THREE ESSAYS IN APPLIED MICROECONOMIC THEORY

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Economics

by

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ABSTRACT

The first essay of my dissertation, “Ethnic Conflict and Civic Engagement” discusses that despite similar levels of ethnic diversity, some places manage to remain peaceful while others experience ethnic conflict. Using a game theoretic framework, I argue that this variation is related to the structure of ethnic engagement in the society. Ethnic engagement refers to a business relationship between two individuals, which can be inter (with an individual of opposite ethnicity) or intra (with an individual of same ethnicity). I show, the more segregated an economy is i.e., the higher is the degree of intra-relative to inter-ethnic engagements, the more conflict prone the economy is. The chances of conflict are lowered if there are inter-ethnic ties in form of social engagement, i.e. if individuals derive utility from social interactions. Absolute poverty can also play a role in precipitating conflict. I also provide an empirical analysis in the context of Hindu-Muslim violence in India. The analysis shows that higher is the inbreeding homophily at a place the greater is the probability of occurrence of a conflict there, which validates the main result of the paper.

The second essay, “Informal Insurance and Group Size Under Individual Liability Loans” is a joint work with Somdutta Basu. There has been a recent shift from joint liability to group loans with individual liability by the Grameen Bank and some other prominent micro lending institutions across the world. Under the joint liability lending mechanism a group of individuals were given a loan and individuals in a group were jointly liable for the loan given. Under the new lending regime a group of individuals are given their individual shares of a group loan. Although they have to be in a group in order to have access to the loan, individuals are not liable for the loan of other members in the group. An individual is only liable for her share of the loan. Some recent field experiments observed no change in repayment rates with this regime change. This paper investigates the role of informal insurance among group members to explain the success of group lending with individual liability. In our model members of a group face idiosyncratic shocks and realization of output is private information. They can insure each other through informal arrangements in repeated interactions. This paper focuses on a repeated game analysis of both joint and individual liability group lending. We show that with informal insurance individual liability lending can lead to repayment rates as same as joint liability. However individual’s welfare is strictly lower under individual liability lending. This paper also sheds light on the optimal group size that villagers should maintain under the new lending mechanism.

The third essay of the dissertation is entitled “Urban Ethnic Conflicts” which is a joint work with Pathikrit Basu and Suraj Shekhar. Raw data on Hindu-Muslim conflict in India reveals that over 70 percent of conflicts between 1950 and 1995 took place in towns or cities. This is severely disproportionate to the fraction of Indian population living in urban areas.2 In this paper we propose a model which sheds some light on this empirical observation. Conflicts are often precipitated by false rumors. Suppose that whenever there is a false rumor there is always one person \{b\} who can prove that the rumor is false. Our model suggests that conflict caused by a false rumor is unlikely to happen in a small population because players meet a large fraction of the population and are therefore likely to meet \{b\}. This has two effects - not only do the players who meet \{b\} know that the rumor is false; they also estimate (from the commonly known meeting process) that a large part of the population must also know. This allows them to coordinate to not fight and enjoy the high peacetime payoff as opposed to the lower wartime payoff.
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DEDICATION

To my mother

~ Kajari Dutta ~
Chapter 1

Ethnic Conflict and Civic Engagement

Abstract

Despite similar levels of ethnic diversity, some places manage to remain peaceful while others experience ethnic conflict. Using a game theoretic framework, I argue that this variation is related to the structure of ethnic engagement in the society. Ethnic engagement refers to a business relationship between two individuals which can be inter (with an individual of opposite ethnicity) or intra (with an individual of same ethnicity). I show, the more segregated an economy is i.e., the higher is the degree of intra-relative to inter-ethnic engagements, the more conflict prone the economy is. The chances of conflict are lowered if there are “inter” ethnic ties in form of social engagement, i.e. if individuals derive utility from social interactions. Absolute poverty can also play a role in precipitating conflict. I also provide an empirical analysis in the context of Hindu-Muslim violence in India. The analysis shows that higher is the inbreeding homophily at a place the greater is the probability of occurrence of a conflict there, which validates the main result of the paper.

1.1 Introduction

1.1.1 Motivation and Question

It is often suggested that ethnic conflict is likely to occur in places where there is ethnic diversity in the population. A puzzling fact, that despite of similar ethnic diversity, some places (villages, towns or cities) manage to remain peaceful, while others experience violence. This paper argues that “inter” ethnic engagement can reduce the occurrence of ethnic conflict.¹

¹As Horowitz argues, all conflicts based on ascriptive group identities—race, language, religion, tribe, or caste—can be called ethnic. Under this usage ethnic conflicts can range from (1) the Protestant-Catholic conflict in Northern Ireland and the Hindu-Muslim conflict in India to (2) black-white conflict in the United States and South Africa, (3) the Tamil-Sinhala conflict in Sri Lanka, and (4) Shia-Sunni troubles in Pakistan. In this paper, the term ethnic
Varshney (2001) first pointed out the role of ethnic engagement in his study on India. He compared three pairs of cities in India - each pair had a city where communal violence is endemic and a city where it is rare or entirely absent. After the Baburi mosque demolition, a very sacred religious place for the Muslims, at Ayodhya, in India in 1992, there was unprecedented violence across India. The storm of the Ayodhya agitation, the biggest since India’s independence led to gruesome violence at Aligarh while Calicut remained peaceful. Calicut is a city in the southern state of Kerala while Aligarh is a city in the north Indian state of Uttar Pradesh. Both cities have 36-38 percent of Muslim population while the remaining population comprises mostly of Hindus. Despite having similar diversity in the population in terms of ethnicity, why did the two cities respond so differently? According to Varshney, there are two kinds of civic interactions: associational forms of engagement and the second everyday forms of engagement. Business associations, professional organizations are examples of the former while different communities visiting each other or jointly participating in festivals are examples of the latter. According to Varshney, both forms of engagement when interethnic, reduces the occurrence of a conflict. This paper formally explains Varshney’s reasoning using a game theoretic framework.

In this paper, I use the term engagement in the sense that two individuals are in a business relationship. These engagements can be inter (with an individual of opposite ethnicity) while it can be intra (with an individual of same ethnicity). A segregated economy is characterized with higher degree of intra ethnic engagement while an integrated economy is where the degree of inter ethnic engagements is higher. This paper shows that with similar ethnic diversity, a segregated economy is more conflict prone than an integrated one. This result is further validated by an empirical analysis using data from Hindu-Muslim violence in Indian villages. I use data from the Rural and Economic Development Survey (REDS), 2006 which contains information on the linkages among individuals as well as conflict data across villages in 17 major states in India. I do not pretend that my formulation of interethnic interactions is the only mechanism that explains the occurrence of a conflict or prevalence of peace. Rather I provide an explanation towards understanding conflicts that is yet unexplored.

1.1.2 Description of the Model

In the model, there is a finite number of individuals in an economy. There are two ethnic groups, $H$ and $M$. Each individual belongs to one of the two ethnic groups. We assume that both groups have the same number of individuals. An individual has “potential” links with all the others in the economy. However a subset of these links are activated at the beginning of the game. Links with opposite ethnicity (inter) are activated with probability $\alpha$ while links with the same ethnicity is used in its broader meaning as explained by Horowitz. For more details see Donald Horowitz, “Ethnic Groups in Conflict” (Berkeley: University of California Press, 1985)

$^2$In section 1.6.2, there is a discussion if the group sizes are different. The results do not change qualitatively.
(intra) are activated with probability $\beta$. These probabilities are parameters in the model and are exogenously given. An individual only knows her set of active links and does not know the entire set of active links in the economy. However $\alpha, \beta$ are common knowledge.

Once links are activated, all individuals in the economy realize an endowment $e$. An individual has to take two actions. An individual can enter into a business arrangement by investing an amount $c$ with an individual with whom she has an active link. These business arrangements can be with “intra” as well as “inter” links. Secondly the individual has to vote for conflict or peace. The decisions are taken simultaneously by all individuals. An individual when making her decisions is not aware of others’ decisions.

There is an exogenously given budget which is available to provide a public good. In times of peace, all individuals enjoy the public good. A conflict occurs when the majority of at least one group votes for conflict. If a conflict occurs, one ethnic group wins and seizes the entire budget. This budget is then used to provide an “ethnic” based public good. The members in the winning group who voted to participate enjoy a payoff which is higher than the peace time payoff. The members in the losing group receive zero irrespective of whether they voted to participate or not. We assume that both the groups have an equal probability of winning in the conflict. If a conflict occurs, then an agent does not derive any business payoff if she has a business arrangement with an individual of the opposite ethnicity. However she receives the business payoff if she has an arrangement with an individual of the same ethnicity irrespective of whether conflict occurs or not. An individual does not derive any payoff from links of opposite ethnicity if she votes for conflict and the conflict does not occur.

I study Nash equilibrium in this game. There are multiple equilibria in this setting. There is an equilibrium where all individuals invest in links of opposite ethnicity and vote for peace. The other equilibrium is where individuals never invest in links of opposite ethnicity and decide to participate in the conflict. However my analysis concentrate on the set of equilibria where voting for conflict depends on whether an individual has a business arrangement with a link of the opposite ethnicity or not.

1.1.3 Description of Main Results

I initially consider an economy where individuals have sufficient endowment to invest even if all “possible” links are activated. This economy is termed as “unconstrained.” In an unconstrained economy, I show that an individual always invests in a link of the opposite ethnicity provided $\alpha$ is large enough and she votes for peace. In this economy, if $\alpha$ is less than some threshold which

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3 An “ethnic” based public good can be a mosque or a temple.
I calculate, then no individual invests in a link of the opposite ethnicity and conflict occurs in equilibrium.

Next we consider an economy which we term as “constrained.” In a constrained economy an individual has enough endowment to invest only in a single link. In this situation, I show that an individual will invest in a link of the opposite ethnicity only when $\alpha$ is high enough and $\beta$ is below a certain threshold. Both these thresholds are endogenously determined given the other parameter values. An individual always is better off by investing in a link of the same ethnicity as there are no chances of losing the payoff. So if $\beta$ is high enough, then most “intra” links are activated and individuals invest in a link of the same ethnicity. Hence all individuals would vote for conflict and hence conflict occurs in equilibrium. For $\alpha$, the similar reasoning holds as in the “unconstrained” economy. Hence if $\beta$ is low enough along with $\alpha$ being sufficiently high, individuals invest in links of opposite ethnicity and conflict is avoided. These findings in the paper reveals another interesting feature that an economy with higher resources, characterized by higher endowment for all individuals is less conflict prone\(^4\) than an economy with scarce resources, i.e. low endowment for all individuals. In other words, a wealthier economy tends to be more peaceful than a poorer economy.

Next I characterize a heterogeneous economy where all individuals in one group have a higher endowment than all individuals in the other group. This heterogeneous economy is less conflict prone as compared to a homogeneous economy where all individuals have low endowment. On the other hand this heterogenous economy is more conflict prone than a homogeneous economy where all individuals have a higher endowment. This points out that absolute poverty can also play a role in precipitating conflict. Further I show that even if individuals are not linked to people of opposite ethnicity through business (associational forms of engagement) but derive utility from interacting with them (everyday forms of engagement), such “inter” ethnic ties can also play a role in lowering the probability of conflict.

\subsection{1.1.4 Empirical Analysis}

I also provide an empirical analysis to show the impact of ethnic engagement on religious conflicts in the context of Hindu-Muslim violence in India. This analysis supports the main proposition of this paper that segregated societies are more conflict prone than the integrated ones. I use data from the Rural and Economic Development Survey (REDS), 2006 which contains information on the linkages among individuals as well as conflict data across 241 villages in 17 major states in India. The dataset is one of its kind in the sense that it has information both on linkages as well as on religious conflict. For the empirical analysis, I use data for 49 villages which have both Hindu

\footnote{Peace can be maintained for larger ranges of $\alpha$ and $\beta$.}
and Muslim residents. The reason to select only Hindu-Muslim villages is that most of the conflicts reported were Hindu-Muslim violence.

The data reports information at the household level, who they would approach in the village to borrow money in times of family emergency and to borrow simple food items. This information is used to study the patterns of homophily by religion and then to calculate an inbreeding measure for each village. I calculate two inbreeding measures, one based on borrowing money and the other based on borrowing food items. The dataset reports 1 if there was a conflict else reports 0. Using a Probit model, with conflict as the dependent variable and the calculated inbreeding measure as the primary independent variable, I show that higher is the inbreeding, the greater is the probability of occurrence of a conflict. The result holds even when we add for different controls like literacy rates, per capita income, total population, fraction of Muslim population in the village which are often thought to have a major influence on the occurrence of conflict.5

1.1.5 Literature

Varshney (2001) argues that interethnic and intraethnic networks of civic engagement play very different roles in the occurrence of ethnic conflict. Since they build bridges and manage tensions, interethnic networks are agents of peace, but if communities are organized only along intraethnic lines and the interconnections with other communities are very weak or even nonexistent, then ethnic violence is quite likely. This paper formalizes this argument put forward by Varshney (2001) in a theoretical framework.

There is a second area in the literature where scholars have explained how cooperation can be sustained between two ethnic groups. Though in a different context, the idea of cooperation between two groups dates back to a paper by Greif (1993) in the context of Maghribi traders. The pioneering paper by Fearon and Laitin (1996) sustains cooperation in an infinitely repeated game where players are paired at random to play a prisoner’s dilemma every period. Larson (2012) builds on Fearon and Laitin (1996) but allows for the possibility that some members of an ethnic group may not have perfect information about all others in the same ethnic group. The current paper adds to the literature by providing an alternative analytical framework.

Another area in the literature, for e.g. Wilkinson (2004), argues that when politicians need minority support, they prevent violence and when they don’t, they don’t. Moreover if they need to incite ethnic polarization, then they might just promote ethnic violence. Chandra (2004, 2005) argues that electoral laws, are likely to influence the type of ethnic identities that become politicized in the first place.

5The concern in the empirical analysis is that there is a potential issue of reverse causation i.e., previous conflicts may have played a role in determining the pattern of inter or intra linkages that we observe in 2006. I take care of this concern which is explained in Section 1.7.5
Scholars in economics have also talked about different aspects of communal conflict. Esteban and Ray (2008) points out why ethnic conflict is more likely to occur than class conflict. Esteban and Ray (2011) uses a theoretical model to show how within-group heterogeneity in radicalism and income help in precipitating an ethnic conflict. Dasgupta and Kanbur (2005) and Dasgupta (2009) studies ethnic conflict between workers and employers.

This paper also points out that as a nation is more prosperous the chances of conflict are lowered. Empirical work has shown that ethnic conflict is more likely when countries are less developed (see for example Collier and Hoeffler (2004), Gurr (1968), Barrows (1976), Mitchell and Morgan and Clark).

1.1.6 Outline of the Paper

Section 1.2 introduces the model. In section 1.3 we analyze the game. In section 1.3.1, we consider the unconstrained economy, where individuals have enough resources. In section 1.3.2, we consider the constrained economy where individuals have limited resources and section 1.3.3 does a welfare analysis. In section 1.4 we work out an example with two individuals in each group. Section 1.5 introduces social links and section 1.6 discusses two extensions. In section 1.7 we provide an empirical analysis and section 1.8 concludes.

1.2 The Model

1.2.1 The Environment

Consider an economy where there are $2N$ individuals where $N$ is large and even. I use the notation $H$ and $M$ to denote two ethnic or religious groups. Each individual in this economy belongs to one of the two ethnic groups. Each ethnic group has $N$ individuals each. For the moment, I start with an economy which has equal number of individuals in each ethnic group. Individuals in this economy are linked to each other. An individual “potentially” has $N - 1$ links with members of her own ethnic group and $N$ links with members of the opposite ethnic group.

There are two kinds of links, “inter” and “intra”. The “intra” links are links between members of the same ethnicity. Links between members of the opposite ethnicity are termed as “inter”. In the rest of the paper I use $HH$ to denote a link between two individuals belonging to the group $H$ and $MM$ to denote a link between two individuals belonging to the group $M$. An “inter” link between an individual belonging to group $H$ and another individual belonging to group $M$ is denoted by $HM$. 

1.2.2 Link Formation

At the beginning of the game, links are activated by Nature. Let $i_e j_{\tilde{e}}$ be a “potential” link between individual $i$ and individual $j$ where $i$ belongs to group $e$ and $j$ belongs to group $\tilde{e}$ where $e \in \{H, M\}$ and $\tilde{e} \in \{H, M\}$. Let $Q$ be the set of “potential” links in the economy.

$$Q = \{i_e j_{\tilde{e}} \mid i, j \in \{1, 2, \ldots, N\} \times \{1, 2, \ldots, N\}; e, \tilde{e} \in \{H, M\} \times \{H, M\}; i_e \neq j_{\tilde{e}}\}$$

From the set $Q$, Let $Q^A$ be a subset of links that are activated. Hence the set of “active” links of an individual is a subset of her “potential” links. Let $HH$ and $MM$ links are activated with probability $\beta$. Let $\alpha$ be the probability with which $HM$ links are activated. Let $\alpha, \beta \in [0, 1]$. When $\beta = 1$, then all the “intra” links are activated in the society whereas $\alpha = 1$ means that all the “inter” links are activated. Let $ij$ denote an active link between an individual $i$ and an individual $j$ where $i \neq j$. For each individual $i$, we denote the set of active links of $i$ as

$$Z_i = \{i_e j_{\tilde{e}} \mid i_e j_{\tilde{e}} \text{ is active and } j \neq i\}$$

Let $A_i$ denote the set of active links in the economy excluding the active links $i$ has. This is given by

$$A_i = \{k_e j_{\tilde{e}} \mid k_e j_{\tilde{e}} \text{ is active and } k, j \neq i\}$$

An individual knows the set $Z_i$ but does not know $A_i$. However $\alpha$ and $\beta$ are common knowledge. The values of $\alpha$ and $\beta$ act as proxies for the degree of “inter” and “intra” linkage in an economy. These links are undirected and any two individuals who have an active link can enter into a business arrangement. The details are spelt out later in the paper.

1.2.3 Timeline of Events

Individuals have an utility function $U(x) = x$. Each individual has an endowment $e > 0$. Individuals can enter into business arrangements with whom she has an active link. To enter into business with an active link, an individual has to make an investment. The investment decision, $d$ is a binary decision where $d \in \{0, c\}$. Investing $c$ in business with an active link generates a payoff $F$. To generate a payoff from business both the individuals linked need to invest in the business. If one of the paired individuals decide not to invest, i.e., $d = 0$ then both the individuals derive a zero payoff from the link. The proposal for investing in business are made simultaneously by the individuals. On the other hand, the individual can simply consume the endowment. I assume that $F > c$, i.e.

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6We can alternatively think that once the links are activated, individuals list the links that they want to invest in. If individual $i$ lists $j$ as a potential business partner and $j$ also lists $i$ as a potential business partner then the linked individuals get into a business partnership.
the utility from business payoff is higher than the utility from not investing.

There is an exogenously given budget which is available to provide a public good. The status quo is peace and the budget is used to provide the public good. On the other hand either of the ethnic groups or both can form an alliance and enter into a conflict to seize the budget in their favor. The individuals vote for conflict or no conflict. Hence an individual has an action \( a \in \{P, NP\} \). This voting is also done simultaneously. An action \( a = P \), means that an individual votes for conflict and \( a = NP \) indicates that an individual does not vote for conflict. An alliance is formed if there are at least \( N/2 \) people in a group who vote for conflict. Conflict occurs only if any of the ethnic group forms an alliance. All payoffs are realized after the voting is done. If there is a conflict then an individual does not derive any business payoff from a link of opposite ethnicity irrespective of whether an individual plays an action \( P \) or \( NP \). However individuals always derive business payoffs from link of same ethnicity irrespective of whether a conflict occurs or not. If the conflict does not take place then individuals receive the business payoffs from the links of opposite ethnicity. However I assume that an individual having a business arrangement with an individual of the opposite ethnicity does not receive the business payoff if she votes for conflict but it does not happen.

In this game an individual has an action profile \((a, d)\). The payoffs are realized at the end of the voting process. In the next section we layout the payoffs in detail.

### 1.2.4 Payoffs

In this section I describe the payoffs that each player receives in the game that we stated above. Let’s first describe the payoffs that an individual receives from conflict and peace. If both the ethnic group fails to form an alliance then there is peace and the budget is used to deliver a public good devoid of any ethnic characteristics. This can be thought of investing in a primary or secondary school or building a hospital. In times of peace, each individual receives a payoff of \( v \) from the public good. If one of the ethnic groups form an alliance then conflict occurs and the group forming the alliance seize the entire budget. Each member in the group forming the alliance who voted to participate receives \( E - C \). However if both the groups form alliance then we assume that each group has an equal chances of winning in the conflict. The members in the winning group who voted to participate receives \( E - 2C \) whereas the members in the losing group receive 0. In case of a conflict, the budget is used to deliver a public good that is more favorable to one of the ethnic groups, i.e. it would have certain ethnic characteristics. Examples of ethnic-based public goods include the funding to build temples or mosques. They may also include employment in or access to certain economic sectors dominated by one ethnic group or the other. They can include possible job reservations in bureaucratic or political positions. \( C \) is the direct cost of conflict. I assume that if two groups form alliance then the conflict is more violent and hence payoffs are lower.
I assume that

\[ 0 < \frac{E}{2} - C < v < E - C \]

An ethnic based public good is always valued more than a public good devoid of ethnic characteristics. However with both groups entering into conflict, the expected payoff from conflict is lower than the peace time payoff. However if one group forms the alliance then it is strictly dominant for the other group to form the alliance too.

Consider an individual with an endowment, \( e \) and \( k \) business links. Let \( k_s \) be the number of links with the same ethnicity while \( k_o \) is the number of links with the opposite ethnicity. Hence \( k = k_s + k_o \). The individual at the end of the game would receive a payoff

<table>
<thead>
<tr>
<th>Conflict and win</th>
<th>Conflict and Lose</th>
<th>Peace</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participate (( a = P ))</td>
<td>( E - 2C + k_s F + (e - kc) )</td>
<td>( k_s F + (e - kc) )</td>
</tr>
<tr>
<td>Not Participate (( a = NP ))</td>
<td>( k_s F + (e - kc) )</td>
<td>( k_s F + (e - kc) )</td>
</tr>
</tbody>
</table>

Here the payoffs are written down assuming that the other ethnic group forms the alliance. If the other ethnic group does not form the alliance then an individual in the group forming the alliance receives \( E - C + k_s F + (e - kc) \) provided she voted to participate while an individual in the group not forming the alliance receives \( k_s F + (e - kc) \).

An individual has to decide on whether to invest in business links or not. An individual always benefit from investing in a business link rather than keeping the endowment. However an individual need to decide on whether to invest in a link of the opposite ethnicity because if a conflict occurs then it leads to loss of payoffs from those links.

1.3 Analysis

Before we analyze the model, we first describe the game tree (see figure 1.1) and the equilibrium concept. In the game tree, individual 1 moves first whether to invest or not invest. Then he has to decide to play \( P \) or \( NP \). Next individual 2 moves. However individual 2 is at the information set because the actions are taken simultaneously by all. An individual strategy \( s_i : (E, C, F, c, \alpha, \beta) \rightarrow \{0, c\}^m \times \{P, NP\} \) where \( m \) is the maximum number of links she can invest in. I restrict to pure strategies. Given the game described, I now look at Nash equilibrium. A strategy profile, \( s^* \) is a Nash equilibrium if \( \forall i, \)

\[ EU(s^*_{-i}, s^*_{-i}) \geq EU(s_i, s^*_{-i}) \forall s_i \in \Delta(S_i) \]

In this setting, there are multiple equilibria. I first describe two equilibria, one where conflict always occur and the other where peace is the equilibrium outcome irrespective of the values of \( \alpha \).
Proposition 1: There always exist a conflict equilibrium where individuals never invest in a link of opposite ethnicity and there is always a peace equilibrium where individuals always invest in a link of opposite ethnicity.

Proof:

Suppose that all individuals play the action \( a = P \). Under this situation an individual will never invest in a link of the opposite ethnicity. This strategy with no investment, i.e. \( d = 0 \) in a link of opposite ethnicity and vote for conflict constitutes an equilibrium where conflict occurs. An individual cannot be better off by deviating from this strategy. Given that all players follow this strategy, there is no incentive for an individual to deviate and invest in a link of the opposite ethnicity. Given that conflict would occur in equilibrium, an individual has no incentive to deviate and invest in a link of the opposite ethnicity. An individual by investing in a business link of the
opposite ethnicity would receive a payoff

\[ \frac{E}{2} - C + k_s F + \delta x \]

whereas by not deviating from the strategy would receive

\[ \frac{E}{2} - C + k_s F + \delta (x + c) \]

where \( x \) is the amount of endowment left after investing in business links. Thus by following the strategy an individual has a higher expected payoff. Moreover an individual cannot be better off by not playing \( P \) as given by the payoffs. Hence the following strategy constitutes a Nash equilibrium.

Now consider the other equilibrium. Suppose all individuals play the action \( a = NP \). Under this situation an individual always invest in a link of the opposite ethnicity. Hence the strategy with always invest in a link of the opposite ethnicity and vote for no conflict constitutes a peace equilibrium. Since everyone votes for no conflict then peace is the outcome. An individual by investing in a link receives

\[ v + F + (e - c) \]

whereas by not investing receives

\[ v + e \]

Since \( F > c \), an individual receives a higher payoff from investing. Moreover an individual also does not benefit by voting for conflict if she invests in a link of opposite ethnicity as is clear from the payoffs specified earlier. Hence this also constitutes a Nash equilibrium □

Now I would like to concentrate on equilibria where an individual votes for no conflict if she has a link of the opposite ethnicity. In other words I would like to concentrate on equilibria where peace can be maintained by making individuals to invest in links of opposite ethnicity. This would be more in line with Varshney where individuals having links with opposite ethnicity would not participate and hence if there are enough such links then peace can be maintained in the society.

As stated before individuals have an endowment \( e \), and there is a cost \( c \) to invest in each business link. An individual can potentially have all \( N \) “inter” links and \( N - 1 \) “intra” links activated. Hence an individual who has all the links activated would require \((2N - 1)c\) amount of resources if she wishes to start business with all the activated links. Initially I start with an economy where individuals have sufficient resources so that they can invest in all possible business links i.e., \( e \geq (2N - 1)c \). This kind of an economy is termed as “unconstrained” economy in the
paper. Later I consider economies where individuals face endowment constraints so that there is a limit on the maximum number of business links that they can maintain. These economies are termed as “constrained” because individuals have limited resources.

1.3.1 Unconstrained Economy

In this section, assume that individuals have sufficient endowment such that \( e \geq (2N - 1)c \). In addition, assume that the following is satisfied

\[(E - C - v) < F \] (A.1)

This means that losing a single link is also costly for an individual, i.e. the expected gain from conflict is lower than the payoff received from a single business link.

**Proposition 2:** Consider the following strategy: Irrespective of the value of \( \beta \), an individual always invest \( d = c \) in a business link of the same ethnicity. An individual does not invest in any business link of the opposite ethnicity \( \forall \alpha \leq \alpha^* \) and invest in links of the opposite ethnicity \( \forall \alpha > \alpha^* \). This constitutes an equilibrium where conflict always occur \( \forall \alpha \leq \alpha^* \).

**Proof:**

An individual always invest in a business link of the same ethnicity. Investing in the business link of the same ethnicity is always profitable as there are no chances of losing the link even in times of conflict. A business link generates a higher payoff than not investing.

Consider an individual \( i \), who has to decide on whether to invest in a business link of the opposite ethnicity. An individual calculates the probability of conflict. Let \( \mu_{NN}(\alpha) \) be the probability of no conflict.\(^7\) \( \mu_{NN}(\alpha) \) is the sum of all the probabilities of events where there are at least \( N/2 \) individuals from either group who have at least one link. Let \( \mu_{NA}(\alpha) \) be the sum of all the probabilities of events where there are at least \( N/2 \) individuals from group \( H \) who have at least a link of the opposite ethnicity while there are less than \( N/2 \) individuals in group \( M \) who do not have a link of the opposite ethnicity. Similarly define \( \mu_{AN}(\alpha) \) as the probability where the group \( H \) forms an alliance while group \( M \) does not. Finally \( \mu_{AA}(\alpha) \) is the probability where both the groups form an alliance. These probabilities are independent of \( \beta \), because individuals have enough resources to invest in all possible links. So what I need to take care of is that individuals have at least one link of the opposite ethnicity.

Since links are activated independently, \( \mu_{ij}(\alpha) \) is a polynomial function in \( \alpha \), where \( i, j \in \{A, NA\} \). This implies that \( \mu_{NN}(0) = 0 \) and \( \mu_{NN}(1) = 1 \) with \( \frac{\partial \mu_{NN}(\alpha)}{\partial \alpha} > 0 \).

\(^7\)We work out an example with two individuals in each group in details
Hence the expected payoff by investing in a business link of the opposite ethnicity is

\[
P_I = \mu_{NN}(\alpha)[v + (e - c) + F] + \mu_{NA}(\alpha)[0 + (e - c)] + \mu_{AN}(\alpha)[E - C + (e - c)] + \mu_{AA}(\alpha)[E - C + (e - c)]
\]

The expected payoff from not investing in a business link of the opposite ethnicity is given by

\[
P_{NI} = \mu_{NN}(\alpha)[v + e] + \mu_{NA}(\alpha)[0 + e] + \mu_{AN}(\alpha)[E - 2C + e] + \mu_{AA}(\alpha)[E - 2C + e]
\]

Now

\[
P_I - P_{NI} = \mu_{NN}(\alpha)F - c
\]

Thus the expected benefit from investment is higher when \(\mu_{NN}(\alpha) > \mu_{NN}(\alpha^*) = \frac{c}{F}\). Since \(F > c\), so that \(\frac{c}{F} < 1\). Given that \(\frac{\partial \mu_{NN}(\alpha)}{\partial \alpha} > 0\), \(\exists\) an \(\alpha\) such that \(\forall \alpha > \alpha^*\), individuals invest in business link of opposite ethnicity. Since investing in one link is beneficial, individuals would also invest in more links of opposite ethnicity if activated.

An individual with no link would always participate in the conflict as there is nothing to lose. However an individual with a link will never participate in conflict because the losses are higher than gains.

Now if \(\alpha < \alpha^*\), no individual invest in a link of the opposite ethnicity and hence all individuals would then prefer a conflict over peace and hence conflict occurs.\(\blacksquare\)

Suppose the assumption A.1 is relaxed i.e., the parameter values are such that it is no longer costly to lose a single link. Now I assume that

\[
(E - C - v) > F
\]

\[
(E - C - v) < NF
\]

This implies that losing a single link may not be very costly but at the same time losing all the links of opposite ethnicity can prove to be costly. This means \(\exists\) some \(k = k^*\) such that

\[
(E - 2C - v) = k^*F
\]
Now $k^*$ may not be an integer and hence we take $\lfloor k^* \rfloor$, i.e. the largest integer not greater than $k^*$.

Here I should mention that if $(E - C - v) > NF$, then individuals would always prefer a conflict and losing even all the links of the opposite ethnicity is not very costly. In this situation conflict occurs with probability one irrespective of the value of $\alpha$. Individuals while deciding to invest would take this into account and hence would not invest in any business link of the opposite ethnicity. Thus conflict always occur in equilibrium.

Hence with $(E - C - v) < NF$, all individuals who have business links less than $k^*$ would be interested to participate in the conflict. Consider an individual who has to decide on whether to form a business link with a member of the opposite ethnicity. Since $\mu_{NN}(\alpha)$ is only relevant for calculation, let it be denoted by $\mu(\alpha)$. Let $\mu_k(\alpha)$ as before denote the probability of no conflict as evaluated by the individual. I add the subscript $k$ to denote that an individual with more than $k$ links do not participate in a conflict. While calculating this probability, the individual has to calculate that there are at least $N/2$ individuals who have more than $k^*$ links of the opposite ethnicity.

As before, $\frac{\partial \mu_k(\alpha)}{\partial \alpha} > 0$, and an individual would be interested to invest in business link if

$$\mu_k(\alpha) \geq \mu_k(\alpha^*) = \frac{c}{F}$$

Hence I obtain that $\forall \alpha \geq \alpha^*$, individuals would invest in a link of the opposite ethnicity and $\forall \alpha < \alpha^*$, individuals do not invest in the links of the opposite ethnicity.

**OBSERVATION 1:** The value of $\alpha^*$ increases as the critical value of $k$, i.e. $k^*$ increases.

**Proof:**

This observation points out that as the minimum number of links that an individual must have with the opposite ethnicity which deters an individual from a conflict i.e. $k^*$, increases, then for an individual to invest in a link of the opposite ethnicity we require the critical value of $\alpha$, i.e. $\alpha^*$ to be higher. This is intuitive because as $k^*$ increases, the probability of no conflict is more difficult to satisfy for a given $\alpha$, hence we need $\alpha^*$ to increase. Let $\alpha^*(k^*)$ denote the critical value of $\alpha$ when the critical value of $k$ is $k^*$. I calculate the probability of conflict from the point of view of an individual who is willing to invest.

Here I can use the properties of the binomial distribution to prove this. For large values of $N$, we can approximate the probability of conflict by using the binomial distribution.
First I calculate the probability that an individual has less than $k^*$ links.

$$\Pr(\text{individual has links } \leq k^*) = \sum_{m=0}^{k^*} \binom{N}{m} \alpha^m (1 - \alpha)^{N-m} = \gamma$$

Using the probability that an individual has less than $k^*$ links, we can calculate the probability that the alliance is formed. i.e., there are at least $N/2$ individuals who have less than $k^*$ links.

$$\Pr(\text{there are at least } N/2 \text{ individuals prefer conflict}) = \sum_{m=N/2}^{N} \binom{N}{m} \gamma^m (1 - \gamma)^{N-m} = \lambda$$

Thus $1 - (1 - \lambda)^2$ gives the probability that there is at least one ethnic group forming an alliance and hence the conflict occurs.

Now suppose that we take $k_1^* > k_2^*$. From equation 1, I obtain that $\gamma_1 > \gamma_2$. From the properties of the binomial distribution, I obtain that $\lambda_1 > \lambda_2$. Hence the probability of conflict increases as $k^*$ increases and hence the probability of no conflict goes down as $k^*$ increases for any given $\alpha$. Hence if I plot $\mu(k)$ for $k_1^*$ and $k_2^*$, then I will obtain $\alpha^*(k_1^*)$ and $\alpha^*(k_2^*)$ as in Figure 1.2. An individual

Figure 1.2: Proof of Observation 1
would invest in a link of the opposite ethnicity as long as the probability of no conflict is greater than or equal to \( \frac{c}{F} \). From the above diagram it is clear that \( \alpha^*(k_1^*) > \alpha^*(k_2^*) \). Hence an economy with a higher \( k^* \) would have more chances of a conflict as compared to the the economy with low \( k^* \). This is intuitive because in an economy where individuals value the payoff from conflict more than maintaining the links would have higher chances of a conflict.

Now I turn to economies where there is a constraint on the maximum number of links that an individual can invest in.

1.3.2 Constrained Economy

Suppose that individuals are budget constrained i.e. they have endowment, \( e \) only to invest in one business link. This analysis is carried out under the assumption that losing even a single link is costly, i.e.

\[
(E - C - v) < F
\]

**Proposition 3:** Consider the following strategy which constitutes an equilibrium: An individual always invest in a business link of the same ethnicity whenever possible. There exists a \( \beta = \beta^* \) such that

a) \( \forall \beta \geq \beta^* \), an individual does not invest in a link with someone of the opposite ethnicity and hence conflict occurs

b) \( \forall \beta < \beta^* \), \( \exists \) an \( \alpha = \alpha^* \) corresponding to each \( \beta \) such that \( \forall \alpha, \alpha > \alpha^* = \alpha^* \), an individual invests in a business link with someone of the opposite ethnicity while \( \forall \alpha \leq \alpha^* \), the individual does not invest in a business link with someone of the opposite ethnicity and hence conflict occurs.

**Proof:**

An individual would always invest in a business link of the same ethnicity whenever possible. This is always beneficial as there are no chances of losing the link even in times of conflict. A business link generates a higher payoff as compared to not investing.

Now consider an individual who has a link activated with another individual of the opposite ethnicity. An individual calculates the probability of conflict. Let \( \mu_{NN}(\alpha, \beta) \) be the probability of no conflict, i.e., there are atleast \( N/2 \) individuals in both the groups who have at least one link of the opposite ethnicity and no links of the same ethnicity. This means that \( \mu_{NN}(\alpha, \beta) \) polynomial in \( \alpha \) and \( (1 - \beta) \). Similarly I define \( \mu_{AN}(\alpha, \beta) \) as the probability where group \( H \) forms an alliance and group \( M \) does not. Let \( \mu_{NA}(\alpha, \beta) \) be the probability where group \( M \) forms an alliance and \( H \) does not and \( \mu_{AA}(\alpha, \beta) \) is the probability where both forms an alliance.

Now let us calculate the expected payoff from investing in a business link of the opposite
ethnicity

\[ P_I = \mu_{NN}(\alpha, \beta)[v + F] + \mu_{NA}(\alpha, \beta)[0 + (e - c)] + \mu_{AN}(\alpha, \beta)[E - 2C + (e - c)] + \mu_{NN}(\alpha, \beta)[\frac{E}{2} - C + (e - c)] \]

Suppose the individual do not invest in the business link. Then the expected payoff is given by

\[ P_{NI} = \mu_{NN}(\alpha, \beta)v + \mu_{NA}(\alpha, \beta)[E - C] + \mu_{NN}(\alpha, \beta)[\frac{E}{2} - C] + (e - c) + \mu_{NN}(\alpha, \beta)F \]

Now

\[ P_I - P_{NI} = \mu_{NN}(\alpha, \beta)F - e \]

This leads us to the point that an individual would invest in a business link provided that

\[ \mu_{NN}(\alpha, \beta) \geq \mu_{NN}^*(\alpha, \beta) = \frac{e}{F} \]

Since the only relevant \( \mu_{ij}(\alpha, \beta) \) is \( \mu_{NN}(\alpha, \beta) \), let us denote \( \mu(\alpha, \beta) = \mu_{NN}(\alpha, \beta) \).

Given, \( \mu(\alpha, \beta) \) it is easy to verify \( \frac{\partial \mu}{\partial \alpha} > 0 \), \( \frac{\partial \mu}{\partial \beta} < 0 \) and \( \frac{\partial^2 \mu}{\partial \alpha \partial \beta} < 0 \).

As \( \beta \) approaches one, the probability of no conflict would approach zero irrespective of the value of \( \alpha \). In fact, if \( \beta \) is high enough individuals do not invest in a business link of the opposite ethnicity. I can choose the combinations of \((\alpha, \beta)\) such that

\[ \mu(\alpha, \beta) = \frac{e}{F} \] (3)

Now starting from \( \beta = 0 \), there is a corresponding \( \alpha_0 \) such that \( \mu(\alpha_0, 0) = \frac{e}{F} \). Now corresponding to this \( \alpha \), we know that \( \forall \alpha \geq \alpha_0 \), individuals would invest in business links of opposite ethnicity. As the value of \( \beta \) increases, given that \( \frac{\partial^2 \mu}{\partial \alpha \partial \beta} < 0 \), the corresponding \( \alpha \) such that \( \mu(\alpha, \beta) = \frac{e}{F} \) would also increase. In fact the value of \( \beta^* \) is determined by plugging \( \alpha = 1 \) in equation 3 and solving for \( \beta \). Hence \( \beta^* \) is determined from the equation

\[ \mu(1, \beta) = \frac{e}{F} \]

The existence of \( \beta^* \) is guaranteed from the Intermediate Value Theorem. It is easy to see that \( \mu(1, 0) = 1 \) and \( \mu(1, 1) = 0 \). Given that \( \frac{\partial \mu}{\partial \beta} < 0 \), \( \exists \beta = \beta^* \) such that \( \mu(1, \beta^*) = \frac{e}{F} \).

Since links are activated independently of each other, if \( \beta = 1 \), then \( \mu(\alpha, \beta) = 0 \). Hence
\( \forall \beta \geq \beta^*, \) irrespective of \( \alpha \), probability of no conflict is lower than the critical value, individuals do not invest in any link of the opposite ethnicity and hence the probability of conflict in equilibrium is one.

\( \forall \beta < \beta^*, \exists \) an \( \alpha = \alpha^* \) corresponding to the \( \beta \) such that \( \mu(\alpha, \beta) = \frac{e}{F} \). Given that \( \frac{\partial \mu}{\partial \alpha} > 0 \), this implies that \( \forall \alpha < \alpha^* \), individuals never invest in links of the opposite ethnicity and hence the probability of conflict is one. ■

This result is intuitive because if the “intra” links are formed with very high probability then an individual when deciding to invest in a link of the opposite ethnicity would know that most individuals have a link of the same ethnicity and hence would invest in them. Thus the probability of conflict is very high and hence would not invest in a business link of the opposite ethnicity even if the value of \( \alpha \) is one. This is driven by the fact that there are resource constraints. Investing in link of the same ethnicity is always preferable under any circumstances.

In the unconstrained economy, conflict occurs only when the “inter” linkage are not activated with a sufficiently high probability. However in this constrained economy even if the “inter” linkages are activated with a high enough probability we need that the “intra” linkages are activated with a low enough probability so as to avoid a conflict.

At this juncture the natural question that arises is that what happens if the individuals have enough resources to invest in \( m \) possible business links where \( m \leq (2N - 1) \). As I relax the constraint on the endowment available for investment, the parametric restrictions on \( \beta \) to avoid a conflict becomes less stringent. We still carry our analysis under the assumption A.1 i.e. \( (E - C - v) < F \).

**Observation 2:** The value of \( \beta^* \) increases as the value of \( m \) increases.

**Proof:**

Let \( \mu(\alpha, \beta) \) be the probability of no conflict. This is calculated as shown in Proposition 3. An individual would invest in a link of the opposite ethnicity provided that

\[
\mu(\alpha, \beta) \geq \mu^*(\alpha, \beta) = \frac{e}{F}
\]

Now while calculating the probability of no conflict from the point of view of an individual, I need to calculate that there are at least \( N/2 \) individuals who have at least one link with the opposite ethnicity and the rest \( (m - 1) \) links of the same ethnicity.

Hence \( \mu(\alpha, \beta) \) is decreasing in the power of \( (1 - \beta) \) as \( m \) increases. The expression \( \mu(\alpha, \beta) \) will be in power of \( (1 - \beta) \) because links are formed independently.

Thus I obtain that as the constraint is relaxed the value of \( \beta^* \) increases. In fact in the unconstrained economy, conflict occurs only when the “inter” linkage are not activated with a sufficiently high probability. However in this constrained economy even if the “inter” linkages are activated with a high enough probability we need that the “intra” linkages are activated with a low enough probability so as to avoid a conflict.
strained economy the results are independent of $\beta$ as we have shown in Proposition 2. Moreover comparing to Proposition 3, the corresponding $\alpha^*$ for each $\beta < \beta^*$ would also be lower as $m$ increases. Hence the chances of conflict decreases. ■

Proposition 2 and 3 along with Observation 2 brings us to the following corollary,

**Corollary 1:** A wealthier economy tends to be more peaceful than a poor economy.

**Proof:** In the unconstrained economy, if the “inter” linkages are activated with a very high probability, a conflict can be avoided. This is obtained from Proposition 2. However from Proposition 3, I obtain that even if “inter” linkages are activated with a very high probability, i.e. even if $\alpha = 1$, if “intra” linkages are simultaneously activated with a high enough probability, then conflict certainly occurs.

Now as I relax the maximum number of links that an individual can invest in, we obtain that the critical values of $\beta$ increases and $\alpha$ decreases from Observation 2. Hence the chances of conflict occurring is lowered, thus proving the corollary that a wealthier nation tends to be more peaceful than a poor economy. ■

### 1.3.3 Welfare Analysis

At this juncture, it would be appropriate to investigate the welfare implications of a conflict. Given the payoffs that I have specified and it is strictly dominant for one group to form an alliance if the other group forms, then the unique Nash equilibrium is both forming the alliance. Under this situation conflict occurs with both ethnic groups forming alliances. Given the kind of equilibrium we are interested in, I show that conflict happens when “inter” linkages are lower or in case of a poorer economy when “intra” linkages are higher. Now I show that the payoff to the society is lower under conflict than under peace.

**Proposition 4:** Social welfare under conflict is lower as compared to peace

**Proof:**

First I calculate the total welfare of $N$ individuals under conflict. When the conflict occurs, one group wins and the other loses. Hence, the welfare under conflict is

$$W_c = N(E - 2C)$$

The total welfare or payoffs under peace is given by

$$W_p = 2Nv$$
Subtracting $W_p$ from $W_c$ gives

$$W_c - W_p = N(E - 2C - 2v)$$

Given the parametric assumptions, $W_c - W_p < 0$.■

### 1.4 Example

To provide readers a better understanding, it would be nice to work out an example and calculate the probability of conflict in equilibrium. I consider an economy where there are two individuals in each group, i.e. there are two individuals in group $H$ and two individuals in group $M$. So there are a total of 4 individuals in the economy.

Let us call the two individuals in group $H$ as $H_1$ and $H_2$. Similarly for the two individuals in group $M$, let us denote them by $M_1$ and $M_2$.

Let us now denote the set of “inter” and “intra” links. There are 2 possible “intra” links i.e. $H_1H_2$ denoting the link between the two individuals in group $H$ and $M_1M_2$ denoting the link between the two individuals in group $M$.

Similarly there are four possible “inter” links. They are $H_1M_1$, $H_1M_2$, $H_2M_1$ and $H_2M_2$. All the links are undirected, so $H_1M_1$ is equivalent to $M_1H_1$. This holds for all the possible six links in the economy.

As stated in the model before, the “inter” links are activated with probability $\alpha$ while the “intra” links are activated with probability $\beta$.

### 1.4.1 Unconstrained Economy

An individual in this economy potentially has 3 possible links, two “inter” links and one “intra” link. I assume that individuals have enough endowment to invest in all the 3 links.

Consider individual $H_1$ who has a link activated with $M_1$. Now I would try to characterize $\alpha^*$ such that the expected payoff from investing in the activated link is higher than not investing. The events where conflict does not happen are when all the “inter” links are activated, any three of the “inter” links are activated, two “inter” links $H_1M_1$ and $H_2M_2$ are activated and the last case where $H_1M_2$ and $H_2M_1$ are activated. Hence

$$\mu_{NN}(\alpha) = \alpha^4 + 4\alpha^3(1 - \alpha) + 2\alpha^2(1 - \alpha)^2$$

$$= 2\alpha^2 - \alpha^4$$
Similarly I can calculate $\mu_{AN}(\alpha) = 2\alpha^2(1 - \alpha)^2$, $\mu_{NA}(\alpha) = 2\alpha^2(1 - \alpha)^2$.

I can calculate the probability of both groups forming the alliance. This is given by

$$
\mu_{AA}(\alpha) = (1 - \alpha)^4 + 4\alpha(1 - \alpha)^3 + 2\alpha^2(1 - \alpha)^2
= 1 - 3\alpha^4 - 6\alpha^2 + 8\alpha^3
$$

It can clearly be seen that $\mu_{NN}(0) = 0$ and $\mu_{NN}(1) = 1$. As stated before, $\frac{\partial \mu_{NN}}{\partial \alpha} = 4\alpha(1 - \alpha^2) > 0$

Let us now calculate the expected payoff from investing and not investing. The expected payoff from investing in the link is given by

$$
P_I = (2\alpha^2 - \alpha^4)(v + x + F) + 2\alpha^2(1 - \alpha)^2(E - C + x) + 2\alpha^2(1 - \alpha)^2(x)
+ (1 - 3\alpha^4 - 6\alpha^2 + 8\alpha^3)(\frac{E}{2} - C + x)
$$

where $x$ is the amount of endowment left over after investing.

The expected payoff from not investing is given by

$$
P_{NI} = (2\alpha^2 - \alpha^4)(v + x + c) + 2\alpha^2(1 - \alpha)^2(E - C + x + c) + 2\alpha^2(1 - \alpha)^2(x + c)
+ (1 - 3\alpha^4 - 6\alpha^2 + 8\alpha^3)(\frac{E}{2} - C + x + c)
$$

Hence I obtain that

$$
P_I - P_{NI} = (2\alpha^2 - \alpha^4)F - c
$$

An individual will be willing to invest only if $P_I - P_{NI} \geq 0$. We can solve for $\alpha^*$.  

Hence $\forall \alpha < \alpha^*$, an individual would not invest in a link of the opposite ethnicity and conflict occurs and $\forall \alpha \geq \alpha^*$, individuals would invest in links of opposite ethnicity.

---

8The value of $\alpha^* = \sqrt{1 - \sqrt{1 - (c/F)}}$
1.4.2 Constrained Economy

Suppose that individuals in this economy have enough resources so that they can invest only in one link. Consider individual $H_1$ and suppose that the link $H_1M_1$ has been activated. $M_1$ would be willing to invest only if there is no link activated with a member of the same ethnic group, i.e. $M_2$. Similarly for individual $H_1$.

Now in this case I need to calculate $\mu_{NN}(\alpha, \beta)$. In addition to the events where no group forms an alliance and hence conflict does not happen, here I need that none of the “intra” links are activated. Hence $\mu_{NN}(\alpha, \beta) = (1 - \beta)^2[2\alpha^2 - \alpha^4]$.

Thus the condition where investing in an “inter” link is better than not investing is given by

$$P_I - P_{NI} = (1 - \beta)^2(2\alpha^2 - \alpha^4)F - c \geq 0$$

Hence I can first calculate the value of $\beta^* \text{ by plugging } \alpha = 1$. So for any positive value of $\beta$, the probability of no conflict is lower in the constrained economy as compared to the unconstrained one.

1.5 Social Links

Consider the constrained economy where individuals have enough resources to invest only in one single link. An individual as before would always invest in a business link of the same ethnicity.

Now suppose there is another kind of link called the social link. Social links would represent friends and relatives with whom individuals can interact and derive some pleasure. I assume that an individual has a social link with the rest of the members in the same ethnic group. This may be due to the fact that individuals of the same ethnic group have similar cultural and religious activities whereby they tend to come closer to each other. In a constrained economy, despite of active links an individual may not have enough resources to invest in business. An individual who has an active link with a member of the opposite ethnicity but has no business relationship is automatically considered as a social link. Let an individual derive an utility $\theta_S$ from interacting with a person of the same ethnicity and $\theta_O$ from interacting with a person of the opposite ethnicity. An individual can have a social link as well as a business link with a member of the same ethnicity. This utility is additive to the individual utility function.

I assume that $F > \theta_S > \theta_O$. Hence an individual would always prefer to invest in business with an active link. Moreover she derives more pleasure from interacting with an individual belonging to the same ethnicity as compared to an individual belonging to opposite ethnicity. However a conflict
would lead to a mistrust and all the social links of the opposite ethnicity would no longer exist. This brings us to the next proposition

**Proposition 5:** In the constrained economy the probability of conflict is less than one under the presence of social links even when $\beta > \beta^*$. 

**Proof:**

An individual would always invest in a business link of the same ethnicity. Now consider an individual who has a business link with the same ethnicity and $k$ social links of the opposite ethnicity. An individual would prefer conflict over peace only when

$$E - C + F + (N - 1)\theta_S \geq v + F + (N - 1)\theta_S + \theta_O$$

$$\Rightarrow k \leq \frac{(E - C - v)}{\theta_O} = k^*$$

An individual who has less than $k^*$ social links with members of opposite ethnicity would prefer a conflict over peace. This holds true even if the individual has no business link with a person of the same ethnicity.

Now suppose $k^* < N$, individuals who have more than $k^*$ social links with members of opposite ethnicity will prefer peace over conflict. Suppose that $\beta > \beta^*$, in the unconstrained economy with no social links conflict occurs in equilibrium as stated in Proposition 3. Now suppose that there are social links. Individual strategy is to invest in a business link of the same ethnicity whenever possible and to invest in a business link of the opposite ethnicity only if $\alpha > \alpha^*$. An individual would prefer peace over conflict if the number of social links with the opposite ethnicity is greater than $k^*$. $\alpha^*$ is determined from

$$\mu(\alpha^*) = \frac{e}{F}$$

where $\mu(\alpha)$ is the probability of no conflict and is calculated so that there are at least $N/2$ individuals in both the groups who have at least $k^*$ social links of the opposite ethnicity.

This leads us to the point that even when $\beta > \beta^*$, conflict does not always happen in equilibrium. ■

An implicit assumption underlies the above Proposition. I assume that the expected utility that an individual derives from a social link of opposite ethnicity i.e. $\theta_O$ is sufficiently high enough so that $k^* < N$. If $k^* > N$, then individual have a higher expected payoff from a conflict than losing the social links of the opposite ethnicity. Hence social links have no impact on the probability of conflict and we would obtain the same results as in Proposition 3.

This proposition brings us to the point that even if there are "inter" ethnic social interactions
the probability of conflict can be lower as compared to the situation where there are no social interactions.

1.6 Extensions

In this section I present two simple extensions to the model. In the first extension I analyze the situation when endowments differ across the two groups i.e. individuals in group H have a different endowment as compared to individuals in group M. The second extension analyzes when number of individuals differ across the two groups.

1.6.1 Heterogeneous Endowment

Suppose that individuals in group H have a higher endowment than individuals belonging to group M, i.e. $e_H > e_M$. I consider two cases, first where $c > e_M$, i.e. they do not have enough resources even to invest in a single link and second where $e_M > c$.

**Case 1: $e_H > c > e_M$**

In this economy the individuals belonging to group M have so low endowment that they cannot invest even in a single link. Hence individuals in group M cannot form a single business link. Individuals in group M may form business links among themselves. Hence in this economy, irrespective of the values of $\alpha$ and $\beta$, only “intra” links are formed and hence conflict occurs with probability one.

**Case 2: $e_H > e_M > c$**

Suppose $e_H$ is such that, individuals belonging to group H have enough endowment to invest in all possible links. I assume that $e_M$ is such that individuals in group M have enough endowment only to invest in a single link. Now let us compare the economy where all individuals have $e_H$ to another situation where all individuals have $e_M$. Under this situation I obtain the following result

**Proposition 6:** A heterogeneous economy is less prone to conflict as compared to a homogeneous economy with constrained resources but more prone to conflict than the unconstrained economy.

**Proof:**

As before let $\mu_{NN}(\alpha, \beta)$ be the probability of no conflict. The probability of no conflict is calculated so that there are atleast $N/2$ individuals in each group with atleast one link with the opposite ethnicity and atleast $N/2$ individuals in group M who have no link with members of the same ethnicity.
Now I calculate the expected payoff from investing in a business link of the opposite ethnicity

\[ P_I = \mu_{NN}(\alpha, \beta)v + \mu_{AN}(\alpha, \beta)[E - 2C] + \mu_{NN}(\alpha, \beta)[\frac{E}{2} - C] + (e - c) + \mu_{NN}(\alpha, \beta)F \]

Suppose the individual do not invest in the business link and keeps the endowment with himself. The expected payoff is given by,

\[ P_{NI} = \mu_{NN}(\alpha, \beta)v + \mu_{AN}(\alpha, \beta)[E - 2C] + \mu_{NN}(\alpha, \beta)[\frac{E}{2} - C] + e \]

Now

\[ P_I - P_{NI} = \mu_{NN}(\alpha, \beta)F - c \]

In the economy where all individuals have endowment \( e_H \), I obtain the result as in Proposition 2. Lets for simplicity of notation, denote \( \mu_{NN}(\alpha, \beta) \) as \( \mu(\alpha, \beta) \).

An individual would invest in a link of the opposite ethnicity provided that

\[ \mu(\alpha, \beta) \geq \mu^*(\alpha, \beta) = c/F \]

In the homogeneous economy with endowment \( e_M \), \( \mu(\alpha, \beta) \) has higher degree of power in \( (1 - \beta) \) as compared to the heterogenous economy. So \( \mu_{HET}(\alpha, \beta) > \mu_{HOM}(\alpha, \beta) \). Now plugging \( \alpha = 1 \), and equating \( \mu(1, \beta) = c/F \), I obtain that \( \beta^*_{HET} > \beta^*_{HOM} \). Now from Proposition 3 that \( \forall \beta \geq \beta^* \), the probability of conflict is one. Hence I obtain that the heterogenous economy is less conflict prone.

Moreover \( \forall \beta < \beta^*_{HOM} \), using similar logic it can be shown that \( \alpha^*_{HET} < \alpha^*_{HOM} \)

Now once again referring back to back to the example in Section 4, suppose that individuals in group \( H \) have enough resources to invest in all the three possible links while the individuals in group \( M \) have resources so that they can invest only in a single link.

The probability of no conflict, i.e. \( \mu_{NN}(\alpha, \beta) \) given by

\[ (1 - \beta)[2\alpha^2 - \alpha^4] \]

To calculate the probability of no conflict I need that in addition to all the events under which conflict does not take place, the “intra” links in group \( M \) are not formed. Now the following
inequality holds
\[ 2(2\alpha^2 - \alpha^4) - (1 - \beta)(2\alpha^2 - \alpha^4) \geq (1 - \beta)^2(2\alpha^2 - \alpha^4) \]

Hence a heterogenous economy is more conflict prone than a homogeneous economy with abundant resources but less conflict prone than a homogeneous economy with scarce resources. This result once again reinforces that absolute poverty plays an important role in precipitating conflict.

1.6.2 Heterogenous Group Size

Suppose that there are \( N_H \) individuals in group \( H \) and \( N_M \) individuals in group \( M \). Hence the total population in the economy is given by \( N = N_H + N_M \). I assume that both \( N_H \) and \( N_M \) are even. Suppose with out loss of generality, \( N_H > N_M \) i.e. group \( H \) is a majority.

Suppose when a conflict occurs then the probability of winning in the conflict is given by the function

\[ p(n_H, n_M) \]

where \( n_H \) and \( n_M \) are the number of individuals participating from group \( H \) and group \( M \) respectively. We assume that \( p_1 > 0 \) and \( p_2 > 0 \), i.e. the probability of winning the conflict increases as the number of people participating in the conflict increases. The assumption that both groups have an equal chance of winning in the conflict would no longer be meaningful in this context.

All other specifications remain unchanged as was stated previously. Given that Hindus form a majority in the economy, the individuals in group \( H \) would have higher “intra” linkages and lower “inter” linkages as compared to the individuals in group \( M \) in probabilistic terms. Individuals in group \( H \) would have less expected number of active links with members of the opposite ethnicity and given that the probability of winning is increasing in the number of people participating, hence more individuals would be willing to participate and hence ex-ante the expected payoff from conflict would be higher. Thus group \( H \) would be more prone to form the alliance and hence the majority group will be responsible for the conflict.

This is in line with the empirical research by Mitra and Ray (2010), where they point out that the Hindus who are the majority group is mainly responsible for the Hindu-Muslim violence in post independence India. Varshney’s study chose similarity in demographic proportions as the minimum control in each pair of cities that he studies. Both in India’s popular political discourse and in theories about Muslim political behavior, the size of the community is considered to be highly significant. However Varshney pointed out that similarity in demographic proportions coexists with variance in outcomes—peace or violence. To capture this the model has same population size for both the groups.
1.7 Empirical Analysis

The empirical analysis that follows provides a strong support to the main result of the paper that as the degree of “inter” linkages between two ethnic groups in a place increases, the probability of occurrence of an ethnic conflict decreases. This is not a systematic attempt to test all the results in the theory but to show that the reason behind the occurrence or absence of ethnic conflict as laid out in the paper has an empirical validity.

1.7.1 Data and Descriptive Statistics

Systematic statistical information on outbreaks of conflicts along with data on inter or intra linkages among individuals of a place is relatively hard to come by. Even when there are data sets available on conflicts or warfare, it is very difficult to find data on the linkages among individuals in those same places. To the best of my knowledge, the Rural and Economic Development Survey\(^9\) (REDS), 2006 has data on conflict as well as information from which I calculate a close approximation of the nature of linkages among individuals.

This survey was conducted primarily in 2006. The survey was conducted at three levels - head of all the households in the village, in-depth survey of selected households in the village and the last at the village level. I primarily use the part where all the head of the households were interviewed. In this part of the survey all households in each of the villages were interviewed. The data covers 115430 households across 241 villages in 17 major states in India. For every household interviewed, it reports the name of the village, tehsil, block, district and the state to which this household belongs to. Then it reports the age, sex, religion, caste, number of years of schooling and the primary occupation for the head of the household. The survey also provides information on whether the household is a migrant in the village and if yes the year and cause of migration to the village. In addition it also reports whether the household owns any land or not and the value of the land. It also reports the income of the household and by different sources i.e. the amount of income generated from agriculture, livestock, self employment, salary and wages etc.

The head of the households were also asked two other questions. The first question was they had to identify three households within the village to whom they would approach if they had to borrow Rs1000 (approximately $20) to meet a family emergency. The second question was also identifying three households within the village to whom they would go if they had to borrow simple food items such as chillies, spices, vegetables etc. This data is used to proxy for linkages that exist in each of the villages which will be specified in details later.

I use another part of the survey that collects data at the village level. In this part of the

\(^9\)I acknowledge, with gratitude, Andrew Foster’s generosity in letting me to have access to this data.
survey two officials from the local government organizations or panchayats were interviewed. This
has data on whether there has been conflicts in these villages between 1999-2006 year wise and the
nature of the conflict. There are eleven types of conflicts reported and whether they have occurred
in the village in a particular year by conflict type. The variable reports one if a particular type of
conflict had occurred in a given year in the village but does not exactly report the number of times
such a conflict had occurred in the village in a particular year. The types of conflicts reported
are labor, sharing of drinking water, sharing irrigation water, caste, religion, rent collection from
share croppers and tenants, encroachment on public land, inter family disputes, political conflicts,
dacoities and Naxalite(Maoist).

In this paper I focus on Hindu-Muslim conflicts and see how the degree of inbreeding in a village
have an impact on the probability of occurrence of a religious conflict. I study a sample of 49 villages
comprising of 35,145 individuals where there are people residing from both the religions, Hindu
and Muslim. In the original dataset there are six major types of religion reported, Hindu, Muslim,
Christian, Jain, Buddhist and Sikh. To start with there were 78 villages where the population
belongs to only one religion. Now these kind of villages are not useful for the analysis because I
cannot calculate the degree of interlinkage among individuals belonging to different religions. One
out of these 78 villages were populated only by Sikhs and the rest were Hindu villages. Some of
the other villages had population belonging to a particular religion but comprised less than 1% of
the village population. We considered a religion to exist in a village only if a considerable number
of people belonging to that religion resided in that village. To this purpose, I used a selection
criteria that a religion is considered to exist in a village only if there were atleast 20 individuals
belonging to that religion residing in the village in 2006. Applying this selection criteria there
were another 78 villages where the population comprised of a single religion. Hence now there are
a total of 156 villages where the population belongs to a single religion. This implies that there
are 85 villages where the population belongs to more than one religion, in particular there are 75
villages where the population belongs to only two religions and 10 villages where the population
belongs to more than two religions. I dropped all villages with more than two religions because of
lack of instruments to calculate the pattern or degree of integration in a village. Suppose there is
a village with three religions - Hindu, Muslim and Christians. It would be very difficult to make
sense of how the pattern of linkages between the Hindus and Christians can have an impact on
Hindu-Muslim religious violence. To avoid this kind of complicated interpretations I chose villages
where there are only two religions. Hence there are 71 villages which have population belonging to
only two religions and also conflict data. Out of these 71 villages 49 are Hindu-Muslim villages, 10
are Hindu-Sikh, 7 are Hindu-Christian and 5 are Hindu-Buddhist villages.

Now coming to the conflict data there has been a total of 81 religious conflicts reported across
241 villages. Below I provide the number of conflicts that have been reported across 241 villages
by year.
Out of these 81 conflicts, 63 conflicts have occurred in Hindu-Muslim villages. Since most of the conflicts have been concentrated only in Hindu-Muslim villages and they also form 70% of the villages where there is population belonging to only two religions, I primarily concentrate my analysis to only Hindu-Muslim villages. In a later section, I present the analysis involving all the 71 villages which have population belonging to only two religions.

The following summary provides information on 35145 individuals across 49 villages that are primarily considered for the analysis. Among these households, 27000 (76.82%) are Hindus and the rest 8,145 (23.18%) are Muslims. According to the Census of India (2001), $^{10}$ 80.5% of India’s population are Hindus and 13.4% are Muslims. So the sample is a close approximation to the national percentages. Out of these 49 villages, there are 7 villages where the Muslims are a majority and in the rest, the Hindus are a majority. In the sample 31541 (89.78%) individuals are males and the rest 3589 (10.22%) are females. This is not surprising because India is a patriarchal society where the head of the family is generally a male member. The mean age of the head of the household is 47.29 years with a standard deviation of 13.63. The youngest head of the household is 19 years old and the oldest head of the household is 106 years old. The average years of schooling and college is 4.6 with a standard deviation of 4.7. The data also provides information on the number of members in each household. The average number of members in each household is 5.7. With regard to occupation of the household the major occupations are cultivators on their own land (30.3%), agricultural laborers (15.4%) and laborers (16.9%) other than agriculture. Among other major occupations are merchants and shopkeepers (3.6%), housewives (2.5%), clerks (2.2%) and teachers or professors in schools, colleges and universities (1.2%). Regarding the occupational patterns by religion, there is no particular occupation which is dominated by a single religion. Considering the cultivators, 31.5% of the Hindus are involved in cultivating their own land while 26.6% of the Muslims do the same. With respect to agricultural laborers, 14.8% Hindus are involved in this occupation while 17.79% of the Muslims are involved. 15.9% Hindus are laborers while 20.22% Muslims are in the same occupation. Now analyzing the migration data of households, there are only 1510 (4.3%) out of 35145 who have migrated to these villages. The primary reason for migration is due to employment. Out of the total migrants, 87.6% have migrated in search of employment, 6.9% have migrated due to marriage and a meagre 3.45% have migrated to escape from war and conflicts.

\[\text{http://censusindia.gov.in/Census_And_You/religion.aspx}\]
1.7.2 Specification

The primary goal in this analysis is to show that villages that are segregated across religion are more prone to religious conflict. In this regard I have chosen 49 Hindu-Muslim villages in India and try to find a relationship between the probability of occurrence of a religious conflict and the extent of inbreeding within religious groups. There is a huge existing literature in social networks which studies a fundamental and pervasive phenomenon of such networks which is known as “homophily”. This term refers to a tendency of various types of individuals to associate with others who are similar to themselves with respect to certain characteristics like age, race, gender, religion or profession. I will begin my analysis studying the patterns of homophily in the data. To do this I use the information from the two questions that were asked to the head of the households regarding to whom they would approach in times of family emergency and the other one to borrow food items. Now from the question that was asked to identify households to whom they would approach if they need Rs1000 in case of a family emergency I can find that whether an individual approaches more often to an individual of his same religion or to an individual of another religion. There is always a problem in this kind of data where the nature of friendship may be directed. In other words an individual $i$ may name individual $j$ to whom he can approach for help but $j$ may not necessarily name $i$ to whom he would approach in case of an emergency. So the nature of linkage here is directional as opposed to undirected links in my theoretical model. This however does not pose any serious problem to the empirical analysis that is carried out in the paper.

Now I calculate inbreeding homophily by each religion in each of the villages. In networks literature there are various ways to measure homophily. Here I use the inbreeding homophily measure due to Coleman (1958). The inbreeding homophily of type $i$ is given by

\[ H_i - w_i \]

\[ \frac{1}{1 - w_i} \]

where $H_i$ denotes the average number of friendships that agents of type $i$ have with other agents who are of the same type and $w_i$ is the relative fraction of type $i$ in the population. Generally, there is a difficulty in simply measuring homophily according to $H_i$. For example, consider a group that comprises 95 percent of a population. Suppose that its same type friendships are 96 percent of its friendships. Compare this to a group that comprises 5 percent of a population and has 96 percent of its friendships being same-type. Although both have the same homophily index, they are very different in terms of how homophilous they are relative to how homophilous they could be. Comparing the homophily index, $H_i$, to the baseline, $w_i$, provides some information, but even that does not fully capture the idea of how biased a group is compared to how biased it could potentially be. In order to take care of this I use the measure developed by Coleman (1958) that normalizes the homophily index by the potential extent to which a group could be biased. This index measure the amount of bias with respect to baseline homophily as it relates to the maximum possible bias.
Now before proceeding further two examples are provided from two villages for which I calculate the inbreeding homophily index. Now the table below gives the pattern of friendship or linkage that exists in this village based on the question asked about borrowing money.

<table>
<thead>
<tr>
<th>Village: Dalasanur, Karnataka</th>
<th>Village: Ravapar, Gujarat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hindu</td>
<td>Muslim</td>
</tr>
<tr>
<td>Hindu</td>
<td>0.83</td>
</tr>
<tr>
<td>Muslim</td>
<td>0.67</td>
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</tbody>
</table>

Consider the village Dalasanur in the state of Karnataka in South India, 83% of the Hindus approach Hindu families for a medical emergency while 67% of the Muslims approach Hindu families for help. So these figures suggest that there is some fair degree of inter religious engagement in this village. As compared to this village, now consider the village of Ravapar in the state of Gujarat in the western part of India where 91% of the Hindu families approach families within their own religion while 81% of the Muslims approach families within their own religion. This suggests that there is fairly a large degree of segregation in this village with respect to religion. Now Dalasanur have 219 Hindus and 47 Muslims while in Ravapar there are 298 Hindus and 138 Muslims. Taking into account of the fraction of the population by religion the inbreeding homophily measure for Hindus is 0.57 and 0.44 for Muslims in Dalasanur while it is 0.71 for Hindus and 0.72 for Muslims in Ravapar. So this indeed tells us that even after normalizing for the population, inbreeding is higher in Ravapar as compared to Dalasanur.

I adopt the same approach and calculate inbreeding homophily measure for the other question where households were asked to identify households to whom they would approach to borrow simple food items. In the rest of the paper I will refer the borrowing money question as question A and the borrowing simple food items question as question B. Now in the data households necessarily do not name the same households in question A and question B.

Before I proceed further, there is now a need to create a single measure for each village which would reflect the degree of inbreeding in a particular village. This would give us the degree of segregation in the village by religion. Suppose that $IH_H$ is the inbreeding homophily measure for the Hindus in a particular village and $IH_M$ is the inbreeding measure for Muslims. Let $w_H$ be the fraction of Hindus in that village and let $w_M$ be the fraction of Muslims in the village. Then the inbreeding index for the village is calculated as following

$$w_HIH_H + w_MIH_M$$

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11 Refer to Currarini, Jakson and Pin (2009) for more details on measures of homophily

12 Refer to Golub and Jackson (2012) for more details
Now I create four indices based on the same approach. The first index (index1) is based only on the first household that is reported in question A. Then the second index (index2) is created by taking into consideration of all the households in question A. Since households were asked to name the households they would go to in order of approachability, index1 gives a measure with respect to the best relationship that the household has whereas index2 does not take into consideration of the approachability. A concern at this point may be that individuals in a village may approach a money lender or a very influential person generally for help. This may lead to a bias in the index depending upon the religion of the moneylender. Though it is unlikely that an individual would go to a moneylender in a village in case of an emergency and when the amount required is not very large I still did some checks in the data set so that the indices do not have a bias. The data reveals that there were only 9 out of 35145 individuals who were money lenders or pawn brokers or both by profession. None of these moneylenders had a very significant portion of the village population approaching them for help. Moreover I find that there are only seven individuals in the sample to whom more than 5% of the village population goes to borrow money and the highest being 13.32% of the village population going to an individual. Now neither of these seven individuals are moneylenders or pawn brokers. This shows that there are no chances of index1 and index2 being biased. There is also a third index (index3) which is based on the first household reported in question B while the fourth index (index4) takes into account of all the friends in question B.

So the primary independent variable in my analysis are these indices. The dependent variable in the analysis is that whether conflicts occurred in 2006 or not. The data though has information on conflicts from 1999 to 2006 but since the household level information was collected only for 2006, I restrict my analysis to consider conflicts in 2006 as the dependent variable. Hence the dependent variable takes a value 1 if there was a conflict in 2006 else takes value 0.

Now I perform a probit analysis. In this paper, the analysis is done separately for all the four indices taking each index at a time. The probit model is given by

$$\Pr(Y = 1|X) = \Phi(X'\beta)$$

where Pr denotes probability, and \(\Phi\) is the Cumulative Distribution Function (CDF) of the standard normal distribution.

There are some basic controls that are introduced using the data. In some specifications, I also use an expanded set of controls, more on these below. The dependent variable is \(c06\) which takes a value 1 if there was a conflict in the village and a value 0 if there was no conflict. A quick glossary for all independent variables is included here: \(villagepop\): gives the total population of the village. This is calculated by adding all the members in each of the households. The next is \(avgschool\): means years of schooling in the village which is a proxy for the literacy rate. Another
important control that is introduced is \textit{percapincome}: the per capita income of the village and the other control is \textit{muslimfrac}: fraction of Muslim population in each village. The per capita income is calculated by dividing the total income of the village by the village population. The fraction of Muslim population in each village is obtained by dividing the number of Muslims by the total population in the village.

1.7.3 Basic Results

Regression Table 1 contains the results with index 2 as the primary independent variable. In the first column there are no controls. In the next column there is a control, the fraction of Muslim population. The third column controls in addition for average schooling. The fourth column further includes per capita income of the village and the last controls in addition for village population.

<table>
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<td>(2.143)</td>
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Table 1.1: Regression Table 1

Index 2 have a positive impact on the probability of occurrence of a conflict. Now introducing the various controls the impact gets stronger and more significant statistically. The coefficient of index 2 is positive which implies that greater is the segregation in a village, higher are the chances of a religious conflict occurring there. The fraction of Muslim presence tend to have a positive
impact on the occurrence of a conflict. The higher is the average years of schooling and higher is per capita income the lower are the chances of a conflict. However the coefficient on the per capita income almost tend to zero. The population of the village seems to have a positive impact but here also the coefficient tends to be very small.

Now subsequently I do the same analysis with the primary independent variable as index1, index3 and index4 separately. The controls remain the same as in the first regression and they appear in the same order as in the previous analysis. The regression results are in the appendix. In Regression Table A1, similar kind of results hold as in Regression Table 1. Now considering question B, index 3 and 4 are calculated. Regression Tables A2 and A3 present the results when the main independent variable is index 3 and index 4 respectively. Both the tables are presented in the appendix. The results do not change qualitatively when I measure the indices based on question B. There is a positive impact of inbreeding on the probability of occurrence of conflicts. The higher is the inbreeding in a village, the greater are the chances of a conflict.

1.7.4 Robustness

The basic results are robust to the different variations I have tried; a brief description is given below

Alternate ways of measuring controls: In this section I introduce similar controls but calculate them in a slightly different manner. Instead of average years of schooling, I now introduce a new measure for literacy. I consider a person to be literate if the individual has atleast one year of schooling.\textsuperscript{13} This measure is based on the data for the head of the household and we assume that this reflects the literacy rate of the village. We name this control as \textit{litrate}. Now instead of the population of the village I now consider the total number of households. This is named as \textit{totalhhd}. Given the total number of households it is easy to calculate the fraction of Muslim households, \textit{mfrac} and per household income which is labeled as \textit{perhhdincome}. Some of the regression results are presented in the Appendix in Regression Table A4 with the new set of controls. The qualitative results do not change and the analysis still consistently support that higher inbreeding leads to a higher probability of occurrence of conflict.

Previous Conflict: So far the analysis does not include any control for previous conflicts, i.e. whether there was a conflict in the previous year. Some regions do exhibit violence more persistently over time than others, and besides, there is truth to the aphorism that “violence begets violence”. There is also a positive correlation between conflict occurring in period $t$ and period $t - 1$ observed

\textsuperscript{13}In India, according to the census the definition of literacy had been both ability to read and write in any language. I assume that a person with one year of schooling has the ability to read and write in some language. For details see http://censusindia.gov.in/Data_Products/Library/Indian_perceptive_link/Census_Terms_link/censustermst.html
in the data. So I introduce the control prevconflict which basically captures that whether the village reported a conflict in the previous year i.e. 2005. The table below gives some of the results with the new control. The results show that previous conflict can have a positive impact on the probability of occurrence of conflict in 2006. However the coefficient on the indices are positive and statistically significant.

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Standard errors in parentheses
+ p<0.10, * p<0.05, ** p<0.01, *** p<0.001

Table 1.2: Regression Table 2

**Income Inequality:** A general concern that is often found in the economic literature is that income inequality across two groups can have an impact on the occurrence of conflicts. The general notion is that greater is the income inequality between two groups the greater are the chances of the two groups entering into a conflict. To test this notion I introduce a variable *incomediff* which captures the extent of income difference between the two groups. This is calculated by taking the square of (x-y) where x is the per capita income of Hindus and y is the per capita income of Muslims in the village respectively. Some of the regression results are presented in the table below. The results clearly show in Regression Table 3 that there is no impact of income differences on the probability of occurrence of conflict in a village.

**Hindu-Muslim balance:** The analysis already has tested for a direct linear relationship between the Muslim percentage of the population in a place and the probability of occurrence of conflict.
Sometimes it is often cited in the literature that there is a curvilinear relationship between the Muslim population percentage in a place and the occurrence of riots, with riots becoming more frequent the closer the Hindu-Muslim percentages are to 50-50. To test for this relationship I define a new control \textit{muslimctcurve}, the Muslim percentage defined as the square of \((50\%-x\%)\) where \(x\) is the Muslim percentage of the village. This measure is drawn from Wilkinson (2004). Now as he shows that as \textit{muslimctcurve} goes down, the level of riots goes up. According to him, if we assume relatively cohesive Muslim and Hindu voting patterns, the incentives to polarize will increase as the relative sizes of the community approach parity and it becomes more important to win over the small group of swing voters. The results that I obtain are close to Wilkinson but in the sixth column the coefficient changes sign when we introduce controls like \textit{percapincome} and \textit{villagepop} with index 4. Therefore it is difficult to conclude anything from the regression results. The results are presented in Appendix in Regression Table A5.

\[\begin{array}{ccccccc}
\text{\textit{index2}} & 2.721^{*} & 2.749^{*} & 2.076 & 1.922 \\
& (1.437) & (1.452) & (1.650) & (1.673) \\
\text{\textit{muslimfrac}} & 2.069 & 2.014 & 2.026 & 2.066 & 2.142 & 2.126 \\
& (1.507) & (1.523) & (2.471) & (2.507) & (1.480) & (1.485) \\
\text{\textit{avgschool}} & -0.444 & -0.441 & -0.319 & -0.325 & -0.371 & -0.361 \\
& (0.343) & (0.363) & (0.413) & (0.419) & (0.323) & (0.329) \\
\text{\textit{villagepop}} & -0.00000908 & -0.00000518 & -0.00000747 & -0.00000173 & -0.00000149 \\
& (0.0000105) & (0.0000115) & (0.0000133) & (0.0000100) & (0.0000102) \\
\text{\textit{incomediff}} & 4.92e-09 & 4.92e-09 & 4.92e-09 & 4.92e-09 \\
& (6.59e-08) & (6.59e-08) & (6.59e-08) & (6.59e-08) \\
\text{\textit{percapincome}} & -0.000496 & -0.000599 \\
& (0.000453) & (0.000677) \\
\text{\textit{prevconflict}} & 0.629 & 0.629 & 0.629 \\
& (0.942) & (0.942) & (0.942) \\
\text{\textit{index4}} & 2.269^{*} & 2.281^{*} \\
& (1.274) & (1.286) \\
\text{\textit{cons}} & -1.884 & -1.808 & 0.173 & 0.686 & -1.876 & -1.903 \\
& (1.475) & (1.742) & (2.721) & (2.914) & (1.605) & (1.627) \\
\hline
\text{N} & 45 & 45 & 45 & 45 & 45 & 45
\end{array}\]

Table 1.3: Regression Table 3

\[\begin{align*}
&\text{Standard errors in parentheses} \\
&* p<0.10, \; \ast p<0.05, \; \ast\ast p<0.01, \; \ast\ast\ast p<0.001
\end{align*}\]

Sometimes it is often cited in the literature\(^{14}\) that there is a curvilinear relationship between the Muslim population percentage in a place and the occurrence of riots, with riots becoming more frequent the closer the Hindu-Muslim percentages are to 50-50. To test for this relationship I define a new control \textit{muslimctcurve}, the Muslim percentage defined as the square of \((50\%-x\%)\) where \(x\) is the Muslim percentage of the village. This measure is drawn from Wilkinson (2004). Now as he shows that as \textit{muslimctcurve} goes down, the level of riots goes up. According to him, if we assume relatively cohesive Muslim and Hindu voting patterns, the incentives to polarize will increase as the relative sizes of the community approach parity and it becomes more important to win over the small group of swing voters. The results that I obtain are close to Wilkinson but in the sixth column the coefficient changes sign when we introduce controls like \textit{percapincome} and \textit{villagepop} with index 4. Therefore it is difficult to conclude anything from the regression results. The results are presented in Appendix in Regression Table A5.

\textit{All Villages}: Now at this point it may be interesting to check whether the results hold if I introduce all the 71 villages where there is population belonging to two religions but they are not necessarily Hindu-Muslim villages. There are 22 non Hindu-Muslim villages. Now as has been pointed out earlier that there have been very few incidents of conflict in non Hindu-Muslim

villages. Moreover in the year 2006 there was no conflict in a non Hindu-Muslim village. So it would be very difficult to get any meaningful result on whether inbreeding has an impact on the probability of occurrence of conflict. So the presence of these additional 22 villages may create a bias in the results. In order to avoid this I break each index into two parts, hmindex2 is index2 if it is a Hindu-Muslim village and nhmindex2 is index2 if it is a non Hindu-Muslim village. I obtain that nhmindex2 has a negative sign whereas hmindex2 has a positive sign. The coefficients of nhmindex2 may not be very informative because there has been no conflict reported in any of the non Hindu-Muslim villages. Some of the regression results are provided in Regression Table A6 in the Appendix.

1.7.5 Reverse Causality

In this section, I discuss about a concern in the empirical analysis and describe a method to alleviate it. There is a potential issue of reverse causation or an endogeneity problem. The kind of inbreeding that is observed in these villages in 2006 may be due to the conflicts that have taken place before. Previous conflicts may have played a role in determining the pattern of inter or intra linkages that are observed in 2006. The ideal situation would have been if there was data available for measuring inbreeding for all the years from 1999-2006 and observe how this has changed over time. Since the survey data reports that whether households have migrated to the villages, I use the migration data to address this issue. I create two separate groups, migrants who have migrated during this period from 1999-2006 and the non-migrants. If conflicts lead to changes in relationships that households keep, then migrants and non-migrants can have very different patterns of relationships. The migrants potentially had not been affected by the conflicts and they can have a different pattern of relationship as compared to the non-migrants who have suffered the conflict. However we find that the pattern of friendships or relationship does not change significantly across the two groups. From this I can conclude that most likely conflicts do not have a significant effect on the pattern of linkages, rather the linkages that are there have an impact on the probability of occurrence of conflicts.

1.8 Conclusion

This paper explains how different degrees of inter and intra engagement can help in explaining the occurrence of ethnic conflict in some places and absence of it in others. What matters for an ethnic violence is whether the associational ties cut across ethnic lines. This paper shows that more are the ties across ethnic group members the lower are the chances of a conflict in equilibrium. Trust based on interethnic ties are very important in building bridges across two groups and maintaining

15Another way could have been finding an instrumental variable (IV) which can affect the linkages but does not affect conflict. This kind of IV is very difficult to come by.
peace. The theoretical results in the paper are neither specific to any country nor restricted to explain only religious violences. The empirical analysis reassures us that this approach towards explaining ethnic conflicts has its own validity.

The occurrence of a conflict largely would depend upon the ethnic ties locally or in region. Though networks of communities can be built nationally, internationally or even through the electronic channel, the fact remains that most people experience civic or community life locally. Business associations or trade unions may well be confederated across local units and business or labor leaders may also have national arenas of operation, but most of the time most businessmen and workers who are members of such organizations experience associational life locally. The nature of the local networks- “inter” connected or “intra” connected plays an important role in explaining the observable patterns of ethnic violence and peace. The empirical analysis in Section 7 moreover provides support to this claim. The homophily measures are calculated based on the relationships that individuals have within their village. A higher degree of inbreeding in a village leads to an increase in the probability of occurrence of a conflict.

Moreover in the theoretical setting, I show that the levels of wealth in an economy can have a role to play in maintaining peace in certain regions. With the same kind of heterogeneity in ethnicity among the population and similar kind of interconnectedness, less developing regions may more often get into a conflict as compared to the more developed ones.

This paper proposes that interethnic ties should be encouraged which can act as a mechanism of peace. Interethnic ties even in the form of social links can also help in lowering the probability of conflict. The paper provides a foundation for further theoretical and empirical investigation into the role of inter-ethnic and intra-ethnic links in countries that have experienced conflict in some areas while others have remained peaceful.
Appendix A

Table 1.4: Regression Table A1

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Standard errors in parentheses
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Table 1.4: Regression Table A1
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Standard errors in parentheses
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Standard errors in parentheses
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Table 1.8: Regression Table A5
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*Standard errors in parentheses
* p<0.1, ** p<0.05, *** p<0.01
Bibliography


Chapter 2

Informal Insurance and Group Size under Individual Liability Loans

Abstract

There has been a recent shift from joint liability to group loans with individual liability by the Grameen Bank and some other prominent micro lending institutions across the world. Under the joint liability lending mechanism a group of individuals were given a loan and individuals in a group were jointly liable for the loan given. Under the new lending regime a group of individuals are given their individual shares of a group loan. Although they have to be in a group in order to have access to the loan, individuals are not liable for the loan of other members in the group. An individual is only liable for her share of the loan. Some recent field experiments observed no change in repayment rates with this regime change. This paper investigates the role of informal insurance among group members to explain the success of group lending with individual liability. In our model members of a group face idiosyncratic shocks and realization of output is private information. They can insure each other through informal arrangements in repeated interactions. This paper focuses on a repeated game analysis of both joint and individual liability group lending. We show that with informal insurance individual liability lending can lead to repayment rates as same as joint liability. However individuals welfare is strictly lower under individual liability lending. This paper also sheds light on the optimal group size that villagers should maintain under the new lending mechanism.

2.1 Introduction

It has been well established in economic literature that access to credit can empower the poor. Formal financial intermediaries, such as commercial banks, usually refuse to serve poor households because of the high cost of small transactions and lack of traditional collateral. As a consequence, an
enormous pool of potential abilities and talents remain untapped by the society. Providing access to credit to the poor households helps not only to improve their economic condition, but also provides a way to maintain or improve their quality of life. This also encourages self-development of the poor households by helping them to integrate with the broader economic life. The economy benefits from a better utilization of human resources which in turn translates into an overall development.

The Grameen Bank is the world’s best known lender to the poor and reaches more poor people than most of the other micro-lending organizations. It reaches to more than 8.35 million borrowers with the total amount of loan disbursement being Tk 684.13 billion (US $ 11.35 billion) since inception.\footnote{http://www.grameen-info.org} The Nobel Peace Prize 2006 was awarded jointly to Muhammad Yunus (founder of the Grameen Bank) and Grameen Bank “for their efforts to create economic and social development from below”. The unique feature of this bank had been the joint liability loans and similar banking models were subsequently adopted by hundreds of organizations around the world.

Under joint liability, a group of five borrowers were given individual loans, but held jointly liable for repayment. If any member defaulted, future loans to all the group members would be denied or delayed. The economic literature has focussed on this aspect of joint liability as the major factor behind the success of the Grameen Bank. It was believed that joint liability would encourage mutual insurance among group members and generate social pressure on borrowers to repay loans creating a sustainable model of lending.

In recent years, there has been a shift from joint liability to individual liability loans undertaken by some prominent micro lending institutions including the Grameen Bank. Providing useful insights regarding this regime shift, Giné and Karlan (2011) points out some of the drawbacks of group liability lending. First, borrowers disliked the tension caused by group liability as one had to face punishment even when one was not at default. This could also harm social capital among group members by giving rise to free riding problems. Second, clients may decide not to repay their loans believing that other clients will pay it for them while the bank is indifferent because it still gets its money back. Third, group liability is more costly for clients with less risky projects because they are often required to pay back the loans of other group members with riskier projects.

Due to the growing dissatisfaction with joint liability lending among its members, the Grameen Bank in 2002, replaced their model of group lending with Grameen II, which no longer involves joint liability. According to Dr. Yunus,

“Grameen Bank II has emerged. The transition is now complete. The last branch of Grameen Bank switched over to Grameen II on August 7, 2002, completing the process of transition. The new Grameen Bank II is now a real and functioning institution. This
second-generation microcredit institution appears to be much better equipped than it was in its earlier version.”

Following the introduction of the new system, the total number of borrowers increased from 3 to 8 million. At present, all members are individually liable for their loans. Under the new system, access to future credit by an individual borrower is not conditional on the performance of others in the group.

Much of the previous literature has focussed on the fact that under joint liability successful group members might help unsuccessful group members repay, hence risk is shared within the group. The theoretical models inspired by Grameen I suggest that joint liability clauses are key to efficient lending. Giné and Karlan (2011) conducted a field experiment with the Green Bank in Philippines, in which they compared randomly selected branches with joint liability to those without and found no significant change in repayment rates. Their experiment suggests that joint liability may not be the key feature of successful microlending.

The natural question that arises at this point is, what leads to the smooth functioning of a micro lending system with individual liability loans? Before moving on to the answer to this question, we must shed light on the institutional features of Grameen II. The new system abandoned one of the most celebrated features of the old format of Grameen lending, “joint liability”. It also introduced a much more flexible punishment scheme as opposed to Grameen I which unleashed stricter punishments for defaulters. According to Yunus,

”There is no reason for a credit institution dedicated to provide financial services to the poor to get uptight because a borrower could not pay back the entire amount of a loan .... Many things can go wrong for a poor person during the loan period..... Since she is paying additional interest for the extra time, where is the problem?”

Despite the shift from “joint liability” to “individual liability” it is still mandatory for individuals to be in a group in order to obtain a loan from the bank. As before individuals should have their groups formally recognized by Grameen staff. There is a clear distinction between “group liability” and “group lending”. As Giné and Karlan (2011) pointed out, “group liability” refers to the terms of the actual contract, whereby individuals are both borrowers and simultaneously guarantors of other clients’ loans. “Group lending” means there is some group aspect to the process or program, perhaps only logistical, like the sharing of a common meeting time and place to make payments.

Another important feature of Grameen I that has been retained by Grameen II is public repayment meetings. Repayments are made in public meetings where all the borrowers are present.

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2http://www.grameen-info.org
These meetings allow the borrowers to learn about each other which helps in alleviating frictions. As observed by Armendariz and Morduch (2005), when repayments are made in public, “the villagers know who among them is moving forward and who may be running into difficulties”.

The shift to individual liability was not merely done by the Grameen Bank and a few other large, well-known lenders, but many lenders around the world are adopting individual liability. This paper is an attempt to explain the smooth functioning of the micro lending system with individual liability under a theoretical framework. We argue that there are still possibilities of informal insurance and risk sharing under individual liability through a different mechanism. The heart of this paper lies in explaining that though liability is individualized, borrowers can informally insure each other in “groups” leading to repayment rates similar to those as under joint liability. Our paper provides a stepping stone in explaining why the shift from group liability to individual liability loans does not lead to a change in repayment rates as observed by Giné and Karlan. In the process, this paper also suggests that benefits of informal insurance are best reaped when individuals are in an optimal “group” size. The bank can increase social welfare by stipulating a “group” size its clients should maintain to obtain a loan.

In this paper agents are connected through a social network. They borrow from a micro-credit organization under individual liability. Though individuals are not jointly responsible for a loan or default, they still enter into informal arrangements with their neighbors in the social network to avoid the cost of default. The public repayment here plays an important role as observed by Armendariz and Morduch (2005).

In our model we have $N$ risk-neutral villagers who interact in a social network. A bilateral link is given: it comes from two individuals getting to know each other for reasons exogenous to the model. Such links may be destroyed, but no new links can be formed. Each villager can invest in a project that can be a success with probability $p$ or a failure with probability $1 - p$. Villagers can obtain a loan from a microcredit organization to fund this project. Each borrower must pay back the loan along with the interest charged by the bank. A borrower who defaults is punished by the bank and this non-pecuniary cost of punishment is increasing in the amount of default. Our analysis focuses on continuous cost functions that are convex and this assumption is motivated by the fact that Grameen II has switched to a more flexible punishment scheme than Grameen I.

Since default is costly, individuals can enter into informal arrangements with people whom they have direct links with. They cannot get into arrangements with individuals with whom they do not have direct links. A contract of value $x$ specifies the amount the successful individual transfers to her unsuccessful counterpart. The links are undirected in nature. When both are successful or unsuccessful, no transfers are made. At every period $t$, individuals observe their own output levels, but they do not observe others’ output levels. Unsuccessful individuals approach their neighbors with whom they have an arrangement in order to repay their loans. Individuals with positive
probability learn about their neighbors’ outcomes at the public meeting. Once individuals learn about their neighbors’ outcomes, they decide on whether to sever links with the neighbors who did not keep their promises.

In this paper we consider regular networks where each individual has \( n \) direct links and each link is characterized by a promise value \( x \). The analysis focuses on the role of network size on welfare for different cost functions. We show that when punishment equals the amount of default, welfare does not depend on the number of links an individual has. However individuals gain from links whenever cost of default is larger than the amount of default. We show for convex costs, individuals’ expected utility under risk sharing is non decreasing in the number of neighbors. With a small cost of maintaining each link, there exists an optimal network size for which individual’s gains from informal insurance are maximized. Though this result holds true for any general regular network, it has an important policy implication in the context of group loans with individual liability. The bank can stipulate village specific group sizes that individuals need to maintain in order to get a loan.

**Literature:** Much of the earlier literature discusses several institutional features of joint liability which has been summarized by Ghatak and Guinnane (1999). The literature on individual liability lending is still at a nascent stage. In this paper we provide a theoretical framework that emphasizes on the role of informal insurance under a social network in the context of individual liability loans. Our analysis largely relies on the assumption that individuals face internal frictions and cannot enter into arrangements that maximize joint utility.

The work of Townsend (1994) and Udry (1994) stimulated interest in the internal contractual arrangements of poor villagers which can potentially insure them against idiosyncratic shocks. They look at how good or how bad these informal risk sharing institutions are for the villages in southern India. They point out that the informal arrangements are imperfect, because they typically suffer from various kinds of informational and enforcement problems.

However, enforcement problems may be less severe in informal arrangements which are enforced by social sanctions i.e. which rely on social capital instead of traditional collateral. Besley and Coate (1995) discuss the role of social capital in the context of Grameen I. They provide a game-theoretic analysis of repayment decisions under group lending. The two incentive effects they emphasized on are: first, there is always a possibility that a successful borrower may repay the loan of a partner who obtains a bad return on her project. Second, group lending may be able to harness social collateral. Under an individual lending contract, all that the borrower has to fear, if she defaults, are the penalties that the bank can impose on her. Under group lending, she may also incur the wrath of other group members. Our paper retains both these features in the context of individual liability loans with the help of a social network. A successful individual may still be interested in helping her unsuccessful neighbor with the expectation that her neighbor will
help her in bad times. Links are valuable to an individual because they can insure them against idiosyncratic shocks.

Rai and Sjöström (2004) design a lending mechanism that efficiently induces mutual insurance under joint liability lending. The role of bilateral insurance schemes across networks of individuals has been studied by Bloch et al. (2008). They investigate the structure of a self enforcing insurance network where transfers are based on social norms and are publicly observable. Our paper preserves their feature of bilateral insurance schemes across networks of individuals, however in a different context. Our paper also assumes away the observability of transfers across individuals.

Rai and Sjöström (2010), with whom we share some basic modeling similarities, show that in a Coasean world without frictions the village functions as a “composite agent” who minimize the joint expected cost of default. In such a world, the design of the lending contract is rather unimportant and joint liability loans are no better than individual liability loans. However the cost structure they assume is discrete. Punishment is constant for any positive default amount. This cost structure resembles the cost structure of Grameen I which has been too rigid in enforcing repayments. This strict adherence of rigid rules is not desirable, particularly if the credit institution is dedicated to provide financial services to the poor. Many things can go wrong and if these poor people are forced to default they may not find their way back to the credit market. Grameen II allows for more flexible repayments which are structured more in line with the borrower’s cash-flows. Our model differs from Rai and Sjöström (2010) by assuming punishment cost to be a continuous and increasing function of default. This indeed is a better reflection of the highly flexible punishment scheme that has been adopted by Grameen II. Also in contrast to their two agent framework we introduce a general $N$ agent model.

Findings of our paper are strongly supported by two recent field experiments. Giné and Karlan (2009) in their field experiment with Green Bank, a Grameen replica in the Philippines, compares randomly selected branches with joint liability to those without and find no change in repayment rates. They also find that those with weaker social networks prior to the conversion are more likely to experience default problems after conversion to individual liability, relative to those who remain under group liability. This phenomenon is captured in one of our results that shows too few neighbors is not welfare maximizing. A neighbor in our model acts as an insurance possibility rather than a monitoring devise. In other words, lack of neighbors means lack of insurance.

Feigenberg et al. (2010) provide an experimental evidence on the economic returns to social interaction in the context of microfinance. Their results also provide a rationale for the current trend among MFIs of maintaining repayment in group meetings despite the transition from group to individual liability contracts. They emphasize on the role of frequent social meetings to facilitate cooperative behavior.
In response to Feigenberg et al. (2011), Quidt de et al. (2012) derive conditions under which more frequent meetings, modeled as an increase in the amount of time borrowers and loan officers must spend in loan repayment meetings, increases borrowers’ incentive to invest in social capital. They also show that individual lending with or without groups may be welfare improving as long as borrowers have sufficient social capital to sustain mutual insurance. In their paper each link is characterized by pair-specific social capital which is conceptualized as the net present value of lifetime payoffs in a repeated “social game” played alongside the borrowing relationship. In our paper welfare improvement is driven by pair-specific informal insurance arrangements in regular networks. The value of a link comes from the fact that a link functions as an insurance possibility.

Section 2.2 describes the model and section 2.3 carries out the analysis under regular networks. Section 2.4 argues that individuals would not enter into informal arrangements or make promises to her neighbors that they may not be able to keep. In section 2.5 we discuss the case where individuals can enter into punishment sharing arrangements. Section 2.6 briefly discusses about the moral hazard and adverse selection aspects of the model and Section 2.7 concludes.

2.2 The Model

Suppose there are \(N\) villagers, \(i \in \{1, 2, ..., N\}\). Each villager has an investment opportunity which requires an investment of one dollar. The project can be a “success” or a “failure”. Agent \(i\)'s output is denoted by \(y_i = \{0, h\}\). A successful project yields \(h > 0\) amount of output. In case of a failure an individual gets 0. The project can be successful with probability \(p\) and fail with probability \((1 - p)\). Hence the state of the world is a \(N\)-tuple \((y_1, y_2, ..., y_N) \in Y \equiv \{0, h\}^N\). The random variables \(y_1, y_2, ..., y_N\) are independent. The villagers are risk-neutral. They have no assets, so neither self-financing nor borrowing from commercial banks is possible as banks require collateral.

Now suppose there is a benevolent not-for-profit microcredit organization who unlike commercial banks provides credit without collateral. It is assumed that \(h\) is high enough so that the projects are viable i.e. it is efficient to fund the investment opportunities.

\[
h[Np^N + \left(\frac{N}{N - 1}\right)p^{N-1}(1 - p)(N - 1) + \ldots + \left(\frac{1}{1}\right)p(1 - p)^{N-1}] > N
\]

The bank cannot observe the state of the world. So it cannot observe whether a project succeeds or fails. Each villager needs to repay \((1 + r)\). The interest rate charged by the bank, which is exogenously given, is the opportunity cost borne by the bank.

Default is not costless. A borrower who defaults is punished by the bank. It is often argued that villagers may face hard times because of some exogenous shocks and hence may find it difficult to pay back. However for the lender it can be difficult to verify such shocks. If default is costless,
then the borrower has a strategic incentive to default, claiming that for certain exogenous reasons she failed which may be difficult to verify. To prevent such strategic default we introduce that the bank imposes punishment depending by how much an individual defaulted. This non-pecuniary punishment can be interpreted as loans may be given at a higher interest rate.

Let \( C(d) \) be the punishment an individual faces when the amount of default is \( d \) and \( C'(d) > 0 \). Punishment is increasing in the amount of default with \( C(0) = 0 \). Much of the previous literature assumes that a borrower is punished whenever she defaults irrespective of the default amount. The continuous and increasing cost function is a better reflection of the new punishment scheme introduced in Grameen II which is more flexible as opposed to the stricter punishment scheme in the older system. We analyze the model with both linear and convex cost functions later in Section 2.3.

A villager who invests in a project and takes a loan of one dollar from the bank has an expected return

\[
p[h - (1 + r)] - (1 - p)C(1 + r)
\]

We assume this to be positive so that villagers have an incentive to invest in a project. If \( h \) is high enough this is easy to satisfy and hence incentive compatible for a villager to invest in a project.

Agents interact in a social network. Formally, a network \( g \) consists of the \( N \) villagers as the set of nodes and a graph—a collection of pairs of agents—with the interpretation that the pair \( ij \) belongs to \( g \) if they are directly linked. In this paper, a bilateral link is given: it comes from two individuals getting to know each other for reasons exogenous to the model. While such links may be destroyed (for instance, due to an unkept promise) no new links can be created.

An individual can enter into informal arrangements with people whom they have direct links with. We refer to them as “neighbors” of the individual. An arrangement of value \( x \) specifies the amount a successful individual transfers to her unsuccessful counterpart. When both are successful or unsuccessful, no transfers are made. A contract of value \( x = 0 \) means that the linked individuals have no informal arrangement. Hence each link in this network is characterized by a value \( x \). Since default is costly and project returns are independent, villagers can benefit from mutual insurance. If an individual fails while her neighbors are successful, then the successful neighbors can help the individual repay her loan reducing the cost of default. In short these arrangements can act as informal insurance.
2.2.1 Timing

We consider an infinite horizon framework where agents are infinitely lived. Time is discrete and every period individuals face the same investment opportunity as described earlier. The villagers need to take a loan every period because the amount they save after paying back the interest to the bank can only suffice their sustenance. Given that they are very poor and their savings can only sustain their livelihood, they cannot avoid borrowing from the bank. At every period $t$, there are four stages. At stage 1, individuals observe only their own output levels, but they do not observe others’ output levels. A public meeting is convened by the bank where individuals declare in public whether they have been successful or not. At stage 2, an unsuccessful individual approaches her neighbors with whom she has an agreement, in order to repay her loan. The neighbors respond by keeping or not keeping her promise. An individual will be interested in helping out her neighbor with the expectation that her neighbor will help her in her bad times. At stage 3, individuals repay their loans to the bank official in the public meeting. These meetings are held in each center (kendra) or branch of the bank. We make a simple assumption that the $N$ villagers that we consider belong to the same branch. We rule out the possibility that individuals may have neighbors who belong to other branches of the bank. The public repayment meetings facilitate the borrowers to learn about each other. We assume that an individual’s true outcome is revealed with probability $\beta > 0$. At stage 4, individuals decide on which links to sever.

2.2.2 Constraints, Payoffs and Equilibrium

For an individual $i$ with $k$ links, we assume the following is satisfied

$$\sum_{j=1}^{k} x_{ij} \leq h - (1 + r)$$  \hspace{1cm} (1)

where $x_{ij} = x_{ji}$ is the promise value that characterizes the bilateral link between $i$ and $j$. This implies that when individual $i$ is successful the total amount promised to all her links should not exceed the resource available to her after repayment of her loan. In other words the budget constraint is satisfied. This assumption is relaxed later in Section 2.4 where we argue that individuals do not promise any $x$ that does not satisfy the budget constraint.

We make an additional assumption on the parameters of the model,

$$1 + r \geq \frac{h}{2}$$  \hspace{1cm} (2)

This assumption in the context of two person joint liability implies that a successful individual alone cannot repay the entire amount they jointly owe to the bank. In the context of our model
this is the “no leftover” condition which ensures that even when all neighbors of an unsuccessful individual are successful, the maximum amount of help does not exceed the amount to be repaid.³

Given a network \( g \) and a state of the world \( y \), the per-period utility of an individual \( i \) is given by

\[
u_i(g, y) = \begin{cases} 
    h - (1 + r) - \sum x & \text{if successful} \\
    -C(d) & \text{if unsuccessful}
\end{cases}
\]

where \( \sum x \) is the total amount the successful individual transfers to her unsuccessful neighbors. The sum is over the number of unsuccessful links.

**Equilibrium:** An equilibrium consists of a network \((g, N)\) and a set of arrangements \([x^1, x^2, \ldots, x^N]\) where \( x^i \in \mathbb{R}^n_i \) and \( n_i \) is the number of links an individual has, satisfying

1. Each individual’s expected welfare is maximized.
2. Promises are kept whenever possible.

### 2.3 Analysis

In this paper we consider regular networks, that is each individual has \( n \) direct links. Each link is characterized by a specific promise value \( x_{ij} = x, \forall i, \forall j \). The expected utility or welfare of an individual with \( n \) neighbors is given by

\[
W = p \left[ (h - (1 + r)) - \sum_{k=0}^{n} \binom{n}{k} p^k (1 - p)^{n-k} (n - k)x \right] \\
- (1 - p) \left[ \sum_{k=0}^{n} \binom{n}{k} p^k (1 - p)^{n-k} C(1 + r - kx) \right] \quad (2.1)
\]

Individuals choose \( x \) to maximize \( W \) subject to the budget constraint

\[
nx \leq A, \text{ where } A = h - (1 + r) \quad (4)
\]

This constraint implies that \( x \in [0, \frac{A}{n}] \) i.e. the maximum possible insurance level is bounded above by \( A/n \).

³The "no-leftover" condition is a simplifying assumption. If this assumption is violated then situations may arise when an unsuccessful individual can repay her loan in full and still enjoy some surplus. However this does not alter the main results of the paper as discussed in Section 2.3.
We analyze the role of network on an individual’s welfare for linear and convex cost functions which are increasing and has the property $C(0) = 0$. This property ensures that an individual who pays back in full is not punished by the bank. We find that network plays no role when punishment equals the default amount as is explained in Proposition 1. When punishment is greater than the default amount but linear in nature, individuals with informal arrangements are better off than in autarky. However this welfare increment is network size invariant as discussed in Proposition 2. Proposition 3 considers strictly convex cost functions which drive the main result of our paper. With strictly convex cost functions, individual welfare increases with network size.

**Proposition 1:** If cost of punishment is linear i.e. $C(d) = d$ then network plays no role in increasing welfare from the autarkic level.

**Proof:** By replacing the cost function in equation 1 we obtain

$$W = p \left[ (h - (1 + r)) - (1 - p)^n n x - \left( \frac{n}{1} \right) p(1 - p)^{n-1}(n - 1)x - \ldots - p^n0 \right] +$$

$$\left(1 - p\right) \left[ -(1 - p)^n(1 + r) - \left( \frac{n}{1} \right) p(1 - p)^{n-1}(1 + r - x) - \ldots - p^n(1 + r - nx) \right]$$

Note that, all terms containing $x$ cancels out. This is true because,

$$\left( \frac{n}{r - 1} \right) (n - (r - 1)) = \left( \frac{n}{r} \right) r$$

Cancelling out terms we get,

$$W = p [h - (1 + r)] - (1 - p)(1 + r)$$

$$= ph - (1 + r)$$

which is the same as the autarkic utility. □

This implies that with linear costs the expected benefit is the same as the expected cost of maintaining a link and hence the welfare of an individual is unchanged at the autarkic value. Ex-ante, the amount a successful individual transfers to her unsuccessful neighbors is exactly the amount she gets back from her neighbors when she is unsuccessful. Since cost of default equals the default amount, the gain from links is same as the cost of maintaining links.

Now assume that the cost of default is greater than the default level, $C(d) > d$. This ensures that no individual has an incentive to strategically default. Under this cost structure we would be interested in finding the optimal amount of insurance $x^*$, which maximizes the expected utility of an individual. We look for the optimal insurance when the budget constraint (4) is satisfied.
Lemma 1: If $C' > 1$ the optimal insurance is the maximum insurance possible i.e. $x^* = A/n$. 

Proof: For a fixed number of links $n$, we want to find the optimal insurance $x$ that maximizes the expected utility $W$ as in equation (3) subject to the budget constraint (4).

The individual solves the following optimization problem

$$\max_x W$$

subject to $nx \leq A$

With fixed $n$, we take the partial derivative of $W$ with respect to $x$ and obtain

$$\frac{\partial W}{\partial x} = -p(1-p)^n n + \binom{n}{1} p^2 (1-p)^{n-1} (n-1) + \ldots + \binom{n}{n-1} p^n (1-p) + (1-p) \left[ \binom{n}{1} p(1-p)^{n-1} C'(1+r-x) + 2 \binom{n}{2} p^2 (1-p)^{n-2} C'(1+r-2x) + \ldots + np^n C'(1+r-nx) \right]$$

Now, $\binom{n}{k-1} (n-k+1) = \binom{n}{k}$.

We can simplify equation (5) and write

$$\frac{\partial W}{\partial x} = p \left[ (1-p)^n (C'(1+r-x) - 1) + \binom{n}{1} p(1-p)^{n-1} (n-1) (C'(1+r-2x) - 1) + \ldots + \binom{n}{n-1} p^n (1-p) (C'(1+r-nx) - 1) \right]$$

Under the assumption $C' > 1$, $\frac{\partial W}{\partial x}$ is increasing in $x$. Hence the constraint holds with equality implying that the optimal insurance is $x^* = A/n$. □

This result applies to linear cost functions of the form $C(d) = \alpha d$, $\alpha > 1$ and to cost functions which are strictly convex. The above lemma implies that when cost is convex and is greater than the default amount, individuals always gain from insurance. In fact, under such circumstances individuals opt for the maximum possible insurance. Ex-ante the amount a successful individual transfers to her unsuccessful neighbors is less than her welfare gain when she is unsuccessful. We now analyze the effect of network-size on welfare with linear costs where cost is greater than the default amount.

Proposition 2: If $C(d) = \alpha d$, $\alpha > 1$, individuals gain from informal insurance and welfare is higher than autarky. However network size does not play a role, that is, welfare is network-size invariant.

Proof: See Appendix B
The intuitive explanation is similar to Proposition 1. Like the previous case, ex-ante, the amount a successful individual transfers to her unsuccessful neighbors is exactly the amount she gets back from her neighbors when she is unsuccessful. However, the gains from transfers is higher due to the structure of the cost function. Although welfare is higher than the autarkic level, it is independent of the number of links an individual has.

Now we assume that the costs of default is not only strictly increasing but also strictly convex, \( C'' > 0 \). Under this assumption we obtain that welfare is increasing in network size. In other words individuals are better off with more neighbors.

**Proposition 3:** If \( C(d) > d \) and \( C'' > 0 \) then welfare is increasing in \( n \).

**Proof:** See Appendix B

The assumption of convex costs implicitly implies that individuals are risk averse. From Lemma 1, we know that the optimal insurance is the maximum insurance possible. We obtain that the expected utility is increasing in \( n \) evaluated at the optimal level of insurance. Each neighbor can be perceived as an insurance possibility and more neighbors can be associated with higher risk diversification. Since individuals are risk averse they gain from bigger neighborhoods through higher risk diversification and better insurance possibility.

### 2.3.1 Example

In light of the above discussion, for a better understanding of the reader we present a simple example with a particular form of the cost function given by \( C(d) = e^x - 1 \). This cost function satisfies all the properties assumed in our model.

Figure 2.1 depicts the welfare function for the cost function \( C(d) = e^x - 1 \) with parameter values \( h = 3, p = 0.9, r = 0.6 \).

This specific example motivates us to find the shape of \( W \) for any cost function which is increasing and strictly convex with \( C(0) = 0 \). We know from Proposition 3, \( \sigma^2 = \frac{\theta^2}{n} p (1 - p) \). Thus as \( n \to \infty \), \( \sigma^2 \to 0 \) and hence \( \Gamma(n) \to C(1 + r) + \mu C''(1 + r) \), which is constant. This in turn implies that for large values of \( n \) the welfare function is increasing and converges asymptotically. However we do not know the exact shape of the welfare function. Figure 2.2 depicts a particular form that the welfare function can possibly assume.

Now suppose that there is a small cost of maintaining each link. Let \( \theta \) be the cost of maintaining a link where \( \theta > 0 \). Hence an individual with \( n \) neighbors has to spend \( n \theta \) amount of resources to maintain her links. This cost may or may not be nonpecuniary in nature. Pecuniary costs may
involve exchanging gifts among neighbors while non-pecuniary costs may come from socializing with them (opportunity cost of labor or compromise on leisure). This motivates us to the next proposition.

**Proposition 4:** If $C(d) > d$ and $C'' > 0$ and there is a small cost $\theta$ of maintaining each link, then there is an optimal number of links, $n^*$. 

**Proof:** We have already established that $W$ increases with $n$ and converges to a constant as $n \to \infty$. Since there is a cost $\theta$ for maintaining each link an individual will maintain the number of links where the marginal gain from an additional link is no less than the marginal cost. The optimal number of links is obtained at the point after which the marginal gain of an additional link is less than $\theta$. 

![Figure 2.1: Example of Welfare Curve](image1)

![Figure 2.2: Welfare Curve](image2)
Since, $\Gamma(n) \to C(1+r) + \mu C'(1+r)$, there exists a $n^*$ such that for all $n > n^*$, $\Gamma(n+1) - \Gamma(n) < \theta$. In order to obtain the optimal number of links we pick the minimum of such $n^*$'s. □

Abusing the technical intricacies, figure 2.3 roughly depicts the optimal number of links $n^*$ beyond which the marginal benefit is less than the cost of maintaining an additional link.

![Figure 2.3: Optimal Number of Links](image)

Proposition 3 along with Proposition 4 conveys the main results of the paper. The results remain qualitatively unaltered if we relax the “no leftover” condition. Under the assumption $1 + r < h/2$, we redefine the utility function of an individual as

$$u_i(g,y) = h - (1 + r) - \sum x \quad \text{if successful}$$

$$= -C(d) + \text{surplus} \quad \text{if unsuccessful}$$

An utility maximizing individual enjoys a surplus of $kx - (1 + r)$ when she is unsuccessful, $k$ of her neighbors are successful and $kx > 1 + r$. For punishment costs satisfying $C(d) > d$ and $C' > 1$, the optimal insurance level remains at $x^* = A/n$ as obtained in Lemma 1. The welfare function $W$ is now a concave function with a kink and is no longer strictly concave. It can be easily shown that the lottery $z_{n+1}$ as defined in the proof of Proposition 3, second order stochastically dominates $z_n$. Hence, individual welfare in equilibrium is non decreasing in $n$. Moreover individual welfare is bounded above implying that there exists an optimal number of links $n^*$ when there is a small cost of maintaining each link. Though this result holds true for any general regular network, it has an important policy implication in the context of group loans with individual liability. This potentially provides a guidance for an optimal group size that individuals need to maintain in order to get a loan.
2.4 Relaxing the Budget Constraint

Under assumption 1, the choice of \( x \) is restricted to satisfy the budget constraint of an individual. This implies that if an individual is successful and all her neighbors are unsuccessful then the individual is able to keep her promises. Now suppose an individual enters into an arrangement such that her total promise exceeds the budget when some or all of her neighbors are unsuccessful. Individuals may want to promise higher values of \( x \) as they can be thought of as better insurance possibilities. However in equilibrium promises must be kept as links are severed as punishment.

Suppose players have a common discount factor \( \delta \in (0, 1) \). We argue that if players are patient enough then the budget constraint is satisfied endogenously. This leads us to our next proposition.

**Proposition 5:** Suppose \( n \leq n^* \). Consider the following strategy. An individual pays \( x = A/n \) to her unsuccessful neighbors whenever she is successful. She severs link with her neighbor whenever she finds out that her neighbor has not kept her promise. As \( \delta \to 1 \), the above strategy constitutes a Nash Equilibrium.

**Proof:** See Appendix B

The argument that supports the above proposition is as follows. Suppose individuals’ promises are such that there exist events where promises can not be kept and these events occur with positive probabilities. An individual who can not keep her promise is revealed to be successful with probability \( \beta \). Given the strategy specified in the above proposition, the neighbors who do not receive the promised value sever links with the individuals who did not keep their promises. Since, links are valuable insurance possibilities, long term gains from a link exceeds short term gains from deviation.

The natural question that arises here is whether the above strategy constitutes a Subgame Perfect Equilibrium (SPE). Once a neighbor does not keep her promise, it is necessary to check whether the link will indeed be severed. Now consider the following strategy. A successful individual keeps her promise, i.e., she pays \( x \) to her unsuccessful neighbors whenever she is successful. Whenever an individual finds out that her neighbor did not keep her promise the link in question is severed. An individual severs her link with a neighbor whenever her neighbor is found out to deviate from the actions prescribed above.

For the above strategy to be SPE we need some degree of observability of actions. Links in our model are bilateral in nature and the transfers are private to the links. To implement the punishment strategy we need transactions to be verifiable. If there is a positive probability of information leakage from which one’s neighbors can infer if she has deviated from the equilibrium strategy, then the above strategy can be sustained as SPE. However, as discussed in Proposition
5 for Nash Equilibrium to hold we do not require any form of information leakage particular to bilateral transactions.

Consider an individual \( i \) whose neighbor \( j \) has not kept her promise, i.e. \( j \) did not transfer the promised value \( x \) even when she was successful and \( i \) was not. Now, \( i \)'s optimal response is to sever the link with \( j \) if she finds out that \( j \) did not keep her promise. If \( i \) instead decides not to sever the link with \( j \), and her neighbors find this out, then all \( i \)'s neighbors sever their links with \( i \). Losing all the links is costlier than losing a single link. From the point of view of \( i \)'s neighbors, they will not deviate from the prescribed action as deviation will make them lose all their links. Repeating the argument in Proposition 5, one can show that the strategy prescribed above is indeed a subgame perfect equilibrium.

2.5 Collusion

In a world with no frictions, if there is a benevolent non-profit microcredit organization providing credit, then resources would be efficiently used so that individuals maximize their joint welfare. However frictions cannot be ignored in the real world. In our model, frictions impede individuals from maximizing joint welfare through punishment sharing. In this section we abstract away from such frictions and look for the first best solution where individuals can collude to share punishment.

Since cost of default is assumed to be a continuous convex function, punishment sharing can be welfare improving. Suppose there are two individuals and we allow for collusion among individuals in the form of punishment sharing. In our earlier setting individuals pay back their entire loan whenever they are successful and the successful individual helps her unsuccessful neighbor with \( x^* = [h - (1 + r)] \). Consequently, the successful individual does not face punishment from the bank while her unsuccessful neighbor faces the punishment cost \( C(1 + r - x^*) \). However the successful individual can help out her neighbor with some additional \( \varepsilon > 0 \) for which she faces a punishment \( C(\varepsilon) \) and her neighbor’s punishment reduces to \( C(1 + r - x^* - \varepsilon) \). Since cost is convex, for \( \varepsilon \) small enough, the reduction in the unsuccessful individual’s punishment is larger than the punishment cost faced by the successful individual. Thus individuals can gain by entering into arrangements that allow for punishment sharing.

Suppose the arrangement between two individuals is given by \( x \) which specifies the amount a successful individual transfers to her unsuccessful neighbor. Now the welfare function of an individual is given by

\[
W = p [h - (1 - p)C(1 + r - h + x)] - (1 - p) [(1 - p)C(1 + r) + pC(1 + r - x)]
\]
Welfare maximization leads to the optimal arrangement \( x^{**} = h/2 \). Punishment is shared up to the point where both individuals face the same level of punishment. Notice that when only one individual is successful, the bank collects \( h \) in the form of repayments. This is the same amount the bank collects under individual liability loans with no punishment sharing.

The same argument holds when an individual has \( n \) neighbors with whom she enters into punishment sharing arrangements. The welfare of an individual with \( n \) neighbors is then given by

\[
W = p\left[h - \sum_{k=0}^{n} p^k(1-p)^{n-k}C(1 + r - h + (n-k)x)\right] \\
-(1-p)\left[\sum_{k=0}^{n} p^k(1-p)^{n-k}C(1 + r - kx)\right]
\]

and the optimal arrangement is given by \( x^{**} = h/(n+1) \). When the number of successful individuals is \( m \), the bank collects \( m \times h \) which is same as the amount the bank collects under individual liability without punishment sharing.

The optimal punishment sharing arrangement is conceptually equivalent to joint welfare maximization of a group of individuals. In other words, individuals behave as a “composite agent” who minimizes joint expected punishment. Joint welfare maximization is the first best solution that joint liability aims to enforce. Joint liability is sometimes justified as a way to encourage the group members to help each other in bad times by “formalizing” the idea of mutual insurance. However internal frictions often impede this kind of collusive behavior. Our analysis in Section 2.3 provides an alternative model of risk mitigation where internal frictions preclude individuals from punishment sharing. The ex-post collection of the bank in equilibrium is same as the amount it collects under the first best solution.

### 2.6 Discussion

In this section we briefly discuss important issues like moral hazard and adverse selection in the context of our model. The following discussion suggests that stricter punishments are essential to remove moral hazard and sustain the all effort equilibrium where every member of the group exerts high effort. When faced with the adverse selection problem, stricter punishments might help in removing social segregation.
2.6.1 Moral Hazard

When output depends on the choice of effort, an individual’s expected payoff not only depends on her own action but also depends on the action of her neighbors. Since neighbors act as insurance possibilities, neighbors’ choice of effort can affect an individual’s payoff in two ways. The expected amount a successful individual transfers to her unsuccessful neighbor decreases with the neighbor’s effort choice while the expected transfer an unsuccessful individual receives from her successful neighbor increases with the choice of effort. Thus an individual has incentives to take remedial action against a neighbor who does not put effort. However when peer monitoring is prohibitively costly strict punishment schemes may alleviate the moral hazard problem as discussed below.

Suppose there are \( n+1 \) individuals. Each individual puts effort \( e \in \{0, 1\} \). When an individual puts effort \( e = 1 \), the probability of success is given by \( p \) whereas when \( e = 0 \), the probability of success is given by \( q \), \( p > q \). Let \( c > 0 \) be the cost of putting effort.

Let \( \gamma \) be the probability of putting effort and \( \gamma^* \in [0, 1] \) be the symmetric equilibrium effort choice. Let \( p' = \gamma p + (1 - \gamma)q \) be the probability of success of an individual putting effort with probability \( \gamma \).

Given other players play the mixed strategy \( \gamma \), an individual’s gross payoff from putting effort is given by

\[
\pi_1(p') = p \left( h - (1 + r) \right) - p * T_{x^*}(p') - (1 - p)Z_{x^*}(p')
\]

The payoff of the individual from not putting effort is given by

\[
\pi_0(p') = q \left( h - (1 + r) \right) - q * T_{x^*}(p') - (1 - q)Z_{x^*}(p')
\]

where, \( T_{x^*}(\cdot) \) is the total expected transfer an individual makes to her unsuccessful neighbors when she is successful given an arrangement \( x^* \). \( Z_{x^*}(\cdot) \) is the expected punishment an individual faces when she is unsuccessful under the same arrangement \( x^* \).

Suppose \( \gamma^* \in [0, 1] \) be the symmetric equilibrium strategy (assuming existence). Now \( p^* = \gamma^* p + (1 - \gamma^*)q \). Notice that the previous analysis (about optimal insurance and optimal network size) carries over with \( p = p^* \) and \( x^* = \frac{h - (1 + r)}{n} \).

Since we know \( p^* \) and \( x^* \), we can compute \( T_{x^*}(p^*) \) and \( Z_{x^*}(p^*) \). Now

\[
\pi_1(p^*) - \pi_0(p^*) = (p - q) \left( h - (1 + r) \right) - (p - q)T_{x^*}(p^*) + (p - q)Z_{x^*}(p^*)
\]

Since \( h - (1 + r) - T_{x^*}(p^*) \geq 0 \), \( \pi_1(p^*) - \pi_0(p^*) > 0 \).
For an individual to be indifferent between $e = 1$ and $e = 0$, we must have

$$\pi_1(p^*) - \pi_0(p^*) = c$$  \hspace{1cm} (7)

Observe that $T_{x^*}(\cdot)$ and $Z_{x^*}(\cdot)$ are decreasing functions of $\gamma$. This is because as neighbors of an individual put more effort, they are unsuccessful with a lower probability and hence the expected transfer is lower. Similarly a higher $\gamma$ works as a better insurance possibility. Neighbors putting more effort are successful with higher probability and hence reduces expected punishment of an individual who is unsuccessful. Also $\pi_1(\cdot) - \pi_0(\cdot)$ is decreasing in $\gamma$ as $Z_{x^*}(\cdot)$ decreases at a higher rate than $T_{x^*}(\cdot)$. This is because transfers are linear and cost of punishment is convex.

Equilibrium Analysis: For $\gamma^* \in [0, 1]$ to be a symmetric equilibrium, (7) must be satisfied. It is evident from equation (7) that a symmetric mixed strategy equilibrium will exist only for certain parameter values. For example, if $p$ and $q$ are not significantly different, then an interior solution will exist only for small values of $c$.

An all effort equilibrium exists if $(p - q)(h - (1 + r)) - (p - q)T_{x^*}(p) + (p - q)Z_{x^*}(p) \geq c$. This condition implies that it is optimal for an individual to put effort with probability one when all her neighbors do the same. All individuals put effort in this symmetric pure strategy Nash equilibrium.

Let $\gamma^* \in (0, 1)$ be a symmetric mixed strategy equilibrium, i.e. $\pi_1(p') - \pi_0(p') = c$. Now suppose the cost of default $C(d)$ becomes steeper for all default levels maintaining $C(0) = 0$. At $\gamma^*$, $Z_{x^*}$ increases making $\pi_1 - \pi_0 > c$. Since, $\pi_1 - \pi_0$ is decreasing in $\gamma$ the new equilibrium (assuming existence) $\gamma^{**} > \gamma^*$. This implies that steeper punishments lead to higher equilibrium effort.

When peer monitoring is not prohibitively costly and individuals are sufficiently patient a high effort equilibrium can be sustained through a different mechanism. An individual can punish by severing the link with her neighbor who shirks. Suppose the cost of monitoring each neighbor is $\epsilon$ which reveals the neighbor’s actions with probability $\epsilon$. Using similar argument as in the proof of Proposition 5, high effort equilibrium can be sustained as $\delta \to 1$.

2.6.2 Segregation

So far our analysis suggests when the economy consists of homogeneous individuals, a larger network corresponds to insurance possibilities no worse than a smaller network. However in reality, the economy may not consist of homogeneous agents and this may lead to different implications in the context of our model. We capture heterogeneity among individuals by introducing differences in productivity. A high productive individual has a higher probability of success than that of a low productive individual.
Our previous analysis relies on an individual’s willingness to engage herself in informal insurance arrangements with her neighbor. In a homogeneous population with linear or convex costs of default, individuals are never worse off with more links. In a heterogenous economy, a low productive individual fails to act as an insurance possibility as good as a high productive individual. Since a low productive individual fails more frequently, the high productive individual has to help her low productive neighbor more often than being helped by her neighbor. This may preclude the high productive individuals from entering into arrangements with low productive neighbors leading to social segregation. In a segregated society, individuals end up keeping links only with individuals of similar ability. However as already discussed in Section 3, larger number of links imply better insurance possibility, severe punishment schemes adopted by the bank may trigger the need for insurance. This in turn encourages high productive individuals to keep links with low productive neighbors and hence eliminate social segregation.

Suppose a high(low) productive individual is successful with probability \( p(q) \), where \( p > q \). Also suppose there is one high productive individual and one low productive individual in the economy.

The expected welfare of the high productive individual under autarky is

\[
W_A = p \left( h - (1 + r) \right) - (1 - p)C(1 + r)
\]

Expected welfare of the high productive individual when she has a link with the low productive individual

\[
W_L = p \left[ h - (1 + r) - (1 - q)x \right] - (1 - p) \left[ (1 - q)C(1 + r) + qC(1 + r - x) \right]
\]

Now

\[
W_A - W_L = \frac{(1 - p)q[C(1 + r - x) - C(1 + r)]}{(-ve)} + p(1 - q)x_{(+ve)}
\]

Given \( p > q \), we have \( (1 - p)q < p(1 - q) \). Therefore, \( |C(1 + r - x) - C(1 + r)| \) has to be sufficiently higher than \( x \) for \( W_L \) to be larger than \( W_A \). The strictness of the punishment function is captured by the degree of convexity of \( C(\cdot) \). More convex the punishment function higher is the welfare gain from having a link. With linear punishment functions of the form \( C(d) = \alpha d \), \( \alpha > 1 \) social segregation is eliminated for values of \( \alpha \) higher than \( p(1 - q)/q(1 - p) \).
2.7 Conclusion

This study is primarily motivated by the success of Grameen II, individual liability loans in particular. Although joint liability facilitated mutual insurance by formalizing it to a great extent, it is reasonable to think that informal insurance plays a significant role under individual liability lending as well. Individuals help each other in bad times and informal insurance is facilitated by repeated interactions among individuals.

We investigate the role of networks when individuals are not able to enter into contracts which maximize joint welfare for reasons exogenous to the model. We show that informal arrangements play an important role in protecting individuals from idiosyncratic shocks. When the punishment cost is greater than the default amount and is convex, individuals opt for maximum possible insurance. This in equilibrium leads to the same repayment rates as would be observed if individuals could share punishments and maximize joint welfare.

This paper not only provides an alternative explanation for the success of individual liability loans, it also takes up an important policy question that has not been addressed by the existing literature. In an attempt to provide an alternative explanation of Grameen II we emphasize on the importance of bilateral arrangements in a given regular network. This set up in the context of micro-lending is novel in the sense that most of the papers in this literature only deal with groups containing two individuals.

It has been observed in Grameen II and its various replicas that individuals are encouraged to maintain an implicit group structure among themselves even under individual liability. A natural question to ask is if there is an optimal group size that maximizes individual’s welfare. Since under convex costs insurance possibility increases with the number of links an individual has, should the entire village act a single group? Does it really take a village to maximize individual’s welfare? The answer is “no”. Marginal welfare declines as the number of links increases, and if there is a small cost of maintaining each link, only a finite number of neighbors maximize welfare.

The analysis in this paper thus potentially provides a guidance for the optimal group size that needs to be implicitly maintained by the villagers. In accordance with the punishment scheme adopted by the bank a social planner can adopt policies to encourage villagers to maintain the optimum group size. Our results however remains true for any regular network and finding the optimal group size is one mere application of a more general result.
Appendix B

Proof of Proposition 2: Given this cost structure we can write the welfare of an individual as

\[ W = -p\left[-(h - (1 + r)) + (1 - p)^n nx + \left(\frac{n}{1}\right)p(1 - p)^{n-1}(n-1)x + ... + p^n 0\right] \]

\[-(1 - p)\left[(1 - p)^n\alpha(1 + r) + \left(\frac{n}{1}\right)p(1 - p)^{n-1}\alpha(1 + r - x) + ... + p^n\alpha(1 + r - nx)\right] \]

\[ = -p\left[-(h - (1 + r)) + (1 - p)^n nx + \left(\frac{n}{1}\right)p(1 - p)^{n-1}(n-1)x + ... + p^n 0\right] \]

\[-(1 - p)\alpha(1 + r) + (1 - p)\left[\left(\frac{n}{1}\right)p(1 - p)^{n-1}\alpha x + ... + p^n\alpha nx\right] \]

From Lemma 1 we know that the optimal level of insurance will be \( x^* = \frac{A}{n} \). We now evaluate the welfare of an individual at this level of insurance

Let \( \alpha = 1 + \gamma \) where \( \gamma > 0 \).

Thus,

\[ W = p[h - (1 + r)] - (1 - p)\alpha(1 + r) + (1 - p)\gamma \left[\left(\frac{n}{1}\right)p(1 - p)^{n-1} + ... + p^n n\right] \frac{A}{n} \]

\[ = p[h - (1 + r)] - (1 - p)\alpha(1 + r) + (1 - p)\gamma \left[\sum_{r=0}^{n} \left(\frac{n}{1}\right)p^r(1 - p)^{n-r} \right] \frac{A}{n} \]

\[ = p[h - (1 + r)] - (1 - p)\alpha(1 + r) + (1 - p)\gamma n p \frac{A}{n} \]

\[ = p[h - (1 + r)] - (1 - p)\alpha(1 + r) + (1 - p)\gamma p A \]

So the welfare is greater than autarky by the amount \( (1 - p)\gamma p A \) which is positive. Moreover the welfare level is independent of \( n \) i.e. the size of the network. □

Proof of Proposition 3: The welfare function is given by

\[ W = -p\left[-(h - (1 + r)) + (1 - p)^n nx + \left(\frac{n}{1}\right)p(1 - p)^{n-1}(n-1)x + ... + p^n 0\right] \]

\[-(1 - p)\left[(1 - p)^n C(1 + r) + \left(\frac{n}{1}\right)p(1 - p)^{n-1} C(1 + r - x) + ... + p^n C(1 + r - nx)\right] \]

\[ = p[h - (1 + r)] - (1 - p)\sum_{k=0}^{n} \left(\frac{n}{k}\right)p^k(1 - p)^{n-k}(C(1 + r - kx) + kx) \]

Substituting the optimal value of \( x \) in the welfare function from Lemma 1 we get,
\[ W = p[h - (1 + r)] - (1 - p) \left( \sum_{k=0}^{n} \binom{n}{k} p^k (1 - p)^{n-k} \left( C(1 + r - k \frac{A}{n}) + k \frac{A}{n} \right) \right) \]

\[ = p[h - (1 + r)] - (1 - p) \sum_{k=0}^{n} \binom{n}{k} p^k (1 - p)^{n-k} C(1 + r - k \frac{A}{n}) - (1 - p) \sum_{k=0}^{n} \binom{n}{k} p^k (1 - p)^{n-k} k \frac{A}{n} \]

\[ W = p[h - (1 + r)] - (1 - p)pA - (1 - p) \sum_{k=0}^{n} \binom{n}{k} p^k (1 - p)^{n-k} C(1 + r - k \frac{A}{n}) \tag{A1} \]

Now we want to show that in equation (A1) the last term is decreasing in \( n \).

Let

\[ \Gamma(n) = \sum_{k=0}^{n} \binom{n}{k} p^k (1 - p)^{n-k} C(1 + r - k \frac{A}{n}). \] (*)

Define \( z_n \) to be a lottery with outcomes \( \{0, \frac{A}{n}, \frac{2A}{n}, ..., A\} \) following binomial distribution with parameters \( n \) and \( p \). Given an individual has \( n \) neighbors, the \((k + 1)^{th}\) outcome of \( z_n \) which equals \( k \frac{A}{n} \), represents the amount an unsuccessful individual receives when \( k \) of her neighbors are successful.

Hence, we can rewrite (*) as \( \Gamma(n) = EC\left( (1 + r) + z_n \right) \).

Taking second order Taylor series expansion of \( C \) around \((1 + r)\) we get,

\[ \Gamma(n) = EC\left( (1 + r) + z_n \right) \]

\[ \approx E \left[ C(1 + r) + C'(1 + r)z_n + \frac{1}{2} C''(1 + r)z_n^2 \right] \]

\[ = E[C(1 + r)] + C'(1 + r)E(z_n) + \frac{1}{2} C''(1 + r)E(z_n^2) \]

\[ = C(1 + r) + \mu C'(1 + r) + \frac{1}{2} (\mu^2 + \sigma^2) C''(1 + r) \]

where, \( \mu = Ap \) and \( \sigma^2 = A^2 p(1 - p) \).

As \( n \) increases the mean of the lotteries remain unchanged while the variance decreases. Since \( C'' > 0 \), the expected cost \( \Gamma(n) \) decreases. Hence welfare increases as \( n \) increases. \( \square \)

**Proof of Proposition 5:** We know that if the budget constraint is satisfied then the optimal insurance is \( A/n \). Now we want to see if two individuals have incentives to enter into an arrangement \((A/n + \epsilon)\) where \( \epsilon > 0 \). This means under certain events which occur with positive probability at least one link is severed.
Let \( E_\epsilon \) denote the set of events where no link is severed under the arrangement \((A/n + \epsilon)\). Let \( E'_\epsilon \) denote the set of events where a link is severed i.e. an individual fails to keep her promise when she is successful and her true type is revealed. \( E'_\epsilon \) may correspond to situations where all neighbors of an individual is not successful and the individual is successful. In such a situation the successful individual fails to keep her promise to at least one of her neighbors and her true state is revealed with probability \( \beta \). It also includes situations where the individual is unsuccessful, her neighbor is successful and all her neighbor’s neighbors are unsuccessful.

Let \( \gamma \) be the probability that \( E'_\epsilon \) occurs and \( (1 - \gamma) \) be the probability that \( E_\epsilon \) occurs.

Let \( V_\epsilon \) be the normalized expected discounted payoff under the arrangement \((A/n + \epsilon)\) and \( \overline{V} \) be the normalized expected discounted payoff under the arrangement \( A/n \).

Let \( V_0 \) be the normalized expected discounted payoff when a link is severed. Also let \( \overline{z} \) and \( \overline{x} \) be the one period payoffs under \((A/n + \epsilon)\) and \( A/n \) respectively.

Suppose \( \overline{z} > \overline{x} \), i.e. one period deviation is profitable. Notice that, \( \overline{V} = \overline{x} > V_0 \). This follows from the assumption \( n \leq n^* \).

Now,

\[
V_\epsilon = (1 - \delta)\overline{z} + \delta \gamma V_0 + \delta (1 - \gamma) V_\epsilon \\
V_\epsilon = \frac{1 - \delta}{1 - \delta(1 - \gamma)} \overline{z} + \frac{\delta \gamma}{1 - \delta(1 - \gamma)} V_0
\]

Subtracting \( \overline{V} \) from \( V_\epsilon \),

\[
V_\epsilon - \overline{V} = \frac{1 - \delta}{1 - \delta(1 - \gamma)} (\overline{z} - \overline{x}) + \frac{\delta \gamma}{1 - \delta(1 - \gamma)} (V_0 - \overline{x})
\]

As \( \delta \to 1 \), \( 1 - \delta(1 - \gamma) \to \gamma \) implying \( \frac{1 - \delta}{1 - \delta(1 - \gamma)} \to 0 \) and \( \frac{\delta \gamma}{1 - \delta(1 - \gamma)} \to 1 \). Therefore, in the limit \( V_\epsilon - \overline{V} < 0 \).

This proves our proposition.\( \square \)
Bibliography


Chapter 3

Urban Ethnic Conflicts

Abstract

Raw data on Hindu-Muslim conflict in India reveals that over 70 percent of conflicts between 1950 and 1995 took place in towns or cities\(^1\). This is severely disproportionate to the fraction of Indian population living in urban areas.\(^2\) In this paper we propose a model which sheds some light on this empirical observation. Conflicts are often precipitated by false rumors. Suppose that whenever there is a rumor, people believe that there may exist a person \(\{b\}\) who knows the truth about the rumor\(^3\). Our model suggests that conflict caused by a false rumor is unlikely to happen in a small population (as in rural areas) because players meet a large fraction of the population and are therefore likely to meet \(\{b\}\). This has two effects - not only do the players who meet \(\{b\}\) know that the rumor is false, they also estimate (from the commonly known meeting process) that a large part of the population must also know. This allows them to coordinate to not fight and enjoy the high peace time payoff as opposed to the lower conflict payoff.

3.1 Introduction

Ethnic conflicts in India are known to be an urban phenomenon.\(^4\) Presumably, some of this can be explained by under-reporting of rural conflicts\(^5\), larger populations in urban areas, some villages having just one ethnicity etc. While we do not have the empirical resources to dig deeper into the veracity of this observation, we find it extremely surprising since over 70 percent of Indians live in

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\(^1\)Varshney(2003)

\(^2\)70 percent of India’s population lives in rural areas - Census 2011.

\(^3\)I.e. whether it is true or false.

\(^4\)About 70 percent of all Hindu-Muslim conflicts (and more than 96 percent of deaths in these conflicts) between the years 1950 and 1995 have been reported in urban areas - Varshney(2003), Mitra and Ray(2010)

\(^5\)Under-reporting of rural deaths would have to be on the scale of 15-20 times to explain the less than 4 percent of rural deaths in ethnic conflicts - Varshney(2003)
rural areas. In this paper we propose a model which brings out one possible explanation for this empirical observation. Before going any further however, we should make it clear that this model exhibits only one of possibly many mechanisms which could support this empirical observation. Our intuitive idea is the following:

Consider a society which hears a 'bad' rumor. The rumor could be true or false. For now, consider the case where the rumor is false. Note that the players in the game don’t know whether the rumor is true or not. Now, whenever there is a rumor, generally, there are always people who know the truth about the rumor i.e. whether it is true or false. In our model, we will assume that everyone places positive probability on the existence of such people. The bad rumor creates a conflict situation (pre rumor, beliefs are such that peace could be sustained as an equilibrium while post rumor the only equilibrium which remains involves everyone choosing to fight). However, before making the decision to fight or not, there is a meeting stage where players may meet other players. In a small population (as in rural areas), players will meet a large fraction of the population and are likely to meet the people who know the truth about the rumor. So they will learn that the rumor was false. This, by itself, does not make peace possible since it will be optimal to fight if everyone else chooses to fight. The fact that the meeting process is common knowledge allows players to estimate that many others must have also gotten to know the truth. This allows people to coordinate their actions and not participate in the conflict leading to a lower probability of conflict. On the other hand, if the population size is too large (as in urban areas) then each player meets only a small fraction of the society. In this case, even when a player is made aware that the rumor was false, he realizes that very few people could have stumbled upon this truth which means that most people will fight. This makes it optimal for the player to fight as well, thereby making conflict inevitable.

This story draws parallels from real life occurrences of conflicts. Rumors have always played a big role in riots. On top of false rumors some small stories are usually blown out of proportion by biased and irresponsible media coverage. This could be because powerful people have vested interests in making the media cover a story in such a manner. The people involved in the story know the truth but they can only reveal it to the small population they know. More often than not, they will not have access to a media platform to reveal the truth to all. This would be especially true if the original story was fabricated and pushed into publication by political heavyweights. In a village, sufficient people may get to know the truth by randomly meeting the people who know that the rumor is false and may not want to participate in the conflict subsequently. This may not

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6 Census 2011. Moreover, in the period of 1950-1995 (for which we have Hindu-Muslim conflict data - Varshney and Wilkinson), an even larger fraction of the Indian population must have lived in rural areas.

7 'Bad' rumor refers to the kind of rumor which is likely to cause conflict. We will formalize this idea in the model.

8 If they exist.

9 Even in the recent riots in Muzaffarnagar, Uttar Pradesh, India - local news papers were accused of misleading and inciteful reporting. Additionally, local politicians were said to have circulated a fake video of ethnic killings along with propagating instigative rumors.
be true for urban areas where the population is large.

This paper serves to point out that truthful and credible media reporting may go a long way in reducing conflict. We also demonstrate that sometimes private information is not good enough to make people not fight. Players must know (through common knowledge of meeting process or by the fact that it was shown on tv/radio) that other people also have this information.\footnote{This has been shown to be critical in other environments like global games with noisy information about the payoff structure (Carlsson and Van Damme(1993))}

There has been substantial work on ethnic conflicts in India. Varshney’s book ‘Ethnic Conflict and Civic Life - Hindus and Muslims of India’ comprehensively discusses the issue of ethnic conflict in India against the backdrop of Hindu-Muslim conflicts. He considers several theories of ethnic conflict and concludes that while all these theories have some merit they fail to explain some incidences (or non incidences) of conflict. He goes on to show that the missing story could have been that of the impact of inter-ethnic relationships on reducing probability of conflict. Mitra and Ray(2010) also consider Hindu-Muslim conflict in India. They do an empirical study of Hindu-Muslim violence in India post independence era and conclude that the Hindu groups have been primarily responsible for the Hindu-Muslim violence in post-independence India. Both these authors mention that conflict seems to happen a lot more in urban areas. However, they do not offer a model to explain it. There have been a series of papers by Esteban and Ray which offer insights into why ethnic conflicts happen. Esteban and Ray (2008) points out why ethnic conflict is more likely to occur than class conflict. In ethnic alliances where there is within-group economic inequality, ethnic conflict is more likely than a class conflict. Esteban and Ray (2011) use a theoretical model to show how within-group heterogeneity in radicalism and income help in precipitating an ethnic conflict.

The paper is organized as follows. Section 3.2 describes the main features of the model. Section 3.3 talks about strategies and the particular equilibrium concept relevant here. The results are in section 3.4. We finish with a discussion of our assumptions and modeling choices in section 3.5 and the conclusion in section 3.6.

### 3.2 Model

Let the population consist of \( N \) people where \( N \) is even.

#### 3.2.1 Players

Each person can be one of two ethnicities - \{\( H \), \( M \)\}. For simplicity, assume that each ethnicity has \( \frac{N}{2} \) players.\footnote{This assumption is not critical for our results.} Additionally, a player can be one of two types - \( \text{Good} (G) \) or \( \text{Bad} (B) \). The two
types differ in terms of the actions available to them. Players can decide to participate (P) in the conflict or not (NP). The G type player is strategic. He can choose either action and participates in the conflict only if it gives him higher payoff. B type players, on the other hand, will always participate in the conflict. After a rumor arrives, let there be one non-strategic player (outside the population) \{b\} who can prove the veracity of the rumor.\textsuperscript{12} The players place positive beliefs on the existence of \{b\}.

3.2.2 Conflict

If a large enough fraction of at least one group choose to participate then a conflict ensues. If both groups fail to gather enough members to participate, peace prevails. Formally - Let \( c \in (0, 1) \) be an exogenously given threshold. Given an action profile \( a = (a_i)_i \), a conflict takes place iff:

\[
\max\{n_H(a), n_M(a)\} \geq c
\]

where \( n_H(a) = \frac{|\{i \in H | a_i = P\}|}{|H|} \), \( n_M(a) = \frac{|\{i \in M | a_i = P\}|}{|M|} \).

Conditional on the conflict, probability of winning for any group is given by the following rule:

Given action profile \( a \), probability of \( H \) being the winning group is

\[
\frac{|H| * n_H(a)}{|H| * n_H(a) + |M| * n_M(a)}.
\]

Thus, if there is a conflict then an ethnic group wins with higher probability if more of their members participated than members of the rival group.

3.2.3 Payoffs

The payoffs to any player \( i \) of type G depends on his action, whether or not conflict takes place and whether he was part of the winning or losing side if conflict did take place. Thus, payoffs are summarized precisely in the following matrix:\textsuperscript{13}

\[
\begin{array}{c|c|c|c}
   & CW & CL & NC \\
\hline
   P & \alpha & -\beta & -\gamma \\
   NP & -\beta & -\beta & \alpha + \delta \\
\end{array}
\]

\textsuperscript{12}The rumor being false will be the only interesting case here. If it is true, then conflict is inevitable. The assumption that \{b\} is outside the population is just for simplicity of calculation. Also, note again that people don’t know whether the rumor is true or false ex ante.

\textsuperscript{13}The really crucial aspect of this matrix is that peace time payoffs \((\alpha + \delta)\) are higher than the best conflict payoff \((\alpha)\). It is not important that non-participants of the winning side are treated the same as losers. We just need their payoffs to be such that it always pays to fight when conflict is inevitable.
Where $\alpha, \beta, \gamma, \delta > 0$. $CW$ means conflict and win, $CL$ - conflict and lose and $NC$ means no conflict occurs.

### 3.2.4 Rumor

A rumor is any piece of news that everyone hears.\(^{14}\)

### 3.2.5 Meeting Process/Obtaining Information

After the rumor stage, people may get additional information in the following manner: Person $\{b\}$ randomly picks $k$ people from the population and simultaneously sends them letters with one of two signals - True or False. We assume that $b$ is not strategic. He always reveals the truth about the rumor. The contents of the letter serve as a signal of the state of the world.\(^{15}\)

### 3.2.6 Timeline

The timeline of events is depicted in the picture below. At time 0, people have priors on true distribution of types, whether a rumor arrives or not and if the rumor does arrive then whether there exists a person who will know more about the rumor. They also have priors on the contents of the letter (if it exists). They update these beliefs as events unfold. Action to participate or not will be taken after the letters stage i.e. after the rumor (where some people get the letter from $\{b\}$\(^{16}\) and others don’t).

\[ \text{Figure 3.1: Timeline} \]

\(^{14}\)Something in the paper or radio for example.

\(^{15}\)This contrived process of receiving additional information is discussed further in section 5. Our result is not crucially dependent on the above process. We make this modeling choice to make the analysis easier. The fact the $b$ is non-strategic may not be a trivial assumption. However, we believe that it may be reasonable assumption for the following reason - Conflicts are usually precipitated by false rumors which malign the name of the subject of the rumor. In this case, it might be reasonable to assume that the subject would want to clear his name by telling people the truth and revealing that the rumor was false.

\(^{16}\)If $\{b\}$ exists.
3.2.7 Beliefs and Information

Any player’s ethnicity \( \{H, M\} \), conflict threshold \( c \), the payoff matrix and the meeting process is common knowledge. The type \( \{G, B\} \) of a player is private knowledge.

*Hereon, unless otherwise stated, everything is described for only the G type player. This is because the B type player’s actions are fixed.*

All players have common priors.

About Distribution of Types

At time 0, people are uncertain about the distribution of types in the world. Let \( n^y_l \) be the fraction of \( y \) ethnicity people who are \( l \) type. For simplicity, we assume that there are only two kinds of possible type distributions:

Probability \( \omega \) the type distribution is such that \( (n^H_G, n^M_G) = (q, q) \).

Probability \( (1 - \omega) \) the type distribution is such that \( (n^H_G, n^M_G) = (r, r) \)

where \( (1 - q) < c < (1 - r) \).

Thus, if \( (r, r) \) is the true distribution of \( G \) types, then the number of bad types alone is so high that conflict must happen. On the other hand, if \( (q, q) \) is the true distribution of types then conflict may not happen if all the \( G \) types choose not to participate in the conflict. We will be interested in the outcome when the true distribution is \( (q, q) \).

About Rumor

Conditional on the \( (q, q) \) being the true distribution, the rumor arrives with probability \( 1 - \theta_q \).

Conditional on \( (r, r) \) being the true distribution, the rumor arrives with probability \( 1 - \theta_r \). Thus the arrival of a rumor is correlated with the distribution of types in the society.\(^{17}\)

On existence of \( \{b\} \)

Conditional on the true distribution being \( (q, q) \) and the rumor arriving, the probability that there exists one person who knows more about the rumor is given by \( \zeta_q \). Similarly define \( \zeta_r \).

\(^{17}\)A canonical example to keep in mind is that the rumor is “\((r, r)\) is the true distribution of types”
On Contents of Letter

Conditional on the letter arriving and the true distribution of types being \((q, q)\), the probability of receiving the signal \(F\) in the letter is given by \(\phi_q\). Similarly define \(\phi_r\).

3.2.8 Game Tree

The game as viewed by any \(G\) player is described in this tree. \(\overline{R}\) and \(\overline{b}\) indicates the events when rumor does not arrive and non-existence of a player who has additional information about the rumor respectively. Relevant information sets are described by red numbers or the colors green, blue, red. Conditional probabilities are in blue. Pre-rumor everyone is at information set 0. Post rumor everyone is at information set 2. Post letters stage, if a player does not get the letter he will be at one of the six nodes in information set 3 (colored green). If a player gets the letter from \(\{b\}\) with the signal \(F\) then he is at one of the two nodes in information set 4\(F\) (colored blue). If a player gets the letter from \(\{b\}\) with the signal \(T\) then he is at one of the two nodes in information set 4\(T\) (colored red).

3.2.9 Assumptions

1. Players play symmetric pure strategies only.\(^{18}\)

2. \(\zeta_q = \zeta_r.\)\(^{19}\)

3.3 Equilibrium Concept

People are updating beliefs in a Bayesian manner and they choose actions which are optimal given beliefs. Thus, our equilibrium concept is Perfect Bayesian Equilibrium. It is worth pointing out that the equilibrium here could also be interpreted as a correlated equilibrium.

3.4 Results

In this section we want to show two things. First, the conditions under which rumors cause conflict. The first two propositions deal with this. Second, when can this effect of a rumor be negated and how is it related to the size of the population? Theorem 1 answers this question.

\(^{18}\)Thus, people of the same type and same beliefs take the same action.

\(^{19}\)This will make sure that the getting of the letter itself is not informative about the state of the world. We believe this is a reasonable assumption. The fact that there exists someone who knows the truth about the rumor may be independent of the distribution of types in the world.
Proposition 1. Pre rumour, there exists $\omega^* \text{ such that if } \omega > \omega^* \text{ then there exists an equilibrium in which the } G \text{ type players choose } NP. \text{ Moreover, it is the pareto dominant equilibrium.}

Proof. In the pre-rumor stage (information set 0), people have beliefs $\omega$ about the good distribution $(q,q)$ being the actual distribution. Strategies are just a function of types and beliefs. Consider the following pure strategy profile:

\[
S(G, \omega) = NP
\]
\[
S(B, \omega) = P
\]

The $B$ type players have to play $P$. We want to show that if $\omega$ is high enough then it will be optimal for the $G$ players to not participate.\(^{20}\)

\(^{20}\)Note that participate or not participate decisions are actually taken after the letters stage. Here, we ask a hypothetical question - If players were asked to make the decision at information set zero, what would they do? This is important because we want to be able to say that rumor caused conflict i.e. conflict may not have occurred with pre-rumor beliefs but it became inevitable post rumor
Given these strategies, the players will make the following calculations:

Payoff from playing \( P = \omega(-\gamma) + (1 - \omega)((1 - \frac{1+(1-r)\frac{N}{2}}{1+(1-r)\frac{N}{2}+(1-r)\frac{N}{2}})\alpha + (1 - \frac{1+(1-r)\frac{N}{2}}{1+(1-r)\frac{N}{2}+(1-r)\frac{N}{2}})(-\beta)) \)

Payoff from playing \( NP = \omega(\alpha+\delta) + (1 - \omega)((\frac{1-r}{1-(r)\frac{N}{2}+(1-r)\frac{N}{2}})(-\beta) + (1 - \frac{1-r}{1-(r)\frac{N}{2}+(1-r)\frac{N}{2}})(-\beta)) \)

Both expressions are continuous and monotonic in \( \omega \). Note that:

As \( \omega \to 0 \), payoff from \( P \) becomes better than payoff from \( NP \)

As \( \omega \to 1 \), payoff from \( NP \) becomes strictly better than payoff from \( P \).

Thus, by the Intermediate value theorem, there exists an \( \omega^* \in (0,1) \) such that \( \omega > \omega^* \Leftrightarrow \text{Payoff } NP \geq \text{Payoff } P \).

So this strategy profile constitutes a Bayesian Nash equilibrium.

Moreover, note that there is only one other equilibrium possible in pure strategies - an equilibrium in which both \( G \) types and \( B \) types play participate. Since peace time payoffs \( (\alpha+\delta) \) are higher than the best conflict payoff \( (\alpha) \), the former equilibrium Pareto dominates the latter.\(^{21}\)

The first proposition simply says that - pre-rumor - if the priors on the distribution are such that people place high belief on the distribution with less bad types then there exists an equilibrium in which the good types do not want to participate in conflict. There is also an equilibrium in which everyone fights but it is Pareto dominated by the former. We assume that the Pareto dominated equilibrium will not be played.

Proposition 2 describes the conditions under which the arrival of the rumor make peace impossible.

**Proposition 2.** Post rumor and Pre-letters (information set 2), if \( \frac{1-\theta}{1-\theta_q} > \frac{1-\omega^*}{\omega} \frac{\omega}{1-\omega} \), then not participate cannot be supported as an equilibrium. The only equilibrium is the one in which everyone participates in the conflict.

**Proof.** We will show this by demonstrating that the posterior belief on the good distribution falls below \( \omega^* \) under the condition

\[ \frac{1-\theta}{1-\theta_q} > \frac{1-\omega^*}{\omega} \frac{\omega}{1-\omega} \]

\(^{21}\)We only consider the payoffs of the \( G \) type when thinking of Pareto dominance. Since the \( B \) types are always choosing to participate, clearly they are at least indifferent to the result of their actions.
Let $P(q/Rumour)$ be the probability that the true distribution is $(q, q)$ given that the rumour has arrived. Then:

$$P(q, Rumour) = \frac{\omega(1-\theta_q)}{\omega(1-\theta_q) + (1-\omega)(1-\theta_r)}$$

Then $P(q, Rumour) < \omega^*$

$$\Leftrightarrow \frac{\omega(1-\theta_q)}{\omega(1-\theta_q) + (1-\omega)(1-\theta_r)} < \omega^*$$

$$\Leftrightarrow \frac{1-\theta_r}{1-\theta_q} > \frac{1-\omega^*}{\omega^*} \frac{\omega}{1-\omega} \quad \Box$$

First, note that $\omega > \omega^*$ and $\frac{1-\theta_r}{1-\theta_q} > \frac{1-\omega^*}{\omega^*} \frac{\omega}{1-\omega}$ implies that $(1 - \theta_r) > (1 - \theta_q)$. Essentially, proposition 2 tells us that if the arrival of the rumor is sufficiently positively correlated to that state of the world in which the true distribution of types is the one in which there are a lot of $B$ type players in each community then conflict is inevitable following the rumor.\textsuperscript{22}

**Corollary 1.** If $\omega > \omega^*$ and $\frac{1-\theta_r}{1-\theta_q} > \frac{1-\omega^*}{\omega^*} \frac{\omega}{1-\omega}$ but no rumor appears then we can still support the equilibrium in which the good types don’t participate.

This is plain to see. Since arrival of the rumor is more likely when the true distribution of types is the bad one, not arrival of the rumor is more likely when the true distribution of types is the good one. This implies that the posterior on $(q, q)$ if the rumor does not arrive is higher than $\omega$ and therefore higher than $\omega^*$.

Proposition 1, Proposition 2 and Corollary 1 establish conditions under which - before the rumor arrived (or if it does not arrive), $G$ type players would not have participated in conflict but after the rumor arrived everyone chooses to participate and the conflict seems inevitable. So if the true distribution of types was $(q, q)$, conflict would not have occurred pre-rumor but it becomes inevitable post rumor. Thus, rumor induces conflict. Theorem 1 talks about when this effect of rumor can be reversed.

**Theorem 1.** Let $\omega > \omega^*$ and $\frac{1-\theta_r}{1-\theta_q} > \frac{1-\omega^*}{\omega^*} \frac{\omega}{1-\omega}$. Assume $\frac{\phi_q}{\phi_r} > \frac{(1-\omega)(1-\theta_r)\omega^*}{\omega(1-\theta_q)(1-\omega^*)} > 1$. Then, post letters stage, if $\frac{k}{N} \approx 1$ then no conflict can be an outcome of an equilibrium. If $\frac{k}{N} \approx 0$ then conflict is inevitable.

**Proof.** In Appendix. \hfill $\Box$

\textsuperscript{22}Remember there were just two equilibria possible. We have ruled out the one in which the $G$ types don’t participate. The only remaining equilibrium is one in which everyone chooses to participate and conflict happens for sure.
The intuition behind theorem 1 is as follows: strategy for a player after the letters stage is a triple - \((a, b, c)\) where \(a\) gives the action to take if the player does not get a letter, \(b\) gives the action for when the player gets a letter and the letter has the signal - 'False' and \(c\) describes the action to be taken if the player gets a letter and the signal is - 'True'. Consider the case when the rumor is actually false. This means that whoever gets the letter - gets the signal - 'False'. As \(\frac{k}{N} \approx 0\), a very small fraction of the population gets the letter and this is common knowledge. Thus, most people are at information set 3 and have the same beliefs as the post rumor beliefs at information set 2\(^{23}\) which makes it optimal for them to participate. The people who get the letter and know that the rumor was false realize that the state of the world is more likely to be \((q, q)\)\(^{24}\) but they also realize that too many people have not gotten the letter. Since those people are going to fight, conflict is inevitable. So they decide to participate as well. Thus, conflict is the only equilibrium outcome if \(\frac{k}{N} \approx 0\). When \(\frac{k}{N} \approx 1\), the players who don’t get the letter think that if \(\{b\}\) had existed they would have gotten the letter for sure so they conclude \(\{b\}\) does not exist. This makes them think that everyone has the post-rumor beliefs. This makes it optimal for them to choose to participate (by proposition 2). On the other hand, the people who do get the letter conclude that almost everyone must have gotten the letter which means that everyone must have realized that the rumor was false. This would mean that almost everyone places high probability (higher than \(\omega^*\) under the conditions described in the theorem) on the state of the world being \((q, q)\). Then, by proposition 1, there exists a pareto dominant equilibrium in which the \(G\) types don’t participate. So, it becomes optimal for them to not participate. Therefore, when \(\frac{k}{N} \approx 1\), if \((q, q)\) is the true distribution of types, then conflict will not take place.

Since villages have small populations compared to urban areas, we think of urban areas when we think of \(\frac{k}{N} \approx 0\) and villages when \(\frac{k}{N} \approx 1\).

### 3.5 Discussion

In this section we discuss some of our assumptions and modeling choices. We show that our claims are robust to some alterations.

#### 3.5.1 Correlation of Distributions

We assume that only those type distributions are possible which lead to people placing positive weights on \((q, q)\) and \((r, r)\) where \((1 - r) > c > (1 - q)\). This assumption is not crucial to our results. In particular we could have assumed positive weights on a multitude of distribution states like

---

\(^{23}\)This is because \(\zeta_q = \zeta_r\).

\(^{24}\)Since the signal \(F\) is much more likely in the state \((q, q)\) according to the condition on \(\phi_q, \phi_r\). This can be justified as follows. The need for sending out a false rumour to create conflict will be higher in the state \((q, q)\). This is because unlike the other state, conflict is not inevitable here.
\[(q_1, q_2), (q_3, q_4), \ldots, (q_n, q_{n+1}), (r_1, r_2), (r_3, r_4), \ldots, (r_m, r_{m+1})\] where \(\max\{1-q_i\}_i < c < \min\{1-r_j\}_j\).

As long as conflict is inevitable in some states and not in others, our claims will go through. Note that we could allow for beliefs over distributions like \((q, r)\) where \((1-r) > c > (1-q)\) as well but these would be uninteresting (if we allowed for such distributions only) since our definition of conflict makes conflict inevitable if even one ethnicity has enough bad types.

### 3.5.2 Assumption of Pure Strategies

We will relax this assumption and see if the results hold. Although, indifference between participating and not participating in an ethnic conflict seems unusual.

### 3.5.3 Higher \(k\), More \(\{b\}\) in bigger populations?

We have assumed that the number of people who find out the truth \((k)\) and the number of people who know the truth does not change as we increase the population. It is possible that both these figures go up for urban areas (places with higher population). However, as long as they don’t increase too fast with population so that the fraction of people who learn the truth about the rumor still goes to zero (i.e. \(\frac{k(N)}{N} \to 0\) as \(N \to \infty\)), our results will hold.

### 3.5.4 Letters interpretation of Meetings

We have used a contrived definition of 'meetings' to say how players find out that the truth about the rumor. However, note that our results depend on three things - the fraction of the population who get to know the truth, the meeting process being common knowledge and that only a signal is exchanged in meetings (types are not revealed). Thus, any meeting process which guarantees that only \(k\) out of \(N\) people will discover that the rumor was false will give the same results. For example, \(\{b\}\) could tell just one person and then that one person may meet others randomly and inform them and then all those people could inform others and so on. If there are finite meeting stages, such that at the end of all meetings only \(k\) players know that the rumor was false, then our claims would go through. The math could become incredibly messy though!

An alternative way of thinking about \(k\) is that it is the number of people who believe that the rumor was false after getting the signal \(F\). Consider a rumor about an event which causes conflict. Let \(\{b\}\) be the eyewitness to this event. In small villages, one is more likely to hear the truth about the event directly from \(\{b\}\) whereas in places with bigger populations (like urban areas) one is likely to hear the truth from second-third or even fourth-hand sources. It is plausible that people believe first hand sources more. Our model is a reduced form way of modeling this idea.
3.5.5 Non Random Meetings

Potentially, it is more likely that people of the same ethnicity are more likely to meet each other. This spells trouble. Consider an extreme example where player \( b \) has an ethnicity and he sends his \( k \) letters to only his own ethnicity. Conflict may be unavoidable now. This is because the other ethnicity does not learn that the rumor is false and will come out to fight. This is enough for conflict to occur. This example can be extended to a situation where the two ethnicities seldom meet in the meeting stage. Thus, low levels of inter-ethnic integration/communication may lead to one ethnic group not finding the truth. This would lead to a higher probability of conflict.\(^{25}\)

3.5.6 Cost of participation

We have implicitly assumed that there is no cost of participating in a conflict (payoff from participate and lose is the same as payoff from not participate and lose \((-\beta))\). Mathematically, this allows us to say that participating is dominant strategy if a player knows that conflict is inevitable. Consider now the same game but with a fixed cost \( c \) of participating in conflict.\(^{28}\) Now people have a trade off. Suppose conflict is going to happen for sure. By participating one can increase the probability of winning for own ethnicity but there is a private cost of \( c \). Thus, if \( c \) was high compared to the increase in probability of winning then people may not participate. Clearly this would make participation a bigger issue in urban areas.\(^{29}\) However, note that we have also assumed that gains from winning remains the same in urban and rural areas.\(^{30}\) The more natural assumption would have been that the pie is larger in urban areas. If the increase in gains compensate for the private cost then we will still get the same results. Alternatively, our results would go through under the condition that \( c \) was low.

3.6 Conclusion

False rumors are often instrumental in precipitating ethnic conflicts. In this paper we look at conflicts caused by false rumors. We formalize a model in which a false rumor causes conflict with higher probability when population is larger. We present our model as one explanation for why most conflicts between Hindus and Muslims in India happen in urban areas.

\(^{25}\)The inverse relationship between inter-ethnic relationships and ethnic conflicts has been explored in \(^{26}\) and \(^{27}\) among others.

\(^{28}\)We have also tried cost functions where the cost of participating is inversely related to the probability of winning. A similar argument can be made there.

\(^{29}\)Since the population is large, one player’s participation increases probability of winning by just a little but the private cost of participation is fixed at \( c \).

\(^{30}\)That is - it remains unchanged as we increase population
Appendix C

Proof of Theorem 1:

**Proof. 3.6.1 Type space and prior**

We work with type space $T = \{G, B\}^N$. Define $T_q = \{t : \frac{|\{i \in H : t_i = G\}|}{|H|} = \frac{|\{i \in M : t_i = G\}|}{|M|} = q\}$ and similarly define $T_r$. Prior $p \in \Delta(T)$ has the following properties:

1. $p(T_q \cup T_r) = 1$
2. For all $i \in N$, $p(T_q | t_i = G) = \omega \geq \omega^*$
3. $p(t | T_q) = \frac{1}{|T_q|}$

The first condition says that the type distribution is either $(q, q)$ or $(r, r)$. The second condition says that when an agent learns that he is of type $G$, his belief about $(q, q)$ is $\omega$. Third: conditional on $(q, q)$, the type distribution is uniform.

**3.6.2 Strategies**

The tree represents uncertainty faced by a player of good type. He may be at information set 3, 4T or 4F. A strategy prescribes what action to take at each information set.

**Definition**: For player $i$, a strategy a function $\sigma_i : \{3, 4T, 4F\} \rightarrow \{P, NP\}$.

We shall focus on symmetric strategy profiles.

**3.6.3 Results**

$(P, P, NP)$ as an equilibrium

Denote as $(a, b, c)$ the strategy $\sigma(3) = a, \sigma(4T) = b$ and $\sigma(4F) = c$ where $\{a, b, c\} \subseteq \{P, NP\}$. We now show conditions under which $(P, P, NP)$ is an equilibrium. Let $\phi_q$ and $\phi_r$ be the probability of receiving the message $F$ in the state $q$ and $r$ respectively.

**Proposition** Suppose the following are true:

1. $0 < \zeta_q = \zeta_r = \zeta < 1$
2. \( \frac{k}{n} \to 1 \)

3. \( \frac{\phi_q}{\phi_r} > \frac{(1-\omega)(1-\theta_r)\omega^*}{\omega(1-\theta_q)(1-\omega^*)} > 1 \)

then \((P, P, NP)\) can be supported as an equilibrium and no strategy profile with \(\sigma(4T) = NP\) can be supported as an equilibrium.

**Proof** Consider an agent \(i\) of type \(G\) at information set 3. We shall show that under the symmetric strategy profile \((P, P, NP)\), his best response is to play \(P\). Now consider \(i\)'s subjective probability of the truth person not existing conditional on being at information set 3. Call this probability \(Pr(\bar{b}|3)\).

\[ Pr(\bar{b}|3) = (1-\zeta)(1-\zeta) + \zeta(1-kn) \]

As \(\frac{k}{n} \to 1\), \(Pr(\bar{b}|3) \to 1\). Notice that \(Pr(\bar{b}|3) = Pr(\bar{b}|3, q) = Pr(\bar{b}|3, r)\). Now denote \(E(P, b, 3, q)\) and \(E(P, b, 3, r)\) denote the conditional expectation at information set 3 from playing \(P\) when the truth person exists and the true state is \(q\) and \(r\) respectively. Further, denote as \(E(NP, b, 3, q)\) and \(E(NP, b, 3, r)\) the corresponding expected payoffs from playing \(NP\).

Denote as \(Pr(q|3)\) the belief about state \(q\) at information set 3. The expected payoff from playing \(P\) is:

\[ E(P|3) = Pr(q|3)[Pr(\bar{b}|3, q)[\frac{\alpha-\beta}{2}] + Pr(b|3, q)E(P, b, 3, q)] + Pr(r|3)[Pr(\bar{b}|3, r)[\frac{\alpha-\beta}{2}] + Pr(b|3, r)E(P, b, 3, r)] \]

The expected payoff from playing \(NP\) :

\[ E(NP|3) = Pr(q|3)[Pr(\bar{b}|3, q)[-\beta] + Pr(b|3, q)E(NP, b, 3, q)] + Pr(r|3)[Pr(\bar{b}|3, r)[\beta] + Pr(b|3, r)E(NP, b, 3, r)] \]

Now as \(\frac{k}{n} \to 1\), \(E(P|3) \to \frac{\alpha-\beta}{2}\) and \(E(NP|3) \to -\beta\). So \(E(P|3) > E(NP|3)\). Hence, playing \(P\) is optimal at information set 3.

Now consider the decision at information set 4F. Under the conditions stated above \(Pr(q|4F) > \omega^*\). For the players receiving the letter, denote as a letter assignment \(\tau: \{1, \ldots, k\} \to N\) (injective function). Let \(\mathcal{M}\) be the set of all assignments. Let \(T^i_G\) be the set of all type profiles where \(i\) is a good type and the type distribution is \((q, q)\) (state of the world \(q\)). We consider \(i\)'s subjective probability that all good types have received a letter with the message \(F\) conditional on state of the world \(q\). The corresponding event is:
\[E_{G,q} = \{(t, \tau) \in T^G_q \times \mathcal{M} : \text{range}(\tau) \subseteq \{i : t_i = G\}\}\]

Let \(E_{G,r}\) be the corresponding event in the state of the world \(r\). Now, as \(k \to 1\), \(Pr(E_{G,q}|4F, q) \to 1\) and \(Pr(E_{G,r}|4F, r) \to 1\). Let \(E(P, 4F, q)\) and \(E(P, 4F, r)\) be the expected payoff from playing \(P\) at information set \(4F\) if not all good types having received the letter at state \(q\) and \(r\) respectively. Let \(E(NP, 4F, q)\) and \(E(NP, 4F, r)\) be the corresponding expected payoffs from \(NP\). Then, the expected payoff from playing \(P\) at \(4F\) is:

\[
E(P|4F) = Pr(q|4F)[Pr(E_{G,q}|4F, q)(-\gamma) + (1 - Pr(E_{G,q}|4F, q))E(P, 4F, q)] + Pr(r|4F)[Pr(E_{G,r}|4F, r)((\frac{1}{1+1-(1-r)\frac{N}{2}+(1-r)\frac{N}{2}})(1+1-(1-r)\frac{N}{2}+(1-r)\frac{N}{2})\alpha + (1 - \frac{1}{1+1-(1-r)\frac{N}{2}+(1-r)\frac{N}{2}})(-\beta))] + (1 - Pr(E_{G,r}|4F, r))E(P, 4F, r)]
\]

The expected payoff from playing \(NP\) at \(4F\) is:

\[
E(NP|4F) = Pr(q|4F)[Pr(E_{G,q}|4F, q)(\alpha + \delta) + (1 - Pr(E_{G,q}|4F, q))E(NP, 4F, q)] + Pr(r|4F)[Pr(E_{G,r}|4F, r)((\frac{1}{1-\frac{N}{2}+(1-r)\frac{N}{2}})(-\beta) + (1 - \frac{1}{1-\frac{N}{2}+(1-r)\frac{N}{2}})(-\beta))] + (1 - Pr(E_{G,r}|4F, r))E(NP, 4F, r)]
\]

Now as \(k \to 1\), \(E(P|4F) \to Pr(q|4F)(-\gamma) + Pr(r|4F)((\frac{1+1-(1-r)^N}{1+1-(1-r)\frac{N}{2}+(1-r)\frac{N}{2}})\alpha + (1 - \frac{1}{1+1-(1-r)\frac{N}{2}+(1-r)\frac{N}{2}})(1+1-(1-r)^N)(-\beta))\)

And, \(E(NP|4F) \to Pr(q|4F)(\alpha + \delta) + Pr(r|4F)((\frac{1}{1-\frac{N}{2}+(1-r)^N})(-\beta) + (1 - \frac{1}{1-\frac{N}{2}+(1-r)^N})(-\beta))\)

Now since \(Pr(q|4F) > \omega^*\), from proposition 1, we get \(E(NP|4F) > E(P|4F)\) hence, it is optimal to play \(NP\) at \(4F\). Now since under the conditions \(Pr(q|4T) < \omega^*\) a similar argument can be used to show that it optimal to play \(P\) at information set \(4T\). It is also clear that no strategy with \(\sigma(4T) = NP\) can be supported as an equilibrium.

\(\Box\)

**Proposition**: Assume the following:

1. \(\frac{k}{n} \to 0\)
2. \(\frac{(1-\omega)(1-\theta_r)\omega^*}{\omega(1-\theta_l)(1-\omega^*)} > 1\)

Then, \((P, P, P)\) is the unique symmetric equilibrium.

**Proof**: We first show that no profile of the form \((P, b, NP)\) or \((P, NP, b)\) can be supported as an equilibrium. Now, we have \(\frac{k}{n} \to 0\). Hence, for low values for \(k\), \(\frac{1}{2} - \frac{k}{n} > \frac{1}{2}\). This implies that

\[^{31}\text{Since the events that -letter has signal T and letter has signal F are mutually exclusive, we put the letter 'b' in place of the non-relevant action choice.}\]
\[ \frac{n}{2} - k > c \frac{n}{2}. \] This implies that in any community, even if the letters are distributed, conflict will inevitably take place since a large fraction of the community (of proportion greater than \( c \)) will not have received a letter and will be in information set 3 and choose to play \( P \) under the above strategy profile. Hence, agents who do receive the letter would know that a conflict will take place irrespective of the state of the world and would choose to play \( P \) since it is a dominant strategy under conflict.

Now consider a strategy profile of the form \((NP, b, c)\). Now since \( \frac{k}{n} \to 0 \) almost all agents of type \( G \) will be at information set 3. But since the beliefs at information set 2 and 3 about the state of the world is the same, from proposition 1 we can conclude that an agent at information 3 will choose to participate. Hence, no symmetric profile of the form \((NP, b, c)\) can be supported as an equilibrium. Additionally, we know that \((P, P, P)\) can always be supported as an equilibrium and the above argument establishes it as a unique equilibrium.
Bibliography


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Education

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<tr>
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<tbody>
<tr>
<td>Ph.D. in Economics</td>
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Work in progress:
- What it takes to be a Leader [with Kalyan Chatterjee]
- Informal insurance under individual liability loans: Evidence from India [with Somdutta Basu and Abhirup Sarkar]
- Optimal forgiveness in repeated interactions with utility shocks and endogenous partnership length [with Somdutta Basu and Suraj Shekhar]

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