations.

Running multiple simulations in this fashion modifies our earlier assumption that the number of unique equilibriums is bounded as equal to or greater than one, and less than 1024, the number of initial conditions. Due to the fact that there are now potentially 1000 different social networks in which individuals must make their choices, it is possible that the aggregate number of unique equilibriums will exceed 1024.[55] The interpretation of

[55]When the number of unique equilibriums does exceed the number of possible initial conditions, most of this can be attributed to the existence of a large number of cyclical equilibriums. Since each different

the results does not vary from the case where the simulation is only conducted for one randomly generated social network, but the analysis becomes significantly more reliable as the number of simulations increases.[56]

After running the first simulation with the weight parameters defined as above, and the network strength parameter, y, set to .50, we can make observations based on the results in Table A1.0 (and others to follow). It is clear that in the case where private preferences dominate (p>.50) there is a single truth-telling equilibrium to which all 1024 initial conditions converge, for all 1000 networks. Thus, the probability of the stable truth-telling equilibrium is in this case 1, or 100 percent.[57] This result is expected, and confirms our earlier discussion of the p parameter. Tables A1.1-A1.5 display results where the weight parameters have been modified. The results are also listed in Table One (Simulation Summary Sheet). In particular, we have reduced p from .51 to .50, and then down to .10 in increments of .10. In order to satisfy the restraint that the weight parameters sum to unity, we have split the decrease in p between f and s, assigning .75 percent of the weight to f, and .25 percent to s, as in our baseline case above. Several observations can be made. First, it is clear that as the weight on the private preference parameter decreases the probability of a stable truth-telling equilibrium, in which all ten members of society choose to vote their actual preferences, decreases. While in the

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social network can create a different equilibrium dynamic, there is an extremely large number of possible cyclical variations which over 1000 possible trials can result in aggregate unique equilibriums well in excess of the number of initial starting conditions.

[56] The only real limit on how many simulations one chooses to run is computational power. However, as the number of simulations becomes arbitrarily large the benefit to running further simulations approaches zero. While this set of simulations is run 1000 times, increases in this number should give somewhat more specific results. A measure of the accuracy of the results is the probability associated with the two conformist equilibriums. Since on average these two equilibriums should occur with the same frequency, we should observe similar probabilities for these two equilibriums.

[57] A stable truth-telling equilibrium is a static equilibrium. The truth-telling outcome may also be part of an equilibrium cycle, but this is not considered a stable truth-telling equilibrium. Where truth-telling is only part of an equilibrium cycle it is noted as such, but is not recorded as a *stable* truth-telling equilibrium.

private preference dominant case (A1.0) we noted that the truth-telling equilibrium was the only possible equilibrium outcome for all 1024 possible initial starting conditions, when p is reduced to .50 the probability of truth-telling decreases by .01 percent to 99.99. This decrease is not significant, although it does illustrate the fact that even a borderline case with p=.50 can result in non-truth-telling equilibriums. As p is decreased to .40 we notice that the incidence of truth-telling drops significantly to just over 50 percent (again, all of these results are summarized in Table One—Simulation Summary Sheet, and additional detail is provided in the table associated with each particular experiment). When p decreases to .30 stable truth-telling decreases to 17 percent. At p values of .20 and .10 truth-telling occurs with a percent probability of .56 and .02, respectively (A1.4, A1.5). The clear trend is that as the value of p decreases the probability that individuals will tell the truth and that society will converge to a stable truth-telling equilibrium also decreases. Conversely, this can be seen as an increase in societal preference falsification, since a decrease in truth-telling by definition implies an increase in preference falsification. It should be noted however that most of the decrease in truth-telling as a probability outcome occurs between p values of .50 and .30. In fact, when p changes from .20 to .10 the percent probability of truth-telling only decreases by .54 percent, owing to the fact that truth-telling is already such a marginal outcome in terms of probabilities.

We can also note that the incidence of conformist outcomes (where people vote unanimously for policy A or policy B) shows the opposite trend to truth-telling. As the values of p decrease the incidence of conformity increase, from 0 percent when p=.51, to .01 percent when p=.50, all the way to 87.37 percent when p=.20. Interestingly, when p=.10 conformity actually decreases marginally from 87.37 percent to 86.60. This result is not intuitive. Clearly as the values of p are decreased the network is increasingly driving the results, especially since the parameter that is actually responsive to Φ, f, dominates both s and p through experiments A1.3-A1.5, when f exceeds .50. Therefore, it is most likely that the decrease in conformity noted from p=.20 to p=.10, which bucked the previous trend, is driven somehow by the random networks generated in experiments A1.4 and A1.5. In any event, the decrease in conformity is not adequately significant to make us reevaluate the trend of increasing voting conformity when p decreases, although at a decreasing rate as p gets smaller.

We can also observe that as p decreases the number of possible equilibriums (static and cyclical) increases, from 1 when p=.51 up to 5846 when p=.10. This is an interesting result, and it appears to be driven by the randomness of our social networks. In particular, we have already mentioned that when the number of equilibriums exceeds the number of initial starting conditions this is due to the presence of unique cyclical equilibriums that occur in the presence of different social networks. Generating 1000 of these random social networks, in conjunction with possible ties that are broken randomly, allows for the existence of this wide array of equilibrium outcomes. It should be noted further that the vast majority of equilibrium outcomes in cases where the number is high (even a few hundred) are cyclical equilibriums. This confirms our notion that this is driven by the increasing importance of the random social networks, which itself is a result of increases in f, the preference weight that is most closely related to network structure.

Placing the technical results described above in a behavioral context we can make several conclusions from this first set of experiments. My goal with these simulations, apart from introducing the reader to the methodology, was to elucidate issues of conformity surrounding the preference matrix Θ. We note that in this model preference falsification decreases significantly as the weight individuals place on expressing their true preferences decreases, and the weights individuals assign to the opinions (votes) of their friends and of society increase. When adhering to true private preferences in their votes is the overriding concern of economic agents nobody preference-falsifies. When adhering to these private preferences is very marginally relevant when compared to the weight individuals place on the opinions of others—specifically their friends, and to a lesser degree society—we see that preference falsification is widespread, and the probability of attaining a conformist consensus in society increases. In fact, when expressing true private preferences is not very important in society, we see that conformist equilibrium outcomes are by far the most common. Additionally, we see a marked increase in the breadth of equilibrium outcomes as the weight attached to private preferences decreases, with the majority of this increase attributed to cyclical equilibriums. This in turn suggests that societies with certain parameterizations (such as those in A1.3-A1.5) are susceptible to a lot of vote changing by individuals. It would appear that when our actions are increasingly driven by our perceived preferences (votes) of others, society has a greater chance of being stuck in fringe and non-stable cyclical equilibriums, although in our simulations the stable equilibriums still dominate in terms of probability. That is to say, there is a much broader possibility in terms of equilibrium outcomes, due to the large number of cyclical equilibriums. This, of course, is not the same as saying that those cyclical equilibriums will occur with any great probability—only that they are possible. Most of the results we have summarized here are intuitive in that they did not differ significantly in substance from the results I thought would be returned when I first executed the simulation. They are also easily reconciled with much of the economic and social psychological thinking on the subject of conformity.

Experiment B—Network Strength, y

The remaining series of experiments (B, C, D), rather than manipulating the preference parameters p, f and s, focuses on network considerations and the structure of the network matrix, Φ. In Experiment B, I manipulate the network strength, y, of 1000 random social networks, and rerun the experiments from the first section in the context of new—stronger and weaker—networks. Using Experiment A as a baseline (recall, in that set of simulations y=.50 throughout), we will be able to determine the impact of network strength (how closely knit the society is) on conformity. The experiment can answer the question: do the levels of conformity differ between societies that are closely knit and those that have looser social linkages?

The procedure for running the simulations, as well as the general set-up of the experiments is the same as for Experiment A: the only factor that is being altered is the network strength parameter. In particular, I assign a network strength factor of y=.25 for experiments B1.1-B1.5, and y=.75 for B1.6-B1.10. Note that both sets of experiments parallel A1.1-A1.5, where the network strength was .50. The case where the weight on p dominates (A1.0) is omitted.

A short discussion of my choice of weight parameters is in order. In comparing the network strength parameters to what one might expect in a realistic society (say, all of

Canada), all of them seem rather high. It is not reasonable to assume that in the modern world an individual is a friend with even 25 percent of his or her society. While this is true, there are two reasons why this is not a significant problem, and in fact, these parameters are quite suitable. First, since we are testing the effect of the network strength parameter, not so much the reaction of an individual in a real society, the large and variant values allow us to investigate the parameter in more detail. This sort of analysis should allow us to make some comments on just how important—indeed, if at all—the cohesion of a society is to the level of conformity it exhibits. These results can then be interpreted in a "realistic" context. Secondly, and more to the point, we need to keep in mind that there are various definitions of "society". Apart from the more immediate understanding of society as a relatively large collection of people (like the citizens of Canada), a society can also be thought of as a smaller group that for some reason forms an identifiable sub-group within the larger social context. For instance, one can consider the student population at a particular high school as a sub-society in the larger society of the city, which is itself a sub-society within a province or state, and so on. Working to the micro rather than the macro level, we can look at sub-groups within the high school itself, so a particular grade is a sub-society of the high school, and a particular class a sub-society of the grade. At the smallest level, there are the sub-societies of friends, sometimes as small as a few or even two people. Each of these societies can be thought of as but one part of a larger whole, yet with its own distinct set of social rules, norms and customs, and interpersonal relationships. Given this sort of framework, the network strength weights become much more understandable, since it is not unreasonable for a person to be friendly with a larger portion of their "society" when the social size is placed in the proper context. This is not to say that the results of our simulations are limited to small social settings. To the contrary, generalizations to larger social settings are still possible, and can provide important insight (as well as the motivation to simulate this model for larger and more complex societies).

The results for all simulations are again summarized in Table One (Simulation Summary Sheet), with more detailed results available in the respective tables for each individual experiment (B1.1-B1.10). The first five experiments detail what happens in the society with y=.25 (weak social network strength) when p is systematically decreased from .50 to .10 in even increments of .10. In the second set of five the network strength is set to .75. As in Experiment A, 75 percent of the remaining weighting is applied to f, and 25 to s. Since we have already discussed at length the general comparative static characteristics of changes in p, f, and s, I will focus the discussion of these results on contrasting the effects of these reparameterizations when the network strength varies. Several observations can be made. First, it is evident that when the social network is weak, truth-telling and conformity are *both* less likely to occur in our model society. As network strength increases from .25 to .50 and then .75, we see the average percent probability of the stable truth-telling equilibrium increase from 21.77 to 33.90 to 48.06 percent, a clear trend. Conformity increases in a similar fashion, from 20.56 to 44.07 and finally to 46.75 percent. These average results also hold for most (though not all) of the individual simulations in each experiment, meaning that there is no single parameterization that is skewing the average results—an important consideration. The decrease in truth-telling and conformist equilibriums associated with decreased social strength, while perhaps not expected, is not inexplicable. In particular, it would appear that when social networks are weak society is less likely to focus on *any* one particular equilibrium, whether it be conformist or truth-telling in nature or not. One indication for this, apart from the lack of a consensus on these two particular types of equilibriums, is the increasing number of possible equilibrium outcomes observed as the network strength decreases. The average number of possible equilibriums for y=.25 simulations is 7725 (with 13481 as the maximum number, recorded in B1.5). This decreases to an average of 2096 when y=.50, and 561 when y=.75. Thus, while the probability of truth-telling and conformity varies positively with network strength, the results are not due to a particular bias against the two particular equilibriums, but rather an indication of the difficulties inherent in coordinating social opinion on any policy when the networks that bind people together are weak. This explains why our model society with lower network strength has such a high number of possible equilibriums, and why as the strength of the networks increases, coordination increases.

In terms of individual behavior, these results are instructive. They tell us that people respond to social pressure, in particular social pressure that comes from their friends, and that there exists a complex and dynamic interdependency between social outcomes and social networks. When those networks are strong—so we can expect larger numbers of overlapping friends, close-knit social groupings, and each individual being friendly with a large portion of her society—there is a strong force acting upon society, moving it like an invisible hand towards greater consensus. The result is increased consensus on both the conformist and truth-telling equilibriums, and others, as evidenced by the decreased number of equilibrium possibilities. Since we have made the influence of average societal views weaker than the influence of friends' views on shaping individual voting behavior (by assigning f and s accordingly), the network itself is much more capable of achieving consensus than is the social average. Thus, when the strength of this network is increased, we increase the importance of the views of friends in the society (f is more important) not necessarily because each individual has an increased number of friends (though that is part of it), but also because the friends' networks become increasingly interconnected. My decision is now taken into account by many more people if there is a 75 percent chance that each other member of society and I are friends. In effect, individual decisions ripple through the rest of society: when the networks are more extensive, the ripples travel farther. This in turn will push society towards greater consensus.

However, the most important conclusion that can be drawn from this experiment does not deal with the specifics outlined above. Rather, what is most telling is the simple fact that *networks matter!* By changing the network strength, and therefore the nature of the social networks, we have been able to demonstrate drastically different social outcomes. This idea is explored in greater depth in the simulations that follow.

Experiment C—Network Structure

I have shown in Experiment B that networks matter. The goal of this experiment is to demonstrate clearly that different social network structures can have a significant impact on conformity results. Experiment C differs from the previous set of simulations in that we are not manipulating network strength but network structure. Thus, I plan to show that even if individuals have the same number of friends (which is the non-random corollary of a constant network strength parameter), the different arrangement of these friends in society can still strongly influence the results. Consequently, this set of experiments does not involve the replication of multiple random networks. Rather, I create only two separate social networks in order to confirm our hypothesis that the actual network structure is highly important in determining equilibrium outcomes, conformity and diversity levels. The first network, $\Phi = 1$, will be assigned in full by the experimenter, simply by giving each individual four friends sequentially (see Table C1.1 for an illustration of this network). The second network, $\Phi = 2$, will involve the "random" assignment of friends, albeit each individual will still have four friends. The methodology will be to assign a 50 percent probability for each individual being the friend of another and then "slotting-in" friends for the individual, also sequentially, but now based on a probability (see Table C1.6 for an illustration of this network).[58] Since in these experiments we are only interested in the network effects and how they influence our results, we set the social weight preference parameter, s_i, to zero for all i. Keeping the social weight preference parameter at a non-zero level would make it more difficult to investigate the specific network effects we are interested in, because the social parameter reduces the effect of network structure in favor of average social opinion. Five tests are performed with each of the two different social networks (for a total of ten tests, C1.1-C1.10), with decreasing values of p from .50 through to .10, in steps of .10 (as in previous simulations). To satisfy our restrictions that the weight parameters sum to one for each individual, we also have:

$$f_i = 1 - p_i \qquad \forall i$$

or when f and p are considered as vectors,

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[58] For instance, looking at person 1: We consider their relationship to person 2. We "roll a die". An outcome greater that .50 means the individual is that person's friend. To maintain symmetry we also assign the opposite to be true. This is repeated until the person has four friends. The cycle goes on until all individuals in the society have four friends.

$f = 1 - p$

The baseline case in this instance is when the weight of p and f are equal to .50 for all individuals i. As can be observed in Table C1.1, for the first social network ($\Phi =$ 1) all individuals are truth-tellers, and there is only one equilibrium possible (again, results are also summarized in Table One). Keeping the same network structure but reducing the private preference parameter to .40 introduces the two conformist equilibriums as possibilities, although these are still highly improbable and the truth-telling equilibrium dominates with a probability of over 99 percent (C1.2). However, with a further .10 decrease in the value of p we notice that the probability of the truth-telling equilibrium decreases to under 40 percent, and the two conformist equilibriums occur with a 17 percent probability. What is highly interesting is that further decreases in the value of p have no effect on the equilibrium set. Neither do further re-parameterizations change the probabilities associated with any equilibrium. Using the second network ($\Phi = 2$) we can make observations similar in their trends, though not necessarily in their substance. For these experiments we see society swing rapidly from one extreme to the other. Initially, truth-telling is by far the single most dominant equilibrium: 99.90 and 97.07 percent for p=.50 and .40, respectively (C1.6 and C1.7). However, for values of p below .40 truth-telling is not even an equilibrium possibility. It has, with a .10 change in p, been reduced in terms of probability from 97.07 to zero percent. Instead, we see a massive 69.23 percent probability rise in conformity. Truth-telling remains nonexistent for further decreases in p, and conformity continues to dominate unchanged. As in the first five experiments, changes in p and f beyond the .30/.70 split have no effect on the results. Several observations can be made.

First, the general results of changing parameter values found in preceding sections hold. In particular, as the weight on private preferences decreases, the instances of truth-telling equilibriums also decrease, and voting conformity increases. The results are not expected to be perfectly symmetric with the precedents, since in this set of experiments we are no longer assuming non-zero values for the social weight parameter, s, nor are we dealing with the same network structure as was present in the random networks generated earlier (unless by chance).

We should also comment on the fact that there is no change in the results after p reaches .30. It appears that once private preferences are sufficiently irrelevant to individuals it is the structure of the network that determines voting outcomes. When the equilibriums are being driven by the network structure rather than the underlying individual private preferences, it is no longer relevant if one decreases p further. The network has already in effect "taken over" the best response dynamic. Since the network stays constant throughout the experiment, even as we manipulate p, it is understandable that once it is sufficiently important to dictate the results, those results will not change. This is not entirely congruent with earlier results in Experiments A and B. However, in those experiments we maintained a non-zero value for the s parameter. Further, despite s being non-zero we still note that in most of the earlier experiments when f is highly dominant, changes in conformity and truth-telling are small for further increases in f. In particular, for A1.4-A1.5 we note that conformity changes by only .77 percent, and truth-telling by only .54 percent. In B1.9-1.10 conformity changes by only 2.41 percent, and truth-telling by only 2.80. Simulations B1.4-B1.5 are the notable exceptions, with a change of 25.21 in conformity, although truth-telling changes by only .09 percent. What we need to remember in putting these results in context is that the first two experiments used numerous random social networks. Thus we were not able to look at specific networks and their effects. The random networks were required to investigate issues other than network structure. In Experiment C we are adopting the opposite approach, specifically narrowing in on the effects of network structure. The fact that the conclusions of these experiments are not fully represented in the previous experiments is not unexpected, and does not diminish their importance since the different experiments are considering different factors, and controlling different variables. The conclusion, that the network structure with values of f greater than or equal to .7 drives the results, therefore remains valid for these parameterizations.

What is also interesting is that given network structure $\Phi = 1$, truth-telling remains an important and quite likely equilibrium outcome, never falling below a 39 percent probability (which is reached when p=.30). Contrary to some of our results from previous sections, where truth-telling was eventually entirely crowded out as an equilibrium possibility (primarily by the two conformist equilibriums), truth-telling is by far the dominant equilibrium outcome irrespective of p values. Network $\Phi = 2$ yields the opposite result in that truth-telling is entirely eliminated as a possible equilibrium for values of p below .40.

Several summary conclusions can be made from this investigation of network structure. Primarily, changing the network structure has a significant impact on the prominence of conformity and preference falsification in society. This result is highly significant. For one, it helps justify our use of multiple randomly generated networks in preceding experiments. That approach helped us derive results that were independent of a specific network structure, and therefore allowed us to focus on questions of changing Θ parameters and the network strength parameter, y, without having the results polluted by issues of network structure. Additionally these results suggest that any approach to model social conformity that does not address the specific nature of the social network is flawed, since conformity results are significantly influenced by the actual structure of social networks, not just their strengths or the underlying preference sets. The impact of the network structure in this experiment could not be more profound. In the case where the first network ($\Phi = 1$) was used we saw a high instance of truth-telling: it occurred with a greater probability than that of both conformist equilibriums combined, even for marginal values of p. However, using the second network ($\Phi = 2$) saw truth-telling completely disappear from the society at values equal to or less than p=.30. In the following set of experiments we will further investigate the influence of network structure on conformity, only with a more detailed modeling of the social network that includes consideration of how much support or opposition an individual can expect from his social peers.

Experiment D—Social Support

In the preceding set of experiments we created two unique social networks to investigate the relevance of network structure. This set of experiments continues that investigation, although with a different emphasis. In particular, I wish to determine how receiving weak or strong support from your friends will influence an individual's voting behavior, within the context of this model. Will societies where individuals have strong support for their underlying views have lower instances of conformity than societies where people do not receive this support? To investigate these questions we follow an identical simulation procedure as in the previous experiment, only our network modeling process is altered. Again, two social networks are created, $\Phi = 3, 4$ (these are illustrated with Tables D1.1 and D1.6). In the first of these ($\Phi = 3$) each member of society has four friends, but none of them have intrinsic preferences that are identical to their own. Thus, if I am a person with a private preference for policy A, I will have four friends, all of whom will prefer policy B. In this case I can expect to receive very weak support from my friends for the expression of my private preference. Network $\Phi = 4$ involves creating a network where two out of four friends are of like mind, and so an individual with a private preference for policy A is assigned two friends who have the same private preference and two friends who have a private preference for policy B. Note that the number of friends is constant between these two experiments, at four for each person.

As above, the social weight parameter for all these experiments is set to zero, since its introduction would make it more difficult to analyze the network-specific effects we are interested it. We begin by looking at the baseline case for the first social network, $\Phi = 3$. The Θ parameters are assigned exactly as in the previous set of experiments. Thus, we start by setting p=.50, and observing again that

$f_i = 1 - p_i \qquad \forall i.$

The results for this baseline simulation are interesting (see Table D1.1, as well as Table One). In this scenario there is no single static or cyclical equilibrium that dominates, which is contrary to the results we have obtained with this even split between p and f in each of our other simulations so far. In fact, no equilibrium has a probability of occurrence above .59 percent. There is also a large number of equilibrium possibilities (791). A more detailed inspection of the results (not included in Table D1.1) reveals that the majority of these equilibriums are in fact cyclical, with some cycles as long as 13 iterations.[59] The lack of a consensus or even a strong showing for the static truth-telling equilibrium (it does occur, but with a probability of only .001 percent) is puzzling. It suggests that in cases where individuals are expected to receive strong pressure from their friends that may be contrary to their own private preferences, and they value their own and their friends' preferences equally (p=f=.50), the best response dynamic is quite complex. In fact, the interplay of social influence and private preference does not lead to the development of any single dominant equilibrium, and all equilibrium outcomes occur with a similar (and low) probability. Further inspection of the most probable equilibriums (which in this case are all cyclical) reveals that all of them have the truth-telling equilibrium as one of their sub-cycles (see again Table D1.1). This suggests that while truth-telling is still quite prominently present in the model, the truth-telling equilibriums are anything but stable. In particular, they are generally part of equilibrium cycles of varying lengths. This phenomenon is actually caused by the numerous instances of ties in terms of voting outcomes that necessitates the near-ubiquitous use of the random rounding rule.[60] Individuals, under the influence of their four friends who

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[59] Extensive results for all experiments are not included with the printed copy of this thesis, as they are bulk and are not easily printed. They can be requested in electronic form from the author, and are provided in Mathematica 4.2 format.

[60] Some technical comments are in order. The large number of unique equilibriums in this simulation, more so than in previous simulations, is driven somewhat by the design of the experiment. In particular, we can recall that we introduced the random rounding rule. In this case where individuals have friends who have opposite underlying preferences, and the preference weights are split evenly between f and p, there are many instances where the rounding rule is used. This explains why we see many cylces that have truth-telling as one of their equilibrium outcomes. Normally we would expect that there would only be one static truth-telling equilibrium, or one truth-telling equilibrium cycle. Upon the introduction of randomness into this situation this need not be true, since it is possible that even given the truth-telling equilibrium as an initial condition, people will react differently to it each time (sometimes they round up, sometimes down). Consequently we get many equilibrium cycles that have the truth-telling equilibrium as a sub-cycle, since it only takes one person to vote differently when faced with the initial truth-telling equilibrium (twice) to create a cycle. This explanation has been tested by removing the random rounding rule and having the computer round down to 0 when a tie occurs. The immediate result is that there exists only one equilibrium

have the opposite private preferences (which are not in fact observable), often change their minds, even when society finds itself in a truth-telling equilibrium. In what is now a recurring theme, the marked difference in the model results for this social network versus those we have experimented with before also emphasizes the importance of network structure.

As soon as the weight on private preferences is decreased by .10 to .40, a clear dominant equilibrium emerges (see Table D1.2). This equilibrium, which occurs with a probability of 66 percent, is a cyclical equilibrium of length two that cycles between complete preference falsification (everybody votes $v_i \neq R_i$) and truth-telling ($v_i = R_i$). What this type of cycle implies is that this society will find itself in a state of truth-telling (based on this one equilibrium) 33 percent of the time, and total preference falsification 33 percent of the time (66 percent probability of the cyclical equilibrium divided by the length of the equilibrium cycle, 2). The fact that society can jump from these two extremes is quite interesting, as is the lack of a conformist equilibrium in this cycle. One might have expected that the conformist equilibriums would be more prevalent in the case where the weight on the votes of our friends dominates ($f > .50$). This result points to a lack of social coordination. If individuals are quite willing to change their votes in response to the votes of others since the weight they place on the votes of their friends dominates their decision-making process, and they derive utility from conforming to the preferences of others, social welfare is maximized when society chooses one of the two conformist equilibriums. In the cycle described above we have a vicious circle of individuals attempting to conform to the views of their friends, but since their friends are

in this case: the totally conformist zero equilibrium. This corroborates the explanation that random rounding is responsible for these particular results.

at the same time doing the same thing, the system never comes to a static equilibrium, instead flip-flopping as it does. This result also indicates how volatile truth-telling can be: if individuals are sufficiently motivated to accept social influence even a situation where everybody does in fact tell the truth is not stable.

Both static conformist equilibriums occur with a probability of about 2.5 percent (still with p=.40). The number of unique equilibriums falls from 791 (when p=.50) to only 28 (for p=.40), indicating that the number of possible equilibriums decreased by a factor of more than 28. This suggests that while there is little conformity in terms of possible equilibrium outcomes when the weight individuals place on private preferences is equivalent to that placed on the votes of their friends, the *possible* diversity in society decreases markedly with even a small increase in the importance of friends' opinions. These results, as was mentioned earlier, are driven by the extreme instability of opinion in the baseline case, caused by the presence of a large number of ties which are broken using the random rounding rule (see footnote 44).

Decreasing the private preference weight from .40 to .30 (still working with $\Phi = 3$) induces more interesting changes (D1.3). The probability of the flip-flopping cyclical equilibrium above decreases to 29 percent. While this is still the most likely equilibrium outcome, it is less than half as likely as it was when p was equal to .40. In addition to this, the two next most likely equilibriums are the conformist equilibriums, each occurring with just under 10 percent probability. The total number of equilibrium possibilities rises from 28 to 78. As before, further decreases in p do not change the results, suggesting again that the network structure now drives the results, as opposed to the preference parameters or underlying private preferences.

When we run the above five simulations with network four ($\Phi = 4$) for the specification where p=f=.50 we obtain a familiar result: there is only one unique truth-telling equilibrium, occurring with a probability of 100 percent (see Table D1.6 for results and an illustration of the social network). Recall that in network four each individual has four friends, two of which share his or her private preferences, and two that do not. Note the stark contrast of these results with those obtained for network Φ = 3, where there was no clearly dominant equilibrium.

When the private preference parameter is decreased to .40 the two conformist equilibriums are introduced, each with probabilities of .10 percent, bringing the total number of possible unique equilibriums to 3 (D1.7). The truth-telling equilibrium is still by far the most dominant, accounting for almost all of the probability. As before, these results contrast sharply with those obtained under network three. When the preference weight p is reduced to .30 we notice that the two conformist equilibriums are most dominant, together accounting for more than half of the probability (D1.8). We also note that while the truth-telling equilibrium is present the probability associated with it is only 3 percent. Nevertheless, unlike the situation with $\Phi = 3$, network four can result in a static truth-telling equilibrium. In addition, the probabilities associated with the two conformist equilibriums under this network are almost three times as high as for network three, implying a much greater amount of conformity.

These results allow us to make several summary observations. First, we again can note the extreme importance of network structure. In this set of simulations the structure of the network had profound effects on equilibrium outcomes, both in terms of conformity, stability and preference falsification. In particular, we note that when individuals face a higher degree of potential opposition from their friends they are less likely to be truth-tellers, and the truth-telling equilibrium is much less likely. In fact, in the case where individuals have four friends, none of which share their private preferences, the static truth-telling equilibrium is never stable, and can only be found as part of an equilibrium cycle. In some instances the equilibrium cycle containing the truth-telling equilibrium is two cycles long, and truth-telling alternates with complete preference falsification. Further, several results point to greater stability in cases where individuals share some underlying preferences with their friends. For one, networks with greater amounts of private preference overlap (such as network four) lead to greater convergence around specific unique equilibriums. In terms of conformity, higher levels are achieved when individuals have friends who share their private preferences. One explanation of this phenomenon is that the lack of any friends who share an individual's preferences makes for an unstable dynamic in which individuals are constantly trying to adjust to the differing votes of their friends. When friends share underlying preferences they are more likely to "band together" in their choice of votes, and this sort of clustering can have the effect of decreasing system instability. It can also promote conformist outcomes as these sorts of sub-groups or cliques can then stand together to influence the rest of society. In addition to these network-specific effects, these simulations also reinforce the basic comparative statics surrounding Θ that were derived earlier.

Conclusions and Extensions

On the basis of our experiments we can make several concluding statements, and offer ideas for interesting extensions to our model. In particular, we note that:

1. The results of the simulations demonstrate that the model reacts as expected to changes in the weight individuals place on their private preferences. When this weight is sufficiently large, all individuals vote their true preferences, and there is no preference falsification. Further, in this case the single unique static truth-telling equilibrium is stable (not part of a cycle), and all possible initial conditions in society converge to it. As individuals become more interested in accepting the influence of others, the degree of preference falsification and of conformity increases. These results support some of the social psychological theories we have presented, and are in keeping with previous economic modeling attempts.

2. While conformity of votes is more likely in societies where individuals have weaker private preference weights (p), the number of possible equilibriums generally increases as people value their friends' opinions more. This means that in societies where people are less "headstrong" about their beliefs, there is greater diversity in the number of potential equilibrium outcomes.

3. The exact structure of the social network is extremely important in investigating conformity. This is in fact our most important result. For instance, in one set of experiments we found that changing the network structure could move the society from a situation in which truth-telling is always the dominant static equilibrium, to one in which truth-telling does not even exist as an equilibrium possibility (Experiment C). Studies of conformity should therefore make some attempt to specify and investigate the network structures present in society. A failure to do this can yield results which are deceptive in their meanings, since it is difficult to determine if they are driven by underlying preferences and other parameters, or by social networks and network assumptions

implicit in the analysis. One way to take this into account when developing these sorts of models is to allow for the existence of many random networks, as was done here for some of the simulations, and ensuring that comparative static results are robust in the presence of this randomness. This allows the researcher to separate results driven by network structure from other comparative statics she may be interested in exploring.

4. Network strength also has significant effects on social outcomes. Strong networks tend to produce more social consensus around equilibriums than weak ones. Therefore, when a social network is weak, greater diversity is possible (though not necessarily probable). Stronger networks result in increased conformist and truth-telling equilibriums.

5. The social support individuals can expect to receive from their friends is highly important in determining conformist outcomes and the stability of truth-telling equilibriums. In particular, I note that in societies where individuals have friends with different underlying preferences than their own it is very unlikely that the society will reach a stable (static) truth-telling equilibrium, even if people value their own preferences equally with the preferences of their friends. When individuals receive support from half of their friends, truth-telling becomes a stable equilibrium in cases where the weight people give to their private preferences is sufficiently high (even if not dominant). In addition, conformity is much more likely when individuals do in fact have friends with similar underlying preferences than in the case where all their friends have opposing views. This is an intriguing result, and indicates that the ability to "band-together" in smaller social sub-groups, while increasing truth-telling, also increases the probability of

conformist equilibrium outcomes when the social network is symmetric for all individuals.

It is important to reemphasize at this point the fact that our model does not explain the reasons for conformist behavior that individuals use to make their voting decisions, apart from the economic explanation found in their utility functions. Rather, we simply note that there are certain values that people assign to conforming, and to their own attitudes and opinions—the actual reasons for those values are abstracted from. Similarly, the model takes a static approach both to the preference parameters (the weights on individual, friends, and society opinions), as well as the preference vector. These are important points, since such issues can be highly relevant given the complexity and intricacies of social psychological explanations of human behavior, some of which were presented earlier. Despite their importance, these issues have not been dealt with in this paper—while we have used some of the principles and explanations of human behavior found in social psychology to set the stage for our particular utility formulation, we are not out to replicate any one particular social psychological theory. A more detailed replication of such a theory, or rather, its more thorough incorporation into our existing model framework, is certainly an area of research that shows promise and should be pursued.

There are in fact a great number of extensions that can be made to our model. These include possible modifications of the underlying individual utility structure, as well as additional experiments that can be run within the existing structure. In particular, researchers may want to experiment with changing the underlying private preference vector that determines individual policy preferences. This preference vector can also be partially endogenous to the model, taking into account possible social phenomena such as internalization. Interesting experiments can also be conducted in societies where the three weight parameters are not homogenous across individuals, or where certain individuals act as "rebels" and derive negative utility from conformity—consider for instance the stereotypical teenage kid. The binary policy choice can also be replaced with a continuous policy spectrum. One could investigate the impact of commitment constraints on agent choice (either by introducing a commitment constraint or by altering the utility function to incorporate commitment). Social size can also be increased, which would allow for a more accurate modeling of larger societies. While I chose not to pursue this particular aspect, it would be interesting to consider the results when the initial condition is assumed to be the truth-telling equilibrium, or when agents have perfect information regarding the private preferences of others.

On the network side there are countless network formulations that can be tested. Some of particular interest might focus on the effects of sub-grouping (cliques) on social outcomes, and on the effect of linkage strength or social overlap between the subgroups. Other experiments can be conducted to test the voting behavior of social butterflies (people with a lot of friends) versus that of social loners (people with few friends), and the effect these types of individuals might have on the system. A very relevant extension would be to construct networks with specified and varying degrees of social overlap (individuals have different numbers of friends in common).[61] Additionally, one can formulate experiments in which there exists a strong but committed minority, and a large mass of weakly committed individuals. The model can also be used to test assumptions

[61] The development of a social overlap index would greatly add to the understanding of the network effect. This is an area which I plan to pursue in more detail, with others.

about (actual) societies with different cultures and types of networks by replicating actual social conditions and correlating the simulation results with observed social trends.[62]

The most interesting results of this modeling exercise deal with network effects. However, my analysis here is only the beginning of a more detailed investigation of this subject. What is ultimately required is a taxonomy of social networks that captures all the various aspects of networks that were discussed here in some succinct and quantifiable way. This paper can be considered a first step in that direction, and a small one. The development of a proper nomenclature for networks will allow for a wide range of new and interesting experiments to be run by economists, social psychologists, and perhaps others interested in the dynamics of human behavior and conformity. This is an area in which I hope to be joined by other researchers in my pursuit.

It is clear that much more research is necessary to properly explore the ideas presented here, and there is an endless list of interesting modifications that can be made to the simple model presented. That is an encouraging result: it suggests that I have achieved at least some of my goals by providing a robust model for the investigation of conformity induced by social pressure, through the use of simulation techniques, that includes both specific assumptions about individual preferences regarding conformity and a method of incorporating specific network structures into the analysis.

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[62] This idea comes from Eugene Beaulieu, who suggested using empirical evidence on social organization, views, and culture between different countries to investigate conformity in the context of this model.

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Appendix A: Tables

Table 1 Simulation Summary Sheet

Experiment	p	f	s	y or Network Strength	Network	Runs	No. of Equilibriums	Stable Truth-telling	Conformity (either policy)
A1.0	0.5100	0.3675	0.1225	0.5000	Random	1000	1	100.00%	0.00%
A1.1	0.5000	0.3750	0.1250	0.5000	Random	1000	3	99.99%	0.01%
A1.2	0.4000	0.4500	0.1500	0.5000	Random	1000	560	51.79%	1.30%
A1.3	0.3000	0.5250	0.1750	0.5000	Random	1000	1259	17.12%	45.06%
A1.4	0.2000	0.6000	0.2000	0.5000	Random	1000	2810	0.56%	87.37%
A1.5	0.1000	0.6750	0.2250	0.5000	Random	1000	5846	0.02%	86.60%
						Avg.	2096	33.90%	44.07%
B1.1	0.5000	0.3750	0.1250	**0.2500**	Random	1000	3	100.00%	0.005%
B1.2	0.4000	0.4500	0.1500	**0.2500**	Random	1000	6211	5.92%	4.82%
B1.3	0.3000	0.5250	0.1750	**0.2500**	Random	1000	8185	2.66%	14.76%
B1.4	0.2000	0.6000	0.2000	**0.2500**	Random	1000	10747	0.18%	29.00%
B1.5	0.1000	0.6750	0.2250	**0.2500**	Random	1000	13481	0.09%	54.21%
						Avg.	7725	21.77%	20.56%
B1.6	0.5000	0.3750	0.1250	**0.7500**	Random	1000	3	99.99%	0.01%
B1.7	0.4000	0.4500	0.1500	**0.7500**	Random	1000	240	92.03%	2.45%
B1.8	0.3000	0.5250	0.1750	**0.7500**	Random	1000	231	45.44%	39.17%
B1.9	0.2000	0.6000	0.2000	**0.7500**	Random	1000	339	2.82%	94.85%
B1.10	0.1000	0.6750	0.2250	**0.7500**	Random	1000	1994	0.002%	97.26%
						Avg.	561	48.06%	46.75%
C1.1	0.5000	0.5000	0.0000	4 friends	**1**	1	1	100.00%	0.00%
C1.2	0.4000	0.6000	0.0000	4 friends	**1**	1	3	99.61%	0.39%
C1.3	0.3000	0.7000	0.0000	4 friends	**1**	1	10	39.65%	33.59%
C1.4	0.2000	0.8000	0.0000	4 friends	**1**	1	10	39.65%	33.59%
C1.5	0.1000	0.9000	0.0000	4 friends	**1**	1	10	39.65%	33.59%
						Avg.	7	63.71%	20.23%
C1.6	0.5000	0.5000	0.0000	4 friends	**2**	1	2	99.90%	0.10%
C1.7	0.4000	0.6000	0.0000	4 friends	**2**	1	5	97.07%	0.20%
C1.8	0.3000	0.7000	0.0000	4 friends	**2**	1	25	0.00%	69.43%
C1.9	0.2000	0.8000	0.0000	4 friends	**2**	1	25	0.00%	69.43%
C1.10	0.1000	0.9000	0.0000	4 friends	**2**	1	25	0.00%	69.43%
						Avg.	16	39.39%	41.72%
D1.1	0.5000	0.5000	0.0000	4 friends	**3**	1	791	0.10%	0.10%
D1.2	0.4000	0.6000	0.0000	4 friends	**3**	1	28	0.00%	5.08%
D1.3	0.3000	0.7000	0.0000	4 friends	**3**	1	78	0.00%	18.75%
D1.4	0.2000	0.8000	0.0000	4 friends	**3**	1	78	0.00%	18.75%
D1.5	0.1000	0.9000	0.0000	4 friends	**3**	1	78	0.00%	18.75%
						Avg.	211	0.02%	12.29%
D1.6	0.5000	0.5000	0.0000	4 friends	**4**	1	1	100.00%	0.00%
D1.7	0.4000	0.6000	0.0000	4 friends	**4**	1	3	99.80%	0.20%
D1.8	0.3000	0.7000	0.0000	4 friends	**4**	1	28	3.13%	50.98%
D1.9	0.2000	0.8000	0.0000	4 friends	**4**	1	28	3.13%	50.98%
D1.10	0.1000	0.9000	0.0000	4 friends	**4**	1	28	3.13%	50.98%
						Avg.	18	41.84%	30.63%

Table 2 **A1.0**

Preference Parameters	p = [.51, {10}]; f = [.3675, {10}]; s = [.1225, {10}];											
Network Strength	y = .5											
Number of Runs	1000											
No.	**Equilibirum Set**										**Falsifiers**	**Probability**
1	1	1	1	1	1	0	0	0	0	0	0	100%
2	null											
3	null											
4	null											
5	null											
Number of Unique Equilibriums	1											

The Extremes	**Percent Probability**
Stable Truth-Telling	100.00%
Stable Full Falsification	0.00%
Conformity (either policy)	0.00%

Table 3 **A1.1**

Preference Parameters	p = [.50, {10}];											
	f = [.375, {10}];											
	s = [.125, {10}];											
Network Strength	y = .5											
Number of Runs	1000											
No.	Equilibirum Set										Falsifiers	Probability
1	1	1	1	1	1	0	0	0	0	0	0	99.99%
2	0	0	0	0	0	0	0	0	0	0	5	0.00%
3	1	1	1	1	1	1	1	1	1	1	5	0.00%
4	null											
5	null											
Number of Unique Equilibriums	3											

The Extremes	Percent Probability
Stable Truth-Telling	99.99%
Stable Full Falsification	0.00%
Conformity (either policy)	0.01%

Table 4 **A1.2**

Preference Parameters	p = [.4, {10}]; f = [.45, {10}]; s = [.15, {10}];												
Network Strength	y = .5												
Number of Runs	1000												
No.	**Equilibirum Set**											**Falsifiers**	**Probability**
1	1	1	1	1	1	0	0	0	0	0		0	51.79%
2	1	1	1	1	1	0	1	0	0	0		1	3.28%
3	1	1	1	0	1	0	0	0	0	0		1	3.27%
4	1	1	0	1	1	0	0	0	0	0		1	3.05%
5	1	1	1	1	1	1	0	0	0	0		1	3.14%
Number of Unique Equilibriums	560												

The Extremes	**Percent Probability**
Stable Truth-Telling	51.79%
Stable Full Falsification	0.00%
Conformity (either policy)	1.30%

Table 5 **A1.3**

Preference Parameters	p = [.3, {10}]; f = [.525, {10}]; s = [.175, {10}];											
Network Strength	y = .5											
Number of Runs	1000											
No.	**Equilibirum Set**										**Falsifiers**	**Probability**
1	1	1	1	1	1	1	1	1	1	1	5	23.41%
2	0	0	0	0	0	0	0	0	0	0	5	21.65%
3	1	1	1	1	1	0	0	0	0	0	0	17.12%
4	1	1	1	0	1	0	0	0	0	0	1	1.37%
5	1	1	1	1	1	0	0	1	0	0	1	1.16%
Number of Unique Equilibriums	1259											

The Extremes	**Percent Probability**
Stable Truth-Telling	17.12%
Stable Full Falsification	0.00%
Conformity (either policy)	45.06%

Table 6 **A1.4**

Preference Parameters	p = [.2, {10}];											
	f = [.6, {10}];											
	s = [.2, {10}];											
Network Strength	y = .5											
Number of Runs	1000											
No.	**Equilibirum Set**										**Falsifiers**	**Probability**
1	1	1	1	1	1	1	1	1	1	1	5	44.01%
2	0	0	0	0	0	0	0	0	0	0	5	43.36%
3	1	1	1	1	1	0	0	0	0	0	0	0.56%
4	0	1	0	0	0	0	0	0	0	0	4	0.17%
5	1	1	1	0	1	0	0	0	0	0	1	0.13%
Number of Unique Equilibriums	2810											

The Extremes	**Percent Probability**
Stable Truth-Telling	0.56%
Stable Full Falsification	0.00%
Conformity (either policy)	87.37%

Table 7 **A1.5**

Preference Parameters	p = [.1, {10}]; f = [.675, {10}]; s = [.225, {10}];											
Network Strength	y = .5											
Number of Runs	1000											
No.	**Equilibirum Set**										**Falsifiers**	**Probability**
1	1	1	1	1	1	1	1	1	1	1	5	43.63%
2	0	0	0	0	0	0	0	0	0	0	5	42.96%
3	0	0	0	1	0	1	0	1	1	1	8	0.05%
	1	1	1	0	1	0	1	0	0	0	2	
4	0	0	1	1	1	0	0	1	0	1	4	0.04%
	1	1	0	0	0	1	1	0	1	0	6	
5	0	1	0	0	1	1	0	1	0	0	5	0.04%
	1	0	1	1	0	0	1	0	1	1	5	
Number of Unique Equilibriums	5846											

The Extremes	**Percent Probability**
Stable Truth-Telling	0.02%
Stable Full Falsification	0.00%
Conformity (either policy)	86.60%

Table 8 **B1.1**

Preference	p = [.5, {10}];											
Parameters	f = [.375, {10}];											
	s = [.125, {10}];											
Network Strength	y = .25											
Number of Runs	1000											
No.	**Equilibrium Set**										**Falsifiers**	**Probability**
1	1	1	1	1	1	0	0	0	0	0	0	100.00%
2	1	1	1	1	1	1	1	1	1	1	5	0.00%
3	0	0	0	0	0	0	0	0	0	0	5	0.00%
4	null											
5	null											
Number of Unique Equilibriums	3											

The Extremes	**Percent Probability**
Stable Truth-Telling	100.00%
Stable Full Falsification	0.00%
Conformity (either policy)	0.005%

Table 9 **B1.2**

Preference Parameters	p = [.4, {10}]; f = [.45, {10}]; s = [.15, {10}];											
Network Strength	y = .25											
Number of Runs	1000											
No.	**Equilibrium Set**										**Falsifiers**	**Probability**
1	1	1	1	1	1	0	0	0	0	0	0	5.92%
2	1	1	1	1	1	1	1	1	1	1	5	2.88%
3	0	0	0	0	0	0	0	0	0	0	5	1.94%
4	1	1	1	1	1	0	0	0	0	1	1	1.68%
5	1	1	1	1	1	0	0	0	1	0	1	1.57%
Number of Unique Equilibriums	6211											

The Extremes	**Percent Probability**
Stable Truth-Telling	5.92%
Stable Full Falsification	0.00%
Conformity (either policy)	4.82%

Table 10 **B1.3**

Preference Parameters	p = [.3, {10}]; f = [.525, {10}]; s = [.175, {10}];											
Network Strength	y = .25											
Number of Runs	1000											
No.	**Equilibrium Set**										**Falsifiers**	**Probability**
1	1	1	1	1	1	1	1	1	1	1	5	8.03%
2	0	0	0	0	0	0	0	0	0	0	5	6.73%
3	1	1	1	1	1	0	0	0	0	0	0	2.86%
4	1	1	1	1	1	0	0	0	1	0	1	0.86%
5	1	1	1	1	1	0	0	0	0	1	1	0.76%
Number of Unique Equilibriums	8185											

The Extremes	**Percent Probability**
Stable Truth-Telling	2.86%
Stable Full Falsification	0.00%
Conformity (either policy)	14.76%

Table 11	B1.4											
Preference Parameters	p=[.2,{10}]; f=[.6,{10}]; s=[.2,{10}];											
Network Strength	y = .25											
Number of Runs	1000											
No.	Equilibrium Set										Falsifiers	Probability
1	1	1	1	1	1	1	1	1	1	1	5	15.33%
2	0	0	0	0	0	0	0	0	0	0	5	14.05%
3	0	1	0	0	0	0	0	0	0	0	4	0.62%
4	0	0	0	1	0	0	0	0	0	0	4	0.60%
5	1	1	1	1	1	0	1	1	1	1	4	0.56%
Number of Unique Equilibriums	10747											

The Extremes	Percent Probability
Stable Truth-Telling	0.18%
Stable Full Falsification	0.00%
Conformity (either policy)	29.00%

Table 12 **B1.5**

Preference Parameters	p = [.1, {10}]; f = [.675, {10}]; s = [.225, {10}];											
Network Strength	y = .25											
Number of Runs	1000											
No.	**Equilibrium Set**										**Falsifiers**	**Probability**
1	1	1	1	1	1	1	1	1	1	1	5	27.29%
2	0	0	0	0	0	0	0	0	0	0	5	26.93%
3	1	1	1	1	1	0	0	0	1	0	1	0.10%
4	1	1	1	1	1	0	0	0	0	0	0	0.09%
5	0	1	1	1	1	0	0	0	0	0	1	0.08%
Number of Unique Equilibriums	13481											

The Extremes	**Percent Probability**
Stable Truth-Telling	0.09%
Stable Full Falsification	0.00%
Conformity (either policy)	54.21%

Table 13 **B1.6**

Preference Parameters	p = [.5, {10}]; f = [.375, {10}]; s = [.125, {10}];											
Network Strength	y = .75											
Number of Runs	1000											
No.	**Equilibrium Set**										**Falsifiers**	**Probability**
1	1	1	1	1	1	0	0	0	0	0	0	99.99%
2	1	1	1	1	1	1	1	1	1	1	5	0.00%
3	0	0	0	0	0	0	0	0	0	0	5	0.00%
4	null											0.00%
5	null											0.00%
Number of Unique Equilibriums	3											

The Extremes	**Percent Probability**
Stable Truth-Telling	99.99%
Stable Full Falsification	0.00%
Conformity (either policy)	0.01%

Table 14	B1.7											
Preference Parameters	p=[.4,{10}]; f=[.45,{10}]; s=[.15,{10}];											
Network Strength	y = .75											
Number of Runs	1000											
No.	Equilibrium Set										Falsifiers	Probability
1	1	1	1	1	1	0	0	0	0	0	0	92.03%
2	0	0	0	0	0	0	0	0	0	0	5	1.23%
3	1	1	1	1	1	1	1	1	1	1	5	1.22%
4	1	1	0	1	1	0	0	0	0	0	1	0.67%
5	1	1	1	1	0	0	0	0	0	0	1	0.57%
Number of Unique Equilibriums	240											

The Extremes	Percent Probability
Stable Truth-Telling	92.03%
Stable Full Falsification	0.00%
Conformity (either policy)	2.45%

Table 15 B1.8

Preference Parameters	p=[.3,{10}]; f=[.525,{10}]; s=[.175,{10}];											
Network Strength	y = .75											
Number of Runs	1000											
No.	Equilibrium Set										Falsifiers	Probability
1	1	1	1	1	1	0	0	0	0	0	0	45.44%
2	1	1	1	1	1	1	1	1	1	1	5	20.16%
3	0	0	0	0	0	0	0	0	0	0	5	19.01%
4	1	1	1	1	1	0	1	0	0	0	1	1.26%
5	1	1	1	1	0	0	0	0	0	0	1	1.24%
Number of Unique Equilibriums	231											

The Extremes	Percent Probability
Stable Truth-Telling	45.44%
Stable Full Falsification	0.00%
Conformity (either policy)	39.17%

Table 16 B1.9

Preference Parameters	p=[.2,{10}]; f=[.6,{10}]; s=[.2,{10}];											
Network Strength	y = .75											
Number of Runs	1000											
No.	Equilibrium Set										Falsifiers	Probability
1	1	1	1	1	1	1	1	1	1	1	5	47.50%
2	0	0	0	0	0	0	0	0	0	0	5	47.35%
3	1	1	1	1	1	0	0	0	0	0	0	2.82%
4	1	0	1	1	1	0	0	0	0	0	1	0.08%
5	1	1	0	1	1	0	0	0	0	0	1	0.08%
Number of Unique Equilibriums	339											

The Extremes	Percent Probability
Stable Truth-Telling	2.82%
Stable Full Falsification	0.00%
Conformity (either policy)	94.85%

Table 17 **B1.10**

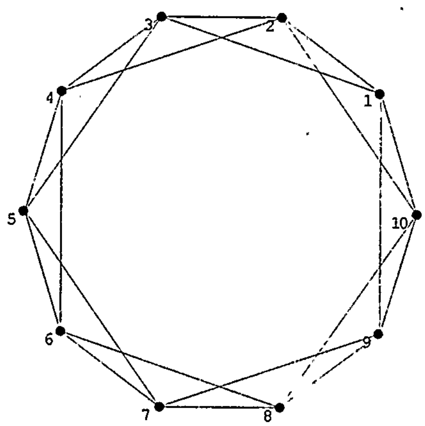
Preference Parameters	p = [.1, {10}]; f = [.675, {10}]; s = [.225, {10}];												
Network Strength	y = .75												
Number of Runs	1000												
No.	**Equilibrium Set**											**Falsifiers**	**Probability**
1	1	1	1	1	1	1	1	1	1	1		5	48.79%
2	0	0	0	0	0	0	0	0	0	0		5	48.47%
3	0	0	0	0	0	1	1	1	1	1		10	0.03%
	1	1	1	1	1	0	0	0	0	0		0	
4	0	0	0	0	0	1	1	0	1	1		9	0.02%
	1	1	1	1	1	0	0	0	0	0		0	
5	0	0	0	0	1	0	1	1	1	1		8	0.02%
	1	1	1	1	0	1	0	0	0	0		2	
Number of Unique Equilibriums	1994												

The Extremes	**Percent Probability**
Stable Truth-Telling	0.002%
Stable Full Falsification	0.00%
Conformity (either policy)	97.26%

Table 18 **C1.1**

Preference Parameters	p = Table[.5, {10}]; f = Table[.5, {10}]; s = Table[0, {10}];											
No.	Equilibrium Set										Falsifiers	Probability
1	1	1	1	1	1	0	0	0	0	0	0	100.00%
2	null											
3	null											
4	null											
5	null											
Number of Unique Equilibriums	1											

The Social Network:

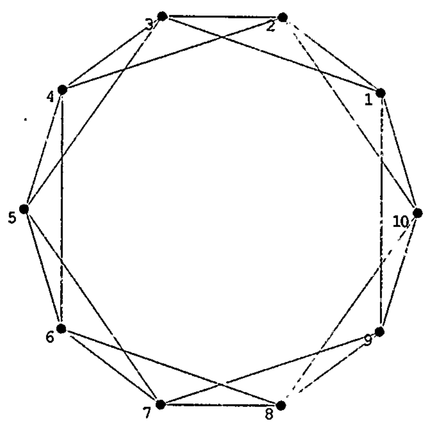


The Extremes	Percent Probability
Stable Truth-Telling	100.00%
Stable Full Falsification	0.00%
Conformity (either policy)	0.00%

Table 19 **C1.2**

Preference Parameters	p = Table[.4, {10}]; f = Table[.6, {10}]; s = Table[0, {10}];											
No.	**Equilibirum Set**										**Falsifiers**	**Probability**
1	1	1	1	1	1	0	0	0	0	0	0	99.61%
2	0	0	0	0	0	0	0	0	0	0	5	0.20%
3	1	1	1	1	1	1	1	1	1	1	5	0.20%
4	null											
5	null											
Number of Unique Equilibriums	3											

The Social Network:

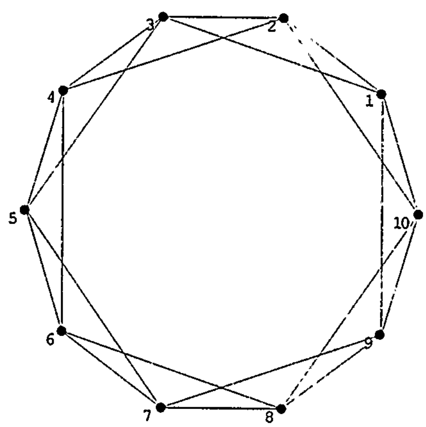


The Extremes	**Percent Probability**
Stable Truth-Telling	99.61%
Stable Full Falsification	0.00%
Conformity (either policy)	0.39%

Table 20 **C1.3**

Preference Parameters	p = Table[.3, {10}];											
	f = Table[.7, {10}];											
	s = Table[0, {10}];											
No.	**Equilibirum Set**										**Falsifiers**	**Probability**
1	1	1	1	1	1	0	0	0	0	0	0	39.65%
2	0	0	0	0	0	0	0	0	0	0	5	16.80%
3	1	1	1	1	1	1	1	1	1	1	5	16.80%
4	0	0	1	1	0	0	0	0	0	0	3	4.98%
	0	1	0	0	1	0	0	0	0	0	3	
5	0	1	1	0	0	0	0	0	0	0	3	4.98%
	1	0	0	1	0	0	0	0	0	0	3	
Number of Unique Equilibriums	10											

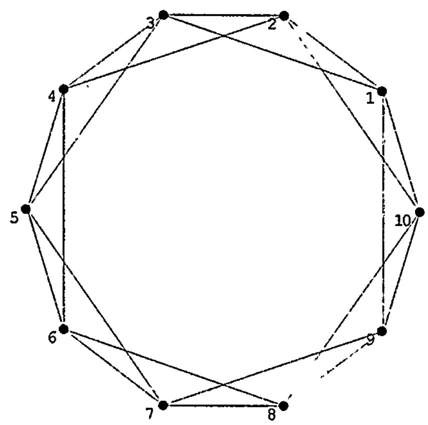
The Social Network:



The Extremes	**Percent Probability**
Stable Truth-Telling	39.65%
Stable Full Falsification	0.00%
Conformity (either policy)	33.59%

Table 21	C1.4											
Preference Parameters	p = Table[.2, {10}]; f = Table[.8, {10}]; s = Table[0, {10}];											
No.	Equilibirum Set										Falsifiers	Probability
1	1	1	1	1	1	0	0	0	0	0	0	39.65%
2	0	0	0	0	0	0	0	0	0	0	5	16.80%
3	1	1	1	1	1	1	1	1	1	1	5	16.80%
4	0	0	1	1	0	0	0	0	0	0	3	4.98%
	0	1	0	0	1	0	0	0	0	0	3	
5	0	1	1	0	0	0	0	0	0	0	3	4.98%
	1	0	0	1	0	0	0	0	0	0	3	
Number of Unique Equilibriums	10											

The Social Network:

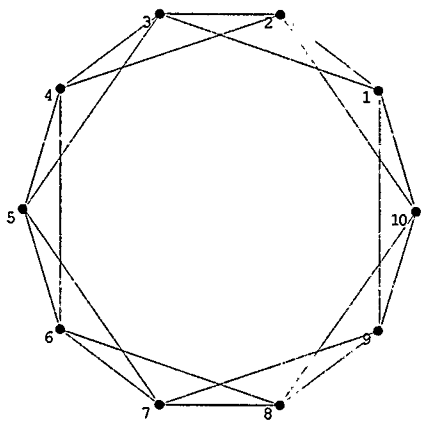


The Extremes	Percent Probability
Stable Truth-Telling	39.65%
Stable Full Falsification	0.00%
Conformity (either policy)	33.59%

Table 22 C1.5

Preference Parameters	p = Table[.1, {10}]; f = Table[.9, {10}]; s = Table[0, {10}];												
No.	**Equilibirum Set**											**Falsifiers**	**Probability**
1	1	1	1	1	1	0	0	0	0	0		0	39.65%
2	0	0	0	0	0	0	0	0	0	0		5	16.80%
3	1	1	1	1	1	1	1	1	1	1		5	16.80%
4	0	0	1	1	0	0	0	0	0	0		3	4.98%
	0	1	0	0	1	0	0	0	0	0		3	
5	0	1	1	0	0	0	0	0	0	0		3	4.98%
	1	0	0	1	0	0	0	0	0	0		3	
Number of Unique Equilibriums	10												

The Social Network:

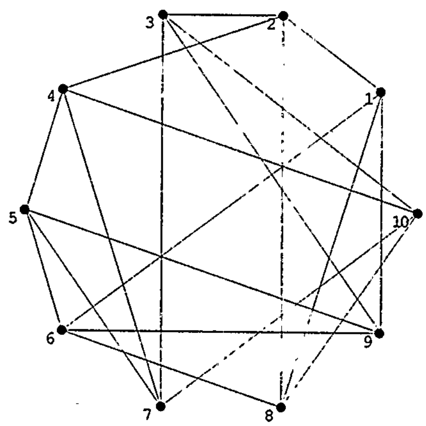


The Extremes	**Percent Probability**
Stable Truth-Telling	39.65%
Stable Full Falsification	0.00%
Conformity (either policy)	33.59%

Table 23 **C1.6**

Preference Parameters	p = Table[.5, {10}]; f = Table[.5, {10}]; s = Table[0, {10}];												
No.	**Equilibirum Set**											**Falsifiers**	**Probability**
1	1	1	1	1	1	0	0	0	0	0		0	99.90%
2	1	1	1	1	1	1	1	1	1	1		5	0.10%
3	null												
4	null												
5	null												
Number of Unique Equilibriums	2												

The Social Network:

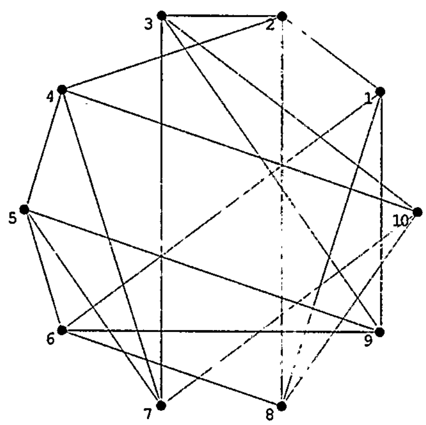


The Extremes	**Percent Probability**
Stable Truth-Telling	99.90%
Stable Full Falsification	0.00%
Conformity (either policy)	0.10%

Table 24 C1.7

Preference Parameters	p = Table[.4, {10}]; f = Table[.6, {10}]; s = Table[0, {10}];											
No.	**Equilibirum Set**										**Falsifiers**	**Probability**
1	1	1	1	1	1	0	0	0	0	0	0	97.07%
2	0	1	0	0	1	0	0	0	0	0	3	1.37%
	1	0	1	1	0	0	0	0	0	0	2	
3	1	1	1	1	1	0	1	1	1	0	3	1.37%
	1	1	1	1	1	1	0	0	0	1	2	
4	0	0	0	0	0	0	0	0	0	0	5	0.10%
5	1	1	1	1	1	1	1	1	1	1	5	0.10%
Number of Unique Equilibriums	5											

The Social Network:

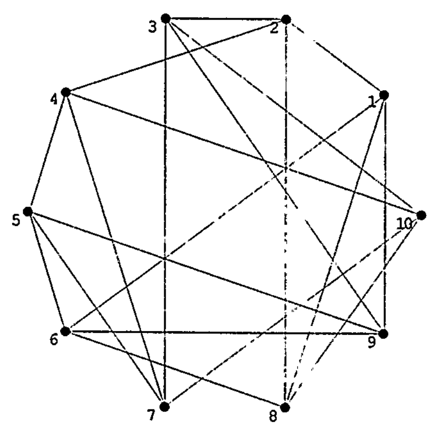


The Extremes	**Percent Probability**
Stable Truth-Telling	97.07%
Stable Full Falsification	0.00%
Conformity (either policy)	0.20%

Table 25 **C1.8**

Preference Parameters	p = Table[.3, {10}]; f = Table[.7, {10}]; s = Table[0, {10}];											
No.	Equilibirum Set										Falsifiers	Probability
1	0	0	0	0	0	0	0	0	0	0	5	36.91%
2	1	1	1	1	1	1	1	1	1	1	5	32.52%
3	0	1	0	0	0	0	1	0	1	0	6	7.32%
	1	0	1	1	1	0	0	0	0	0	1	
4	0	1	1	1	0	0	1	1	1	0	5	5.08%
	1	1	1	1	1	0	0	0	0	1	1	
5	1	0	1	1	1	1	0	1	1	0	4	2.83%
	1	1	0	0	1	1	1	0	1	1	6	
Number of Unique Equilibriums	25											

The Social Network:

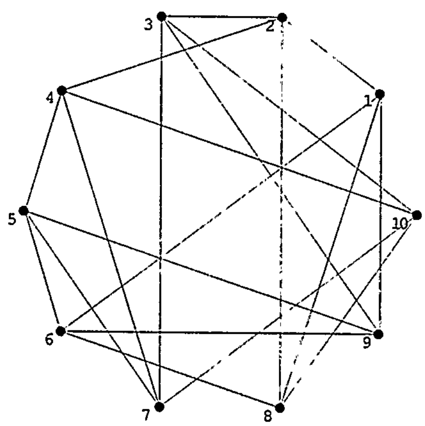


The Extremes	Percent Probability
Stable Truth-Telling	0.00%
Stable Full Falsification	0.00%
Conformity (either policy)	69.43%

Table 26 **C1.9**

Preference Parameters	p = Table[.2, {10}]; f = Table[.8, {10}]; s = Table[0, {10}];											
No.	Equilibirum Set										Falsifiers	Probability
1	0	0	0	0	0	0	0	0	0	0	5	36.91%
2	1	1	1	1	1	1	1	1	1	1	5	32.52%
3	0	1	0	0	0	0	1	0	1	0	6	7.32%
	1	0	1	1	1	0	0	0	0	0	1	
4	0	1	1	1	0	0	1	1	1	0	5	5.08%
	1	1	1	1	1	0	0	0	0	1	1	
5	1	0	1	1	1	1	0	1	1	0	4	2.83%
	1	1	0	0	1	1	1	0	1	1	6	
Number of Unique Equilibriums	25											

The Social Network:

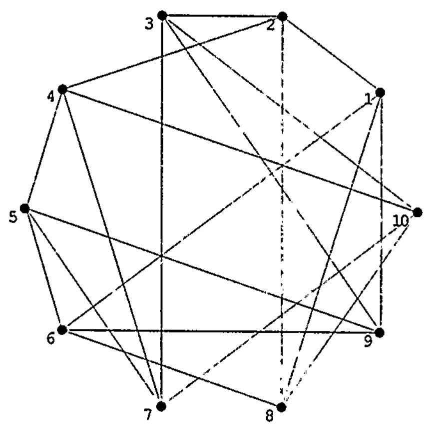


The Extremes	Percent Probability
Stable Truth-Telling	0.00%
Stable Full Falsification	0.00%
Conformity (either policy)	69.43%

Table 27 **C1.10**

Preference Parameters	p = Table[.1, {10}]; f = Table[.9, {10}]; s = Table[0, {10}];											
No.	**Equilibirum Set**										**Falsifiers**	**Probability**
1	0	0	0	0	0	0	0	0	0	0	5	36.91%
2	1	1	1	1	1	1	1	1	1	1	5	32.52%
3	0	1	0	0	0	0	1	0	1	0	6	7.32%
	1	0	1	1	1	0	0	0	0	0	1	
4	0	1	1	1	0	0	1	1	1	0	5	5.08%
	1	1	1	1	1	0	0	0	0	1	1	
5	1	0	1	1	1	1	0	1	1	0	4	2.83%
	1	1	0	0	1	1	1	0	1	1	6	
Number of Unique Equilibriums	25											

The Social Network:

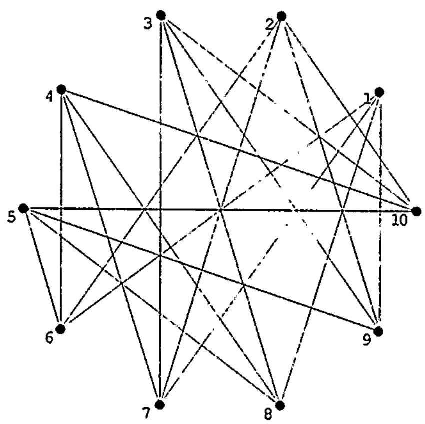


The Extremes	**Percent Probability**
Stable Truth-Telling	0.00%
Stable Full Falsification	0.00%
Conformity (either policy)	69.43%

Table 28 **D1.1**

Preference Parameters	p = Table[.5, {10}]; f = Table[.5, {10}]; s = Table[0, {10}];											
No.	**Equilibrium Set**										**Falsifiers**	**Probability**
1	0	1	1	1	0	1	1	0	1	0	5	0.59%
	1	1	1	1	1	0	0	0	0	0	0	
2	1	0	0	1	0	1	0	0	1	1	6	0.59%
	1	1	1	1	1	0	0	0	0	0	0	
3	1	0	0	0	1	1	0	1	0	0	5	0.39%
	1	1	1	1	1	0	0	0	0	0	0	
4	0	0	1	1	0	1	1	1	0	1	7	0.39%
	1	1	1	1	1	0	0	0	0	0	0	
5	0	0	0	1	0	0	1	1	0	1	7	0.39%
	1	1	1	1	1	0	0	0	0	0	0	
Number of Unique Equilibriums	791											

The Social Network:

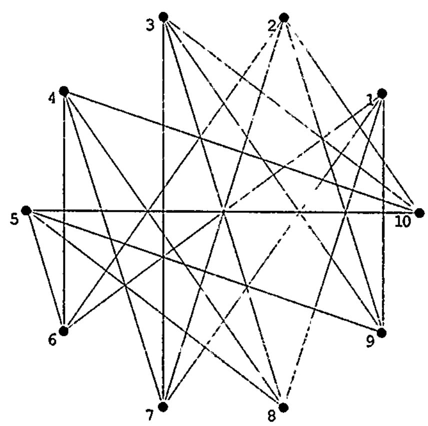


The Extremes	**Percent Probability**
Stable Truth-Telling	0.10%
Stable Full Falsification	0.00%
Conformity (either policy)	0.10%

Table 29 **D1.2**

Preference Parameters	p = Table[.4, {10}]; f = Table[.6, {10}]; s = Table[0, {10}];											
No.	**Equilibirum Set**										**Falsifiers**	**Probability**
1	0	0	0	0	0	1	1	1	1	1	10	66.11%
	1	1	1	1	1	0	0	0	0	0	0	
2	0	0	0	0	0	0	0	0	0	1	6	2.64%
	0	1	1	1	1	0	0	0	0	0	1	
3	0	0	0	0	0	0	0	0	1	0	6	2.64%
	1	1	1	0	1	0	0	0	0	0	1	
4	0	0	0	0	0	0	0	1	0	0	6	2.64%
	1	0	1	1	1	0	0	0	0	0	1	
5	0	0	0	0	0	0	1	0	0	0	6	2.64%
	1	1	1	1	0	0	0	0	0	0	1	
Number of Unique Equilibriums	28											

The Social Network:

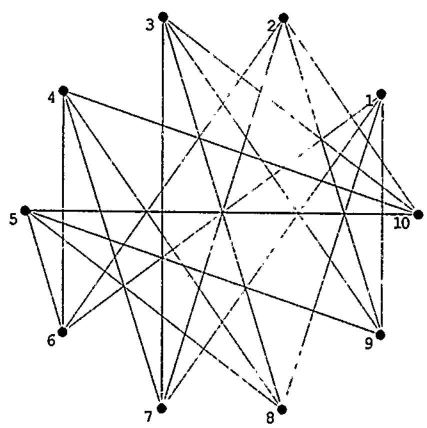


The Extremes	**Percent Probability**
Stable Truth-Telling	0.00%
Stable Full Falsification	0.00%
Conformity (either policy)	5.08%

Table 30 **D1.3**

Preference Parameters	p = Table[.3, {10}]; f = Table[.7, {10}]; s = Table[0, {10}];											
No.	**Equilibirum Set**										**Falsifiers**	**Probability**
1	0	0	0	0	0	1	1	1	1	1	10	28.52%
	1	1	1	1	1	0	0	0	0	0	0	
2	0	0	0	0	0	0	0	0	0	0	5	9.38%
3	1	1	1	1	1	1	1	1	1	1	5	9.38%
4	0	0	0	0	0	0	0	0	1	1	7	2.15%
	0	1	1	0	1	0	0	0	0	0	2	
5	0	0	0	0	0	0	0	1	0	1	7	2.15%
	0	0	1	1	1	0	0	0	0	0	2	
Number of Unique Equilibriums	78											

The Social Network:

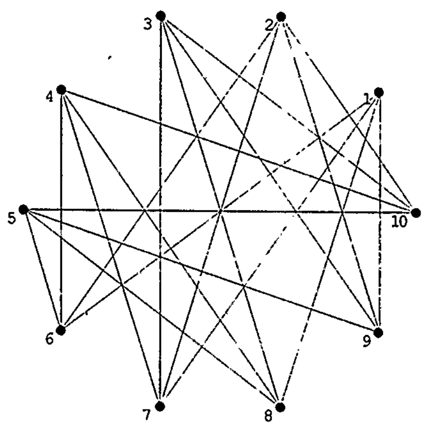


The Extremes	**Percent Probability**
Stable Truth-Telling	0.00%
Stable Full Falsification	0.00%
Conformity (either policy)	18.75%

Table 31 **D1.4**

Preference Parameters	p = Table[.2, {10}]; f = Table[.8, {10}]; s = Table[0, {10}];											
No.	**Equilibirum Set**										**Falsifiers**	**Probability**
1	0	0	0	0	0	1	1	1	1	1	10	28.52%
	1	1	1	1	1	0	0	0	0	0	0	
2	0	0	0	0	0	0	0	0	0	0	5	9.38%
3	1	1	1	1	1	1	1	1	1	1	5	9.38%
4	0	0	0	0	0	0	0	0	1	1	7	2.15%
	0	1	1	0	1	0	0	0	0	0	2	
5	0	0	0	0	0	0	0	1	0	1	7	2.15%
	0	0	1	1	1	0	0	0	0	0	2	
Number of Unique Equilibriums	78											

The Social Network:

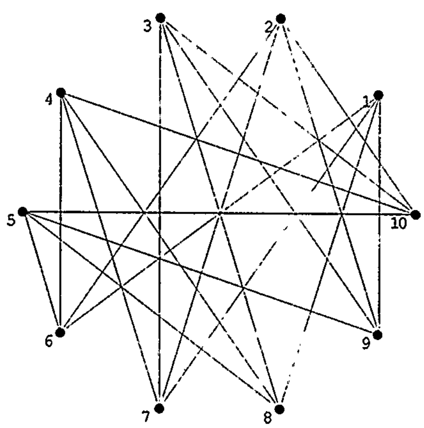


The Extremes	**Percent Probability**
Stable Truth-Telling	0.00%
Stable Full Falsification	0.00%
Conformity (either policy)	18.75%

Table 32 D1.5

Preference Parameters	p = Table[.1, {10}]; f = Table[.9, {10}]; s = Table[0, {10}];											
No.	**Equilibirum Set**										**Falsifiers**	**Probability**
1	0	0	0	0	0	1	1	1	1	1	10	28.52%
	1	1	1	1	1	0	0	0	0	0	0	
2	0	0	0	0	0	0	0	0	0	0	5	9.38%
3	1	1	1	1	1	1	1	1	1	1	5	9.38%
4	0	0	0	0	0	0	0	0	1	1	7	2.15%
	0	1	1	0	1	0	0	0	0	0	2	
5	0	0	0	0	0	0	0	1	0	1	7	2.15%
	0	0	1	1	1	0	0	0	0	0	2	
Number of Unique Equilibriums	78											

The Social Network:

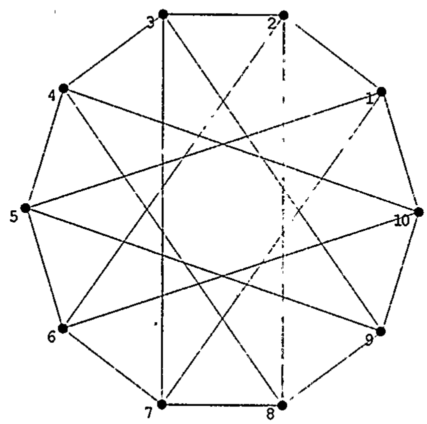


The Extremes	Percent Probability
Stable Truth-Telling	0.00%
Stable Full Falsification	0.00%
Conformity (either policy)	18.75%

Table 33 D1.6

Preference Parameters	p = Table[.5, {10}]; f = Table[.5, {10}]; s = Table[0, {10}];												
No.	Equilibirum Set											Falsifiers	Probability
1	1	1	1	1	1	0	0	0	0	0		0	100.00%
2	null												
3	null												
4	null												
5	null												
Number of Unique Equilibriums	1												

The Social Network:

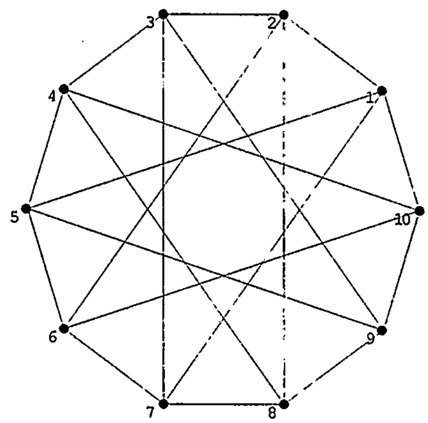


The Extremes	Percent Probability
Stable Truth-Telling	100.00%
Stable Full Falsification	0.00%
Conformity (either policy)	0.00%

Table 34 D1.7

Preference Parameters	p = Table[.4, {10}]; f = Table[.6, {10}]; s = Table[0, {10}];											
No.	Equilibirum Set										Falsifiers	Probability
1	1	1	1	1	1	0	0	0	0	0	0	99.80%
2	0	0	0	0	0	0	0	0	0	0	5	0.10%
3	1	1	1	1	1	1	1	1	1	1	5	0.10%
4	null											
5	null											
Number of Unique Equilibriums	3											

The Social Network:

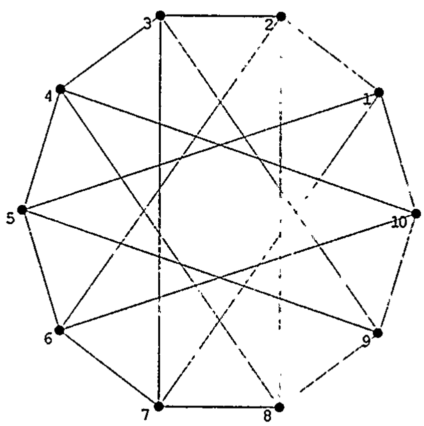


The Extremes	Percent Probability
Stable Truth-Telling	99.80%
Stable Full Falsification	0.00%
Conformity (either policy)	0.20%

Table 35 **D1.8**

Preference Parameters	p = Table[.3, {10}]; f = Table[.7, {10}]; s = Table[0, {10}];											
No.	Equilibirum Set										Falsifiers	Probability
1	0	0	0	0	0	0	0	0	0	0	5	25.49%
2	1	1	1	1	1	1	1	1	1	1	5	25.49%
3	1	1	1	1	1	0	0	0	0	0	0	3.13%
4	0	1	0	1	1	0	1	0	0	1	4	3.91%
	1	0	1	1	0	1	0	1	0	0	4	
5	0	1	0	1	1	0	1	0	1	0	4	3.91%
	1	0	1	0	1	1	0	1	0	0	4	
Number of Unique Equilibriums	28											

The Social Network:

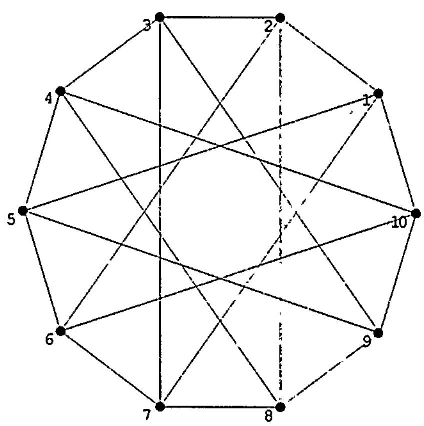


The Extremes	Percent Probability
Stable Truth-Telling	3.13%
Stable Full Falsification	0.00%
Conformity (either policy)	50.98%

Table 36 **D1.9**

Preference Parameters	p = Table[.2, {10}]; f = Table[.8, {10}]; s = Table[0, {10}];												
No.	**Equilibirum Set**											**Falsifiers**	**Probability**
1	0	0	0	0	0	0	0	0	0	0		5	25.49%
2	1	1	1	1	1	1	1	1	1	1		5	25.49%
3	1	1	1	1	1	0	0	0	0	0		0	3.13%
4	0	1	0	1	1	0	1	0	0	1		4	3.91%
	1	0	1	1	0	1	0	1	0	0		4	
5	0	1	0	1	1	0	1	0	1	0		4	3.91%
	1	0	1	0	1	1	0	1	0	0		4	
Number of Unique Equilibriums	28												

The Social Network:

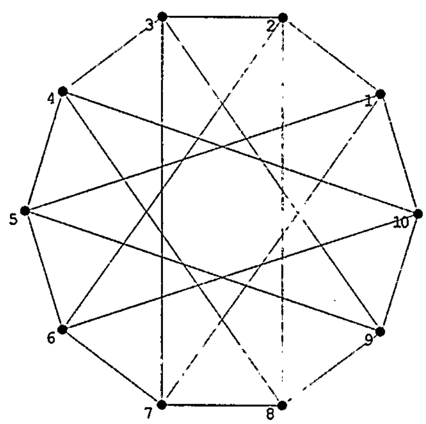


The Extremes	**Percent Probability**
Stable Truth-Telling	3.13%
Stable Full Falsification	0.00%
Conformity (either policy)	50.98%

Table 37 **D1.10**

Preference Parameters	p = Table[.1, {10}]; f = Table[.9, {10}]; s = Table[0, {10}];											
No.	**Equilibrium Set**										**Falsifiers**	**Probability**
1	0	0	0	0	0	0	0	0	0	0	5	25.49%
2	1	1	1	1	1	1	1	1	1	1	5	25.49%
3	1	1	1	1	1	0	0	0	0	0	0	3.13%
4	0	1	0	1	1	0	1	0	0	1	4	3.91%
	1	0	1	1	0	1	0	1	0	0	4	
5	0	1	0	1	1	0	1	0	1	0	4	3.91%
	1	0	1	0	1	1	0	1	0	0	4	
Number of Unique Equilibriums	28											

The Social Network:



The Extremes	**Percent Probability**
Stable Truth-Telling	3.13%
Stable Full Falsification	0.00%
Conformity (either policy)	50.98%

Appendix B: Mathematica Code

Experiment A

```
<<DiscreteMath`Combinatorica`
<<Statistics`

SeedRandom[25]

vote[pref_,state_,p_,f_,s_]:=Table[
  If[Plus@@friends[[n]]\[Equal]0,
    (p[[n]] pref[[n]]+ s[[n]] Mean[Drop[state,{n}]])/(p[[n]]+s[[n]]),
    p[[n]]
    pref[[n]]+ f[[n]] state.friends[[n]]/
        Plus@@friends[[n]]+ s[[n]] Mean[Drop[state,{n}]]]
   //Round,{n,10}]

findCycle[x_]:=Module[{l={},i,n},
  n=x[[i=1]];
  While[FreeQ[l,n],AppendTo[l,n];n=x[[++i]]];
  Drop[l,Position[l,n][[1,1]]-1]
  ]

p=Table[.a,{10}];
f=Table[.b,{10}];
s=Table[.c,{10}];

Clear[x,y]

Solve[x(2-x)\[Equal]y,x]

\!\(x = 1 - \@\(1 - y\)\)

y=.5

x

nstate=Table[IntegerDigits[n,2,10],{n,0,1023}];

summary={};
friendsList={};
nvoteList={};
prefCountsList={};

Do[
 friends=Table[Random[]<x,{i,10},{j,10}];
 friends=ReplacePart[friends,False,Table[{n,n},{n,10}]];
 friends=
   MapThread[(#1□#2)&,{friends,Transpose[friends]},2]/.{False\[Rule]0,True\
```

```
\[Rule]1};
AppendTo[friendsList,friends//TableForm];
  pref={1,1,1,1,1,0,0,0,0,0};
  nvote=Sort/@
    (findCycle[
        FixedPointList[vote[pref,#,p,f,s]&,#,20]]&/@nstate);
  AppendTo[nvoteList,Union[nvote]];
  prefCounts=Count[nvote,#]&/@Union[nvote];
  AppendTo[prefCountsList,prefCounts];
  AppendTo[summary,FrameBox[
      GridBox[
       Prepend[
        Transpose[{
          TableForm[#]&/@Union[nvote],
          PaddedForm[#,4]&/@prefCounts
          }],
        {"Equilibrium Vote","Number of
  Initial\n    Vote States"}],RowLines\[Rule]
    True,ColumnLines\[Rule]True]]//DisplayForm],
  {1000}]//Timing

friends

summary;

nvoteList;

Length[%]

prefCountsList;

Union[Flatten[nvoteList,1]]

Length[%]

prefCountsSummary=Count[Flatten[nvoteList,1],#]&/@Union[Flatten[nvoteList,1]]

Length[%]

randomSummaryTable=Table[0,{Length[Union[Flatten[nvoteList,1]]]},{1000}];

Do[Do[randomSummaryTable=ReplacePart[randomSummaryTable,prefCountsList[[m,
     n]],Append[Flatten[Position[Union[Flatten[nvoteList,1]],nvoteList[[
      m,n]]]],m]],
   {n,Length[nvoteList[[m]]]}],
  {m,1000}]
```

```
randomSummaryTable//TableForm;

FrameBox[
  GridBox[
   Prepend[
    Transpose[{
      TableForm[#]&/@Union[Flatten[nvoteList,1]],
      PaddedForm[#,4]&/@prefCountsSummary,
      (*PaddedForm[#,4]&/@falsifiers,*)
      (*Map[PaddedForm[#,4]&,randomSummaryTable,2],*)
      PaddedForm[#,{6,2}]&/@(Mean/@randomSummaryTable//N)
      }],
    {"Equilibrium Vote","
         Number of\n\
Simulations","Mean"}],RowLines\[Rule]True,ColumnLines\[Rule]True]]//
        DisplayForm


equilibria = Union[Flatten[nvoteList, 1]];
falsifiers =
 Length[Cases[MapThread[Equal, {pref, #}], False]]& /@ #&/@ equilibria

FrameBox[
  GridBox[
   Prepend[
    Transpose[{
      TableForm[#]&/@Union[Flatten[nvoteList,1]],
      PaddedForm[#,4]&/@prefCountsSummary,
      TableForm[#]& /@falsifiers,
      (*Map[PaddedForm[#,4]&,randomSummaryTable,2],*)
      PaddedForm[#,{6,2}]&/@(Mean/@randomSummaryTable//N)
      }],
    {"Equilibrium Vote","
        Number of\nSimulations","Number of\n\
Falsifiers","Mean"}],RowLines\[Rule]True,ColumnLines\[Rule]True]]//\
DisplayForm


DumpSave["1-1 Output.mx"]
```

Experiment B

```
<<DiscreteMath`Combinatorica`

<<Statistics`

SeedRandom[25]

vote[pref_,state_,p_,f_,s_]:=Table[a=If[Plus@@friends[[n]]\[Equal]0,(
   p[[n]] pref[[n]]+s[[n]] Mean[Drop[state,{n}]])/(p[[n]]+s[[n]]),p[[
      n]] pref[[n]]+f[[n]] state.friends[[
           n]]/Plus@@friends[[n]]+s[[n]] Mean[Drop[state,{n}]]];
   a=If[a\[Equal]0.5,Random[Integer],Round[a]],{n,10}]

findCycle[x_]:=Module[{l={},i,n},
   n=x[[i=1]];
   While[FreeQ[l,n],AppendTo[l,n];n=x[[++i]]];
   Drop[l,Position[l,n][[1,1]]-1]
   ]

p=Table[.a,{10}];
f=Table[.b,{10}];
s=Table[.c,{10}];

Clear[x,y]

Solve[x(2-x)\[Equal]y,x]

\!\(x = 1 - \@\(1 - y\)\)

y=.25

x

nstate=Table[IntegerDigits[n,2,10],{n,0,1023}];

summary={};
friendsList={};
nvoteList={};
prefCountsList={};

pref={1,1,1,1,1,0,0,0,0,0};

Do[
 friends=Table[Random[]<x,{i,10},{j,10}];
 friends=ReplacePart[friends,False,Table[{n,n},{n,10}]];
 friends=
```

```
    MapThread[(#1□#2)&,{friends,Transpose[friends]},2]/.{False\[Rule]0,True\
\[Rule]1};
AppendTo[friendsList,friends//TableForm];
  nvote=Sort/@
    (findCycle[
        FixedPointList[vote[pref,#,p,f,s]&,#,20]]&/@nstate);
  AppendTo[nvoteList,Union[nvote]];
  prefCounts=Count[nvote,#]&/@Union[nvote];
  AppendTo[prefCountsList,prefCounts];
  AppendTo[summary,FrameBox[
     GridBox[
      Prepend[
       Transpose[{
          TableForm[#]&/@Union[nvote],
          PaddedForm[#,4]&/@prefCounts
          }],
       {"Equilibrium Vote","Number of Initial\n    Vote \
States"}],RowLines\[Rule]True,ColumnLines\[Rule]True]]//DisplayForm],
  {1000}]//Timing

friends

summary;

nvoteList;

Length[%]

prefCountsList;

Union[Flatten[nvoteList,1]]

Length[%]

prefCountsSummary=Count[Flatten[nvoteList,1],#]&/@Union[Flatten[nvoteList,1]]

Length[%]

randomSummaryTable=Table[0,{Length[Union[Flatten[nvoteList,1]]]},{1000}];

Do[Do[randomSummaryTable=ReplacePart[randomSummaryTable,prefCountsList[[m,
    n]],Append[Flatten[Position[Union[Flatten[nvoteList,1]],nvoteList[[
     m,n]]]],m]],
  {n,Length[nvoteList[[m]]]}],
 {m,1000}]
```

```
randomSummaryTable//TableForm;

FrameBox[
  GridBox[
    Prepend[
      Transpose[{
        TableForm[#]&/@Union[Flatten[nvoteList,1]],
        PaddedForm[#,4]&/@prefCountsSummary,
        (*PaddedForm[#,4]&/@falsifiers,*)
        (*Map[PaddedForm[#,4]&,randomSummaryTable,2],*)
        PaddedForm[#,{6,2}]&/@(Mean/@randomSummaryTable//N)
        }],
      {"Equilibrium Vote","
            Number of\n\
Simulations","Mean"}],RowLines\[Rule]True,ColumnLines\[Rule]True]]//
          DisplayForm


equilibria = Union[Flatten[nvoteList, 1]];
falsifiers =
 Length[Cases[MapThread[Equal, {pref, #}], False]]& /@ #&/@ equilibria

FrameBox[
  GridBox[
    Prepend[
      Transpose[{
        TableForm[#]&/@Union[Flatten[nvoteList,1]],
        PaddedForm[#,4]&/@prefCountsSummary,
        TableForm[#]& /@falsifiers,
        (*Map[PaddedForm[#,4]&,randomSummaryTable,2],*)
        PaddedForm[#,{6,2}]&/@(Mean/@randomSummaryTable//N)
        }],
      {"Equilibrium Vote","
          Number of\nSimulations","Number of\n\
Falsifiers","Mean"}],RowLines\[Rule]True,ColumnLines\[Rule]True]]//\
DisplayForm


DumpSave["N2.1"]
```

Experiment C1

```
<<DiscreteMath`Combinatorica`

<<Statistics`

SeedRandom[25]

vote[pref_,state_,p_,f_,s_]:=Table[a=If[Plus@@friends[[n]]\[Equal]0,(
   p[[n]] pref[[n]]+s[[n]] Mean[Drop[state,{n}]])/(p[[n]]+s[[n]]),p[[
      n]] pref[[n]]+f[[n]] state.friends[[
          n]]/Plus@@friends[[n]]+s[[n]] Mean[Drop[state,{n}]]];
   a=If[a\[Equal]0.5,Random[Integer],Round[a]],{n,10}]


findCycle[x_]:=Module[{l={},i,n},
   n=x[[i=1]];
   While[FreeQ[l,n],AppendTo[l,n];n=x[[++i]]];
   Drop[l,Position[l,n][[1,1]]-1]
   ]

p=Table[.5,{10}];
f=Table[.5,{10}];
s=Table[0,{10}];

Clear[x,y]

Solve[x(2-x)\[Equal]y,x]

\!\(x = 1 - \@\(1 - y\)\)

y=.5

x

nstate=Table[IntegerDigits[n,2,10],{n,0,1023}];

summary={};
friendsList={};
nvoteList={};
prefCountsList={};

\!\(\*
 RowBox[{"friends", "=", GridBox[{
      {"0", "1", "1", "0", "0", "0", "0", "0", "0", "0"},
      {"0", "0", "1", "1", "0", "0", "0", "0", "0", "0"},
      {"0", "0", "0", "1", "1", "0", "0", "0", "0", "0"},
```

```
    {"0", "0", "0", "0", "1", "1", "0", "0", "0", "0"},
    {"0", "0", "0", "0", "0", "1", "1", "0", "0", "0"},
    {"0", "0", "0", "0", "0", "0", "1", "1", "0", "0"},
    {"0", "0", "0", "0", "0", "0", "0", "1", "1", "0"},
    {"0", "0", "0", "0", "0", "0", "0", "0", "1", "1"},
    {"1", "0", "0", "0", "0", "0", "0", "0", "0", "1"},
    {"1", "1", "0", "0", "0", "0", "0", "0", "0", "0"}
    }]}]\)

(friends1=ReplacePart[friends,0,Table[{n,n},{n,10}]])//TableForm

(friends2=MapThread[
   If[#1\[Equal]1□#2\[Equal]1,1,0]&,{friends1,Transpose[friends1]},2])//
       TableForm

ShowGraph[g=MakeGraph[Range[10],friends2[[#1,#2]]\[Equal]1&,Type\[Rule]\
Undirected],VertexNumber\[Rule]On]

Do[
 friends=Table[Random[]<x,{i,10},{j,10}];
 friends=ReplacePart[friends,False,Table[{n,n},{n,10}]];
 friends=
   MapThread[(#1□#2)&,{friends,Transpose[friends]},2]/.{False\[Rule]0,True\
\[Rule]1};
AppendTo[friendsList,friends//TableForm];
  pref={1,1,1,1,1,0,0,0,0,0};
  nvote=Sort/@
    (findCycle[
        FixedPointList[vote[pref,#,p,f,s]&,#,20]]&/@nstate);
  AppendTo[nvoteList,Union[nvote]];
  prefCounts=Count[nvote,#]&/@Union[nvote];
  AppendTo[prefCountsList,prefCounts];
  AppendTo[summary,FrameBox[
     GridBox[
      Prepend[
       Transpose[{
          TableForm[#]&/@Union[nvote],
          PaddedForm[#,4]&/@prefCounts
          }],
       {"Equilibrium Vote","Number of
  Initial\n    Vote States"}],RowLines\[Rule]
    True,ColumnLines\[Rule]True]]//DisplayForm],
  {1}]//Timing

friends
```

```
summary;

nvoteList;

Length[%]

prefCountsList;

Union[Flatten[nvoteList,1]]

Length[%]

prefCountsSummary=Count[Flatten[nvoteList,1],#]&/@Union[Flatten[nvoteList,1]]

Length[%]

randomSummaryTable=Table[0,{Length[Union[Flatten[nvoteList,1]]]},{1000}];

Do[Do[randomSummaryTable=ReplacePart[randomSummaryTable,prefCountsList[[m,
    n]],Append[Flatten[Position[Union[Flatten[nvoteList,1]],nvoteList[[
     m,n]]]],m]],
  {n,Length[nvoteList[[m]]]}],
 {m,1000}]

randomSummaryTable//TableForm;

FrameBox[
  GridBox[
   Prepend[
    Transpose[{
      TableForm[#]&/@Union[Flatten[nvoteList,1]],
      PaddedForm[#,4]&/@prefCountsSummary,
      (*PaddedForm[#,4]&/@falsifiers,*)
      (*Map[PaddedForm[#,4]&,randomSummaryTable,2],*)
      PaddedForm[#,{6,2}]&/@(Mean/@randomSummaryTable//N)
      }],
    {"Equilibrium Vote","
          Number of\n\
Simulations","Mean"}],RowLines\[Rule]True,ColumnLines\[Rule]True]]//
       DisplayForm


equilibria = Union[Flatten[nvoteList, 1]];
falsifiers =
 Length[Cases[MapThread[Equal, {pref, #}], False]]& /@ #&/@ equilibria
```

```
FrameBox[
  GridBox[
   Prepend[
    Transpose[{
      TableForm[#]&/@Union[Flatten[nvoteList,1]],
      PaddedForm[#,4]&/@prefCountsSummary,
      TableForm[#]& /@falsifiers,
      (*Map[PaddedForm[#,4]&,randomSummaryTable,2],*)
      PaddedForm[#,{6,2}]&/@(Mean/@randomSummaryTable//N)
      }],
    {"Equilibrium Vote","
         Number of\nSimulations","Number of\n\
Falsifiers","Mean"}],RowLines\[Rule]True,ColumnLines\[Rule]True]]//\
DisplayForm


DumpSave["1-1 Output.mx"]
```

Experiment C2

```
<<DiscreteMath`Combinatorica`

<<Statistics`

SeedRandom[25]

vote[pref_,state_,p_,f_,s_]:=Table[a=If[Plus@@friends[[n]]\[Equal]0,(
  p[[n]] pref[[n]]+s[[n]] Mean[Drop[state,{n}]])/(p[[n]]+s[[n]]),p[[
    n]] pref[[n]]+f[[n]] state.friends[[
        n]]/Plus@@friends[[n]]+s[[n]] Mean[Drop[state,{n}]]];
  a=If[a\[Equal]0.5,Random[Integer],Round[a]],{n,10}]


findCycle[x_]:=Module[{l={},i,n},
  n=x[[i=1]];
  While[FreeQ[l,n],AppendTo[l,n];n=x[[++i]]];
  Drop[l,Position[l,n][[1,1]]-1]
  ]

p=Table[.5,{10}];
f=Table[.5,{10}];
s=Table[0,{10}];

Clear[x,y]

Solve[x(2-x)\[Equal]y,x]

\!\(x = 1 - \@\(1 - y\)\)

y=.5

x

nstate=Table[IntegerDigits[n,2,10],{n,0,1023}];

summary={};
friendsList={};
nvoteList={};
prefCountsList={};

\!\(\*
 RowBox[{"friendsi", "=",
  TagBox[GridBox[{
      {"0", "1", "0", "0", "0", "1", "0", "1", "1", "0"},
      {"1", "0", "1", "1", "0", "0", "0", "1", "0", "0"},
```

```
      {"0", "1", "0", "0", "0", "0", "1", "0", "1", "1"},
      {"0", "1", "0", "0", "1", "0", "1", "0", "0", "0"},
      {"0", "0", "0", "1", "0", "1", "1", "0", "1", "0"},
      {"1", "0", "0", "0", "1", "0", "0", "1", "1", "0"},
      {"0", "0", "1", "1", "1", "0", "0", "0", "0", "1"},
      {"0", "1", "0", "0", "0", "1", "0", "0", "0", "1"},
      {"1", "0", "1", "0", "1", "1", "0", "0", "0", "0"},
      {"0", "0", "1", "1", "0", "0", "1", "1", "0", "0"}
      },
    RowSpacings->1,
    ColumnSpacings->3,
    RowAlignments->Baseline,
    ColumnAlignments->{Left}],
   Function[ BoxForm`e$,
    TableForm[ BoxForm`e$]]]}]\)

(friends1=ReplacePart[friendsi,0,Table[{n,n},{n,10}]])//TableForm

(friends2=MapThread[
   If[#1\[Equal]1 □#2\[Equal]1,1,0]&,{friends1,Transpose[friends1]},2])//
        TableForm

ShowGraph[g=MakeGraph[Range[10],friends2[[#1,#2]]\[Equal]1&,Type\[Rule]\
Undirected],VertexNumber\[Rule]On]

Do[
 friends=friends2;
AppendTo[friendsList,friends//TableForm];
  pref={1,1,1,1,1,0,0,0,0,0};
  nvote=Sort/@
    (findCycle[
        FixedPointList[vote[pref,#,p,f,s]&,#,20]]&/@nstate);
  AppendTo[nvoteList,Union[nvote]];
  prefCounts=Count[nvote,#]&/@Union[nvote];
  AppendTo[prefCountsList,prefCounts];
  AppendTo[summary,FrameBox[
      GridBox[
       Prepend[
        Transpose[{
          TableForm[#]&/@Union[nvote],
          PaddedForm[#,4]&/@prefCounts
          }],
        {"Equilibrium Vote","Number
  of Initial\n    Vote \
States"}],RowLines\[Rule]True,ColumnLines\[Rule]True]]//DisplayForm],
  {1}]//Timing
```

```
friends

summary;

nvoteList;

Length[%]

prefCountsList;

Union[Flatten[nvoteList,1]]

Length[%]

prefCountsSummary=Count[Flatten[nvoteList,1],#]&/@Union[Flatten[nvoteList,1]]

Length[%]

randomSummaryTable=Table[0,{Length[Union[Flatten[nvoteList,1]]]},{1}];

Do[Do[randomSummaryTable=ReplacePart[randomSummaryTable,prefCountsList[[m,
    n]],Append[Flatten[Position[Union[Flatten[nvoteList,1]],nvoteList[[
     m,n]]]],m]],
  {n,Length[nvoteList[[m]]]}],
 {m,1}]

randomSummaryTable//TableForm;

FrameBox[
   GridBox[
    Prepend[
     Transpose[{
        TableForm[#]&/@Union[Flatten[nvoteList,1]],
        PaddedForm[#,4]&/@prefCountsSummary,
        (*PaddedForm[#,4]&/@falsifiers,*)
        (*Map[PaddedForm[#,4]&,randomSummaryTable,2],*)
        PaddedForm[#,{6,2}]&/@(Mean/@randomSummaryTable//N)
        }],
     {"Equilibrium Vote","
           Number of\n\
Simulations","Mean"}],RowLines\[Rule]True,ColumnLines\[Rule]True]]//
          DisplayForm


equilibria = Union[Flatten[nvoteList, 1]];
```

```
falsifiers =
 Length[Cases[MapThread[Equal, {pref, #}], False]]& /@ #&/@ equilibria

FrameBox[
   GridBox[
    Prepend[
     Transpose[{
        TableForm[#]&/@Union[Flatten[nvoteList,1]],
        PaddedForm[#,4]&/@prefCountsSummary,
        TableForm[#]& /@falsifiers,
        (*Map[PaddedForm[#,4]&,randomSummaryTable,2],*)
        PaddedForm[#,{6,2}]&/@(Mean/@randomSummaryTable//N)
        }],
     {"Equilibrium Vote","
            Number of\nSimulations","Number of\n\
Falsifiers","Mean"}],RowLines\[Rule]True,ColumnLines\[Rule]True]]//\
DisplayForm


DumpSave["B1.6"]
```

Experiment D1

```
<<DiscreteMath`Combinatorica`

<<Statistics`

SeedRandom[25]

vote[pref_,state_,p_,f_,s_]:=Table[a=If[Plus@@friends[[n]]\[Equal]0,(
  p[[n]] pref[[n]]+s[[n]] Mean[Drop[state,{n}]])/(p[[n]]+s[[n]]),p[[
    n]] pref[[n]]+f[[n]] state.friends[[
        n]]/Plus@@friends[[n]]+s[[n]] Mean[Drop[state,{n}]]];
  a=If[a\[Equal]0.5,Random[Integer],Round[a]],{n,10}]


findCycle[x_]:=Module[{l={},i,n},
  n=x[[i=1]];
  While[FreeQ[l,n],AppendTo[l,n];n=x[[++i]]];
  Drop[l,Position[l,n][[1,1]]-1]
  ]

p=Table[.5,{10}];
f=Table[.5,{10}];
s=Table[0,{10}];

Clear[x,y]

Solve[x(2-x)\[Equal]y,x]

\!\(x = 1 - \@\(1 - y\)\)

y=.5

x

nstate=Table[IntegerDigits[n,2,10],{n,0,1023}];

summary={};
friendsList={};
nvoteList={};
prefCountsList={};

\!\(\*
 RowBox[{"friendsi", "=",
  TagBox[GridBox[{
      {"0", "0", "0", "0", "0", "1", "1", "1", "1", "0"},
      {"0", "0", "0", "0", "0", "1", "1", "0", "1", "1"},
```

```
      {"0", "0", "0", "0", "0", "0", "1", "1", "1", "1"},
      {"0", "0", "0", "0", "0", "1", "1", "1", "0", "1"},
      {"0", "0", "0", "0", "0", "1", "0", "1", "1", "1"},
      {"1", "1", "0", "1", "0", "0", "0", "0", "0", "0"},
      {"1", "1", "1", "1", "0", "0", "0", "0", "0", "0"},
      {"1", "0", "1", "1", "0", "0", "0", "0", "0", "0"},
      {"1", "1", "1", "0", "0", "0", "0", "0", "0", "0"},
      {"0", "1", "1", "1", "0", "0", "0", "0", "0", "0"}
      },
     RowSpacings->1,
     ColumnSpacings->3,
     RowAlignments->Baseline,
     ColumnAlignments->{Left}],
    Function[ BoxForm`e$,
     TableForm[ BoxForm`e$]]]}]\)

(friends1=ReplacePart[friendsi,0,Table[{n,n},{n,10}]])//TableForm

(friends2=MapThread[
    If[#1\[Equal]1□#2\[Equal]1,1,0]&,{friends1,Transpose[friends1]},2])//
        TableForm

ShowGraph[g=MakeGraph[Range[10],friends2[[#1,#2]]\[Equal]1&,Type\[Rule]\
Undirected],VertexNumber\[Rule]On]

Do[
 friends=friends2;
  pref={1,1,1,1,1,0,0,0,0,0};
  nvote=Sort/@
    (findCycle[
        FixedPointList[vote[pref,#,p,f,s]&,#,20]]&/@nstate);
  AppendTo[nvoteList,Union[nvote]];
  prefCounts=Count[nvote,#]&/@Union[nvote];
  AppendTo[prefCountsList,prefCounts];
  AppendTo[summary,FrameBox[
     GridBox[
      Prepend[
       Transpose[{
         TableForm[#]&/@Union[nvote],
         PaddedForm[#,4]&/@prefCounts
         }],
       {"Equilibrium Vote","Number of Initial\n    Vote States"}],
  RowLines\[Rule]True,ColumnLines\[Rule]True]]//DisplayForm],
  {1}]//Timing

friends
```

```
summary;

nvoteList;

Length[%]

prefCountsList;

Union[Flatten[nvoteList,1]]

Length[%]

prefCountsSummary=Count[Flatten[nvoteList,1],#]&/@Union[Flatten[nvoteList,1]]

Length[%]

randomSummaryTable=Table[0,{Length[Union[Flatten[nvoteList,1]]]},{1}];

Do[Do[randomSummaryTable=ReplacePart[randomSummaryTable,prefCountsList[[m,
    n]],Append[Flatten[Position[Union[Flatten[nvoteList,1]],nvoteList[[
     m,n]]]],m]],
  {n,Length[nvoteList[[m]]]}],
 {m,1}]

randomSummaryTable//TableForm;

FrameBox[
  GridBox[
   Prepend[
    Transpose[{
      TableForm[#]&/@Union[Flatten[nvoteList,1]],
      PaddedForm[#,4]&/@prefCountsSummary,
      (*PaddedForm[#,4]&/@falsifiers,*)
      (*Map[PaddedForm[#,4]&,randomSummaryTable,2],*)
      PaddedForm[#,{6,2}]&/@(Mean/@randomSummaryTable//N)
      }],
    {"Equilibrium Vote","
         Number of\n\
Simulations","Mean"}],RowLines\[Rule]True,ColumnLines\[Rule]True]]//
       DisplayForm


equilibria = Union[Flatten[nvoteList, 1]];
falsifiers =
 Length[Cases[MapThread[Equal, {pref, #}], False]]& /@ #&/@ equilibria
```

```
FrameBox[
  GridBox[
   Prepend[
    Transpose[{
      TableForm[#]&/@Union[Flatten[nvoteList,1]],
      PaddedForm[#,4]&/@prefCountsSummary,
      TableForm[#]& /@falsifiers,
      (*Map[PaddedForm[#,4]&,randomSummaryTable,2],*)
      PaddedForm[#,{6,2}]&/@(Mean/@randomSummaryTable//N)
      }],
    {"Equilibrium Vote","
        Number of\nSimulations","Number of\n\
Falsifiers","Mean"}],RowLines\[Rule]True,ColumnLines\[Rule]True]]//\
DisplayForm .

DumpSave["B2.1"]
```

Experiment D2

```
<<DiscreteMath`Combinatorica`

<<Statistics`

SeedRandom[25]

vote[pref_,state_,p_,f_,s_]:=Table[a=If[Plus@@friends[[n]]\[Equal]0,(
   p[[n]] pref[[n]]+s[[n]] Mean[Drop[state,{n}]])/(p[[n]]+s[[n]]),p[[
      n]] pref[[n]]+f[[n]] state.friends[[
          n]]/Plus@@friends[[n]]+s[[n]] Mean[Drop[state,{n}]]];
   a=If[a\[Equal]0.5,Random[Integer],Round[a]],{n,10}]


findCycle[x_]:=Module[{l={},i,n},
   n=x[[i=1]];
   While[FreeQ[l,n],AppendTo[l,n];n=x[[++i]]];
   Drop[l,Position[l,n][[1,1]]-1]
   ]

p=Table[.5,{10}];
f=Table[.5,{10}];
s=Table[0,{10}];

Clear[x,y]

Solve[x(2-x)\[Equal]y,x]

\!\(x = 1 - \@\(1 - y\)\)

y=.5

x

nstate=Table[IntegerDigits[n,2,10],{n,0,1023}];

summary={};
friendsList={};
nvoteList={};
prefCountsList={};

\!\(\*
 RowBox[{"friendsi", "=", GridBox[{
      {"0", "1", "0", "0", "0", "0", "1", "0", "0", "0"},
      {"0", "0", "1", "0", "0", "0", "0", "1", "0", "0"},
      {"0", "0", "0", "1", "0", "0", "0", "0", "1", "0"},
```

```
{"0", "0", "0", "0", "1", "0", "0", "0", "0", "1"},
{"1", "0", "0", "0", "0", "1", "0", "0", "0", "0"},
{"0", "1", "0", "0", "0", "0", "1", "0", "0", "0"},
{"0", "0", "1", "0", "0", "0", "0", "1", "0", "0"},
{"0", "0", "0", "1", "0", "0", "0", "0", "1", "0"},
{"0", "0", "0", "0", "1", "0", "0", "0", "0", "1"},
{"1", "0", "0", "0", "0", "1", "0", "0", "0", "0"}
}]}]\)

(friends1=ReplacePart[friendsi,0,Table[{n,n},{n,10}]])//TableForm

(friends2=MapThread[
   If[#1\[Equal]1□#2\[Equal]1,1,0]&,{friends1,Transpose[friends1]},2])//
        TableForm

ShowGraph[g=MakeGraph[Range[10],friends2[[#1,#2]]\[Equal]1&,Type\[Rule]\
Undirected],VertexNumber\[Rule]On]

Do[
 friends=friends2;
  pref={1,1,1,1,1,0,0,0,0,0};
  nvote=Sort/@
    (findCycle[
        FixedPointList[vote[pref,#,p,f,s]&,#,20]]&/@nstate);
  AppendTo[nvoteList,Union[nvote]];
  prefCounts=Count[nvote,#]&/@Union[nvote];
  AppendTo[prefCountsList,prefCounts];
  AppendTo[summary,FrameBox[
     GridBox[
      Prepend[
       Transpose[{
         TableForm[#]&/@Union[nvote],
         PaddedForm[#,4]&/@prefCounts
         }],
      {"Equilibrium Vote","Number of Initial\n    Vote States"}],
  RowLines\[Rule]True,ColumnLines\[Rule]True]]//DisplayForm],
  {1}]//Timing

friends

summary;

nvoteList;

Length[%]
```

```
prefCountsList;

Union[Flatten[nvoteList,1]]

Length[%]

prefCountsSummary=Count[Flatten[nvoteList,1],#]&/@Union[Flatten[nvoteList,1]]

Length[%]

randomSummaryTable=Table[0,{Length[Union[Flatten[nvoteList,1]]]},{1}];

Do[Do[randomSummaryTable=ReplacePart[randomSummaryTable,prefCountsList[[m,
    n]],Append[Flatten[Position[Union[Flatten[nvoteList,1]],nvoteList[[
     m,n]]]],m]],
  {n,Length[nvoteList[[m]]]}],
 {m,1}]

randomSummaryTable//TableForm;

FrameBox[
  GridBox[
   Prepend[
    Transpose[{
      TableForm[#]&/@Union[Flatten[nvoteList,1]],
      PaddedForm[#,4]&/@prefCountsSummary,
      (*PaddedForm[#,4]&/@falsifiers,*)
      (*Map[PaddedForm[#,4]&,randomSummaryTable,2],*)
      PaddedForm[#,{6,2}]&/@(Mean/@randomSummaryTable//N)
      }],
    {"Equilibrium Vote","
         Number of\n\
Simulations","Mean"}],RowLines\[Rule]True,ColumnLines\[Rule]True]]//
       DisplayForm


equilibria = Union[Flatten[nvoteList, 1]];
falsifiers =
 Length[Cases[MapThread[Equal, {pref, #}], False]]& /@ #&/@ equilibria

{{0}}

FrameBox[
  GridBox[
   Prepend[
    Transpose[{
```

```
        TableForm[#]&/@Union[Flatten[nvoteList,1]],
        PaddedForm[#,4]&/@prefCountsSummary,
        TableForm[#]& /@falsifiers,
        (*Map[PaddedForm[#,4]&,randomSummaryTable,2],*)
        PaddedForm[#,{6,2}]&/@(Mean/@randomSummaryTable//N)
        }],
    {"Equilibrium Vote","
            Number of\nSimulations","Number of\n\
Falsifiers","Mean"}],RowLines\[Rule]True,ColumnLines\[Rule]True]]//\
DisplayForm


DumpSave["B2.6"]
```