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WORKING PAPER

Boycotts, power politics or trust building: how to prevent conflict?

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Abstract

In a game of imperfect information, the paper analyzes whether different types of intervention by third parties can ensure that political (ethnic, religious, social, ...) groups within a country will pursue a cooperative strategy and how easy it is to predict their effects. We conclude that a strong boycott is the most effective instrument, then comes a weak boycott, followed by power politics. Finally, apart from requiring very detailed information on the relevant parameters of the economy, the use of confidence building measures has a serious flaw: it is incapable of averting civil war.

JEL classification: C72; D74.
Keywords: Non Cooperative Games; Third-party Intervention; Conflict Prevention.

1 Introduction

The presence of different ethnic or social groups can lead to situations in which groups are excluded from participating fully in the economic activity. It might even give rise to civil war. Both situations are economically pernicious. They hamper economic progress and increase poverty. Civil war is often quoted as a main reason for the poor performance of many developing countries (Azam et al. [2001], Murdoch and Sandler [2002]). Hence, conflict prevention might be an important tool to eradicate extreme poverty and increase economic growth in developing countries. Surprisingly, scholarly attention has primarily focused on ex post third party intervention,[1] i.e. after a conflict has emerged. In contrast, our focus is ex ante: how to prevent conflict by outside intervention.

This paper presents a game-theoretical analysis of the effectiveness of different types of third-party intervention in preventing civil conflict. A first policy punishes the country through a boycott of its international trade in case of conflict. We analyze the effectiveness of two different types of boycott. The first type hits the country as soon as one of the parties chooses a fighting strategy by investing in arms and appropriating the value added of the economy. We call this a 'strong' boycott. The second type only punishes mutual fighting: it is implemented when both parties invest in arms and claim the country's riches, leading to a civil war. This type of boycott will be referred to as the 'weak' boycott. In our model, a strong boycott can always ensure that both parties choose a cooperative strategy. A weak boycott not always has that potential.

We model two other ways in which third parties, such as the United Nations, can try to influence the outcome of the strategic interaction between the groups. First, they can try to establish trust between the parties, by enacting confidence building policies. Analytically, we formulate a game with two groups under imperfect information. Each group is either of an opportunistic type whose strategy depends on its payoffs, or of a bad type who always fights. Groups are informed about their own type, but they are uncertain about the type of the other group. Confidence building policies attempt to increase the beliefs that the other group is of the opportunistic type.

Second, outside parties can pursue power politics by changing the balance of power between the groups (cf. Porsholt [1966], Elbadawi and Sambanis [2000], Regan [2002]). Neither power politics nor confidence building can guarantee that both parties will choose a cooperative strategy. We find that the effects of a change in power are easier to predict than changes in confidence.

In analyzing the effects of the four types of intervention, we ignore the problem of implementation. In reality, boycotts of countries are often circumvented, so that it might be impossible to enforce a boycott effectively. Manipulating confidence is

[1] See, among others, Betts [1994], Mandell [1996], Regan [1996, 1998], Doyle and Sambanis [2000], Boyce [2002].

not straightforward and changing the balance of power in conflicts might be very hard too. The question we ask ignores these issues of implementation: we analyze the effectiveness of different types of intervention in the absence of such problems. If even in the absence of implementation problems the potential effects of a particular intervention are limited and hard to predict, one can seriously question the usefulness of such an intervention.

The rest of the paper is organized as follows: Section 2 presents the core assumptions of the model, and calculates players' (expected) payoffs. Sections 3-4 develop the theoretical model and conduct a comparative static analysis of the respective types of intervention. Section 5 presents conclusions.

2 Assumptions and payoffs

Let N be the size of the population. The population is assumed to be split into two groups, K and L. αN is the size of the population in group K and $(1-\alpha)N$ is the size of the population in group L. Without loss of generality, we assume that $0 < \alpha \leq 1/2$, so that group K is not larger than group L. We follow Hirshleifer [1995] and exclude the within-group coordination and free-riding problem[2].

An economy has two sectors: a productive sector and a subsistence sector. The productive sector is that part of the private economy that creates a high value added (mining, trade or services). Subsistence jobs are usually found in agriculture or traditional trades. The total value created by the productive sector equals YN. We normalize the value created in subsistence jobs at zero, so that national income is equal to YN. The issue at stake is the division of the value added created in the economy over the two population groups. The way jobs are assigned is a typical way to determine how the value added will be divided between the two groups.

We consider a two stage game. In the first stage, groups have the following strategy space: either they choose to cooperate (C) with the other group, or they choose to fight (F). The *cooperative* strategy means that the group does not demand any preferential treatment in the division of value added (or, equivalently, in the way jobs are assigned). The *fighting* strategy on the other hand means that a group aims at a preferential treatment of its members. We will, furthermore, assume that if a player is indifferent between cooperating and fighting, i.e. if his expected utility of cooperating equals his expected utility of fighting, he will choose to cooperate.

Each of the groups can be of a bad or an opportunistic type. The former always plays F. The strategy of the latter depends on its pay-off. When a group has to decide on its strategy in the first stage, it knows its own type, but not the type of the

[2]As Robinson [2001] puts it, "in reality individuals act not purely in isolation, but also as part of larger social groupings and networks". In order to focus on the problem of group interaction, we assume that the social control within each group is sufficiently effective to overcome the free-riding problem. The high level of social control within ethnic groups is often the reason why the fight for resources occurs along 'ethnic' lines (Gates [2002]).

other group. π_o^L is group K's expectation that group L is of the opportunistic type, after group K's type is revealed. A higher value of π_o^L means that group K has more confidence in the cooperativeness of group L. Similarly, π_o^K is group L's expectation that group K is opportunistic after group L's type is revealed.

After the groups decide their strategy, the game enters its second stage, in which the value added will be distributed. We keep this stage as simple as possible. If both groups cooperate, the value added will be allocated randomly over the population and everybody receives Y. When only one group decides to fight, this group becomes dominant[3] and divides the entire value added equally among its members. To resolve the conflict in a conflict society, we include an exogenous variable ρ (resp. $[1-\rho]$) that reflects the probability that the members of group K (resp. L) will manage to 'capture' the value added. ρ can be interpreted as a measure of relative power of group K, and, as in Neary [1997], this measure of relative power allows for different interpretations. It "might be a negotiated division of the stock that takes into account the relative arms levels or it might be the outcome of a winner-take-all contest, where [ρ is player K's] probability of winning".

As a result of the choices made by the groups, there are four potential outcomes of the game: (C, C) when both choose to cooperate, (F, C) when the small group K chooses to fight while L chooses to cooperate, (C, F) when the reverse holds and (F, F) when both choose not to cooperate. The following table shows the nature of the corresponding societies:

(C, C):	fully integrated society	(C, F):	stratified society (L dominates)
(F, C):	stratified society (K dominates)	(F, F):	conflictual society

There are two types of cost that are associated with fighting and conflict. First, there is a private cost of choosing the fighting strategy. To implement preferential treatment in the second stage, a group needs to be able to enforce it. This can be done by purchasing arms, which entails a private cost for each member of the group equal to $c > 0$. In the economic literature on conflict (e.g., Hirshleifer [1991, 1995], Skaperdas [1992] and Neary [1997]) it is usually assumed that a group's probability of winning the conflict depends on the arms expenditures of the groups. In our model this implies that ρ depends on the size of both groups, α and $1-\alpha$. We choose to keep ρ exogenous, for ρ is an obvious channel through which third parties can try to manipulate the outcome of the game. Intervention by foreign governments, the United Nations or multinationals can change relative power, which influences the strategies chosen by the groups and thereby the nature of the resulting society. We compare how the equilibrium of the game changes as ρ is smaller than, equal to or larger than α. These situations can be interpreted as cases in which group K has, relative to its size, inferior, proportional and excessive power, respectively.

[3]Dominance reflects the situation in which one group manages to seize political and economic power. In the present context this means that the *dominant* group is in control and appropriates the value added.

Second, there are societal costs associated with a stratified or conflict society. In a stratified society, the value created by the productive sector (and thus national income) is reduced to $\delta_1 YN$, with $0 \leq \delta_1 \leq 1$. The robustness coefficient δ_1 is inversely related to several types of costs, such as costs due to the mis-allocation of resources (less trade, mis-allocation of talent), the negative incentive effects of nepotism and discrimination, the impact of antagonism between groups on the (over-) exploitation of common resources and a diminished social capital stock. In a conflict society, costs will be even higher since this situation leads to a disruption of all economic activity and a destruction of infrastructure[4]. These additional costs lower the robustness coefficient δ_2. National income is reduced to $\delta_1\delta_2 YN$ with $0 \leq \delta_2 \leq 1$. The magnitude of societal costs of stratification and conflict crucially depends on the kind of economic activity that generates high value added. Activities directed at the exploitation of primary resources such as mining are not much affected. They are concentrated geographically and only a limited number of transport links are needed to operate them. Service industries and trade are much more vulnerable[5]. We model the boycotts as exogenous decreases in the robustness coefficients. A strong boycott decreases δ_1 while a weak boycott decreases δ_2.

Let group $H \in \{K, L\}$ play strategy $X, Y \in \{C, F\}$. Let $u_H(X, Y)$ be the average payoff of a member of an opportunistic group H if group K plays strategy X and group L plays strategy Y. Straightforward calculation shows that individual payoffs are[6]:

$$\begin{array}{ll} u_K(C,C) = Y, & u_L(C,C) = Y, \\ u_K(C,F) = 0, & u_L(C,F) = \frac{1}{(1-\alpha)}\delta_1 Y - c, \\ u_K(F,C) = \frac{1}{\alpha}\delta_1 Y - c, & u_L(F,C) = 0, \\ u_K(F,F) = \frac{\rho}{\alpha}\delta_1\delta_2 Y - c, & u_L(F,F) = \frac{(1-\rho)}{(1-\alpha)}\delta_1\delta_2 Y - c. \end{array}$$

To summarize, groups can be of two types: they can be *opportunistic* (*good*) or *bad*. First nature decides to which type each group belongs. Players only know their own type with certainty. This information is used to form π_o^L and π_o^K, the belief that the other group is opportunistic. Furthermore, denote by $\pi_{c|o}^L$ ($\pi_{c|o}^K$) player K's belief that L (K) will be cooperative if he is of the opportunistic type. $p_{c|o}^L$ ($p_{c|o}^K$) is the probability that L (K) will be cooperative if he is of the opportunistic type. To solve such a game with imperfect information, we compute the Bayesian Nash (BN) equilibria of the game. A BN equilibrium consists of probability beliefs $(\pi_{c|o}^L, \pi_{c|o}^K)$ over strategy C and probabilities $(p_{c|o}^L, p_{c|o}^K)$ of choosing strategy C so that (i) the beliefs are correct: $p_{c|o}^L = \pi_{c|o}^L$ and $p_{c|o}^K = \pi_{c|o}^K$ and (ii) player L (K) chooses $p_{c|o}^L$ ($p_{c|o}^K$) so that his expected utility is maximized, given his beliefs.

[4]Hirshleifer [1988] (p. 205) calls it battle damage.

[5]See Schollaert and Van de gaer [2003] for a detailed discussion of how the structure of the economy influences societal costs of conflict.

[6]By assuming that individuals' utility functions are linear in income, we assume that they are risk neutral.

3 Bayesian Nash Equilibria

3.1 Characterization of the equilibria

We analyze the effects of boycotts, beliefs and changes in relative power by partitioning the $\delta_1 \times \delta_2$–space in different sections that correspond to different types of societies. This immediately shows the effects of a boycott: strong boycotts decrease δ_1, weak boycotts decrease δ_2. In definition 1 we define critical value functions that partition the $\delta_1 \times \delta_2$–space as shown in theorem 1. We delete the arguments of the functions in most of the discussion to simplify the notation.

Definition 1 *Critical value functions :*
$\delta_{2,K1}\left(\delta_1, \alpha, \rho, \frac{c}{Y}\right) \equiv \frac{\alpha}{\rho}\frac{1}{\delta_1}\frac{c}{Y}$.
$\delta_{2,L1}\left(\delta_1, \alpha, \rho, \frac{c}{Y}\right) \equiv \frac{1-\alpha}{1-\rho}\frac{1}{\delta_1}\frac{c}{Y}$.
$\delta_{2,K2}\left(\delta_1, \alpha, \rho, \frac{c}{Y}, \pi_o^L\right) \equiv -\frac{\pi_o^L}{(1-\pi_o^L)\rho} + \frac{\alpha}{(1-\pi_o^L)\rho\delta_1}\left[\pi_o^L + \frac{c}{Y}\right]$.
$\delta_{2,L2}\left(\delta_1, \alpha, \rho, \frac{c}{Y}, \pi_o^K\right) \equiv -\frac{\pi_o^K}{(1-\pi_o^K)(1-\rho)} + \frac{1-\alpha}{(1-\pi_o^K)(1-\rho)\delta_1}\left[\pi_o^K + \frac{c}{Y}\right]$.

Theorem 1 *BN Equilibria :*

(a) The BN Equilibria in pure strategies of the game with two opportunistic players result in the following kinds of societies:

$(C,C) \Leftrightarrow \delta_2 \leq \delta_{2,K2}$ *and* $\delta_2 \leq \delta_{2,L2}$ $\quad (C,F) \Leftrightarrow \delta_2 \leq \delta_{2,K1}$ *and* $\delta_2 \geq \delta_{2,L2}$;
$(F,C) \Leftrightarrow \delta_2 \geq \delta_{2,K2}$ *and* $\delta_2 \leq \delta_{2,L1}$ $\quad (F,F) \Leftrightarrow \delta_2 \geq \delta_{2,K1}$ *and* $\delta_2 \geq \delta_{2,L1}$.

(b) BN Equilibria in mixed strategies occur if and only if $p^L_{c|o} = \frac{1}{\pi_o^L}\frac{\rho\delta_1\delta_2 - \alpha\frac{c}{Y}}{\alpha-\delta_1+\rho\delta_1\delta_2}$ *and* $p^K_{c|o} = \frac{1}{\pi_o^K}\frac{(1-\rho)\delta_1\delta_2-(1-\alpha)\frac{c}{Y}}{1-\alpha-\delta_1+(1-\rho)\delta_1\delta_2}$ *and the following conditions hold simultaneously:*

1. *For player K: either*
   (i) $\delta_2 > \delta_{2,K1}$ *AND* $\delta_2 < \delta_{2,K2}$;
   (ii) $\delta_2 < \delta_{2,K1}$ *AND* $\delta_2 > \delta_{2,K2}$.
2. *For player L: either*
   (i) $\delta_2 > \delta_{2,L1}$ *AND* $\delta_2 < \delta_{2,L2}$;
   (ii) $\delta_2 < \delta_{2,L1}$ *AND* $\delta_2 > \delta_{2,L2}$.

To understand the theorem, we first establish the following equivalences for $\delta_2 \leq \delta_{2,KX}$.

$$\delta_2 \leq (\geq)\, \delta_{2,K1} \Leftrightarrow \rho\delta_1\delta_2 - \alpha\frac{c}{Y} \leq (\geq)\, 0. \tag{1}$$

$$\delta_2 \leq (\geq)\, \delta_{2,K2} \Leftrightarrow \pi_o^L\left[\alpha - \delta_1 + \rho\delta_1\delta_2\right] - \rho\delta_1\delta_2 + \alpha\frac{c}{Y} \geq (\leq) 0. \tag{2}$$

Similar equivalences can be established for $\delta_2 \leq \delta_{2,LX}$. They can be obtained out of (1), and (2) by replacing ρ by $1-\rho$, α by $1-\alpha$ and π_o^L by π_o^K.

We first illustrate the intuition for the conditions of the pure strategy equilibria. For values of $\delta_2 \geq \delta_{2,K1}$, for player K, the expected utility of fighting is larger than the expected utility of cooperating, given that L fights. Similarly, $\delta_2 \geq \delta_{2,L1}$ determines the values of δ_2 for which the expected utility of fighting for player L is larger than the expected utility of cooperation, given that K fights. The (F, F) equilibrium arises when both players fight given that the other player fights (compatibility of their optimizing decisions), and thus when $\delta_2 \geq \delta_{2,K1}$ and $\delta_2 \geq \delta_{2,L1}$. Similarly, $\delta_2 \geq \delta_{2,K2}$ if the expected utility of fighting for player K is larger than of cooperating, given that L cooperates. The (F, C) equilibrium occurs when player K fights given that L cooperates and L cooperates given that K fights. From the above, this occurs when $\delta_2 \geq \delta_{2,K2}$ and $\delta_2 \leq \delta_{2,L1}$. The intuition for the other pure strategy equilibria can be derived analogously.

A mixed strategy equilibrium has the property that the equilibrium probabilities equate the expected utility of cooperation to the expected utility of fighting:

$$\left[\rho\delta_1\delta_2 - \alpha\frac{c}{Y}\right]\left[1 - p_{c|o}^L\pi_o^L\right] - \left[\alpha - \delta_1 + \alpha\frac{c}{Y}\right]p_{c|o}^L\pi_o^L = 0. \tag{3}$$

Solving this expression for $p_{c|o}^L$ results in the expression given in theorem 1. $p_{c|o}^K$ can be derived from a similar condition for player L.

Corollary 1 shows that there are three types of BN equilibria in mixed strategies.

Corollary 1 *Types of mixed strategy equilibria :*

(a) Areas with mixed strategy equilibria and pure strategy equilibria of type (C, C) and (F, F).

(b) Areas with mixed strategy equilibria and pure strategy equilibria of type (F, C) and (C, F).

(c) Areas in which the mixed strategy equilibrium is the only equilibrium. This occurs when conditions 1 (ii) and 2 (i) of part b of theorem 1 hold true.

In the cases where the BN equilibrium is of type (a) or (b), there are three different BN equilibria: one in mixed strategies and two in pure strategies. For some parameter configurations, however, no equilibria in pure strategies exist. All finite games, however, have a Nash equilibrium: when no pure strategy equilibria exist, the Nash equilibrium will be of type (c).

As shown in theorem 1, the critical values in definition 1 play a crucial role in partitioning the $\delta_1 \times \delta_2$–space. To identify the different areas that are characterized by a different type of equilibrium, the following lemma lists important properties of the critical value functions.

Lemma 1 *Let $H \in \{K, L\}$:*

(a) The $\delta_{2,H1}$– and $\delta_{2,H2}$–curves are decreasing and convex with respect to δ_1.

(b) If $\pi_o^H > 0$, the slope of the $\delta_{2,K2}$–curve is more negative than the slope of the $\delta_{2,K1}$–curve.

(c) If $\pi_o^L = 0$ ($\pi_o^K = 0$), $\delta_{2,K2} = \delta_{2,K1}$ ($\delta_{2,L2} = \delta_{2,L1}$). If $\pi_o^L = 1$ ($\pi_o^K = 1$), the slope of the $\delta_{2,K2}$–curve ($\delta_{2,L2}$–curve) becomes $-\infty$.

(d) The $\delta_{2,K1}$– and $\delta_{2,K2}$–curves cross each other at the point:

$$\delta_K^* = \left(\alpha\left[1 + \frac{c}{Y}\right], \frac{1}{\rho}\frac{c}{Y + c}\right),$$

the $\delta_{2,L1}$– and $\delta_{2,L2}$–curves cross each other at the point:

$$\delta_L^* = \left((1-\alpha)\left[1 + \frac{c}{Y}\right], \frac{1}{1-\rho}\frac{c}{Y + c}\right).$$

(e) $\delta_{2,K1} \geq (\leq)\, \delta_{2,L1} \Leftrightarrow \alpha \geq (\leq)\, \rho$.

(f) The $\delta_{2,K2}$– and $\delta_{2,L2}$–curve cross at most once.

From (d), we get that the two curves cross in the positive orthant. Taken together, parts (b) and (d) of lemma 1 imply that the $\delta_{2,H2}$–curve crosses the $\delta_{2,H1}$–curve from above in the point δ_H^*. The area between the $\delta_{2,H2}$– and $\delta_{2,H1}$–curves to the northwest of δ_H^* satisfies the mixed strategy equilibrium condition (i) of theorem 1 for player H, while the area between the $\delta_{2,H2}$– and $\delta_{2,H1}$–curves to the southeast satisfies the mixed strategy equilibrium condition (ii) for player H. Since the area to the northwest satisfies $\delta_2 \leq \delta_{2,H2}$ and $\delta_2 \geq \delta_{2,H1}$, the intersection of both players' northwestern areas will also have a (C, C) and (F, F) equilibrium in pure strategies; they are mixed strategy equilibria of type (a) from corollary 1. The area to the southeast of δ_H^* satisfies $\delta_2 \geq \delta_{2,H2}$ and $\delta_2 \leq \delta_{2,H1}$. Therefore, the intersection of both players' southeastern areas has a mixed strategy equilibrium and a (C, F) and (F, C) equilibrium in pure strategies. This mixed strategy equilibrium is of type (b) described in corollary 1. In those areas where a region southeast to the crossing point of one player intersects the region to the northwest of the other player's intersection point, the mixed strategy equilibrium will be the only BN equilibrium. This area has a mixed strategy equilibrium of type (c) from corollary 1.

Part (c) of lemma 1 implies that the area in which mixed strategies might occur is largest when $\pi_o^K = 1$ and $\pi_o^L = 1$. As long as π_o^K and π_o^L are different from zero, there always exists a region in the $\delta_1 \times \delta_2$–space with an equilibrium in mixed strategies, provided that the relevant areas to the southeast or northwest of the players' δ_H^*

intersect. Moreover, when π_o^H becomes smaller, the $\delta_{2,H2}$–curve approaches the $\delta_{2,H1}$–curve, so that the area between the curves becomes smaller. Consequently, that part of the $\delta_1 \times \delta_2$–area where BN equilibria in mixed strategies might arise shrinks when π_o^H decreases. Mixed strategy equilibria vanish when $\pi_o^K = 0$ or $\pi_o^L = 0$.

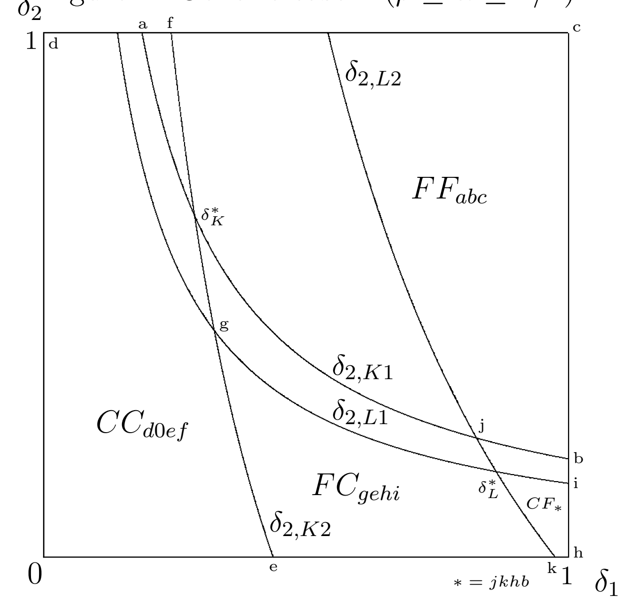
Part (d) of lemma 1 shows that the δ_H^*'s are independent of expectations. Expectations influence the type of equilibrium through their effect on the $\delta_{2,H2}$–curves, but these curves always pass through δ_H^*, irrespective of the value of π_o^H.

3.2 Generic cases

Corollary 2 describes three parameter configurations. We call them 'generic cases' since they demonstrate all the riches of the model: they show all the different kinds of equilibrium areas that might occur for the range of parameter values.

Corollary 2 *The 3 generic parameter configurations*[7] *can be described by figure 1, figure 2 and figure 3:*

Figure 1: Generic case 1 ($\rho \leq \alpha \leq 1/2$)



As ρ increases, we move from figure 1 over figure 2 to figure 3. The qualitative difference between figure 1 and 2 lies in the changed relative position of the $\delta_{2,K1}$ and $\delta_{2,L1}$ curves. In figure 1, the former lies above the latter, in figure 2 we see the reverse. The main difference between figure 2 and 3 is that the δ_2–coordinate of δ_K^*

[7] The figures depict the situations where the weak inequalities are strict inequalities. The cases where $\rho = \alpha = 1/2$ (perfect symmetry) and $\rho = \alpha < 1/2$ (proportional power) are discussed in the next section.

Figure 2: Generic case 2 ($\alpha \leq \rho \leq 1/2$)

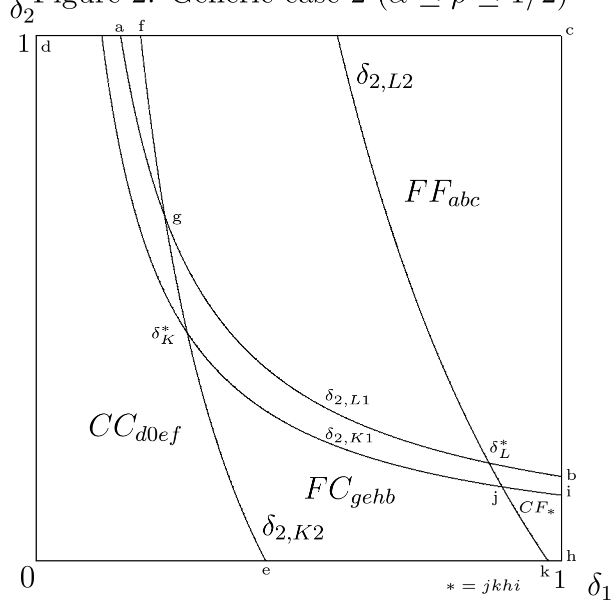
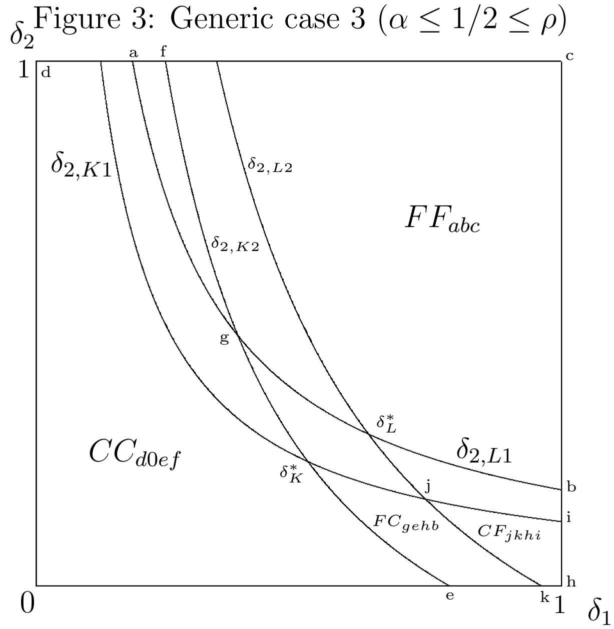


Figure 3: Generic case 3 ($\alpha \leq 1/2 \leq \rho$)



lies above the δ_2–coordinate of δ_L^* in figure 2, but not in figure 3. We will see in section 4.4 that these features are important to determine the comparative static effects of power politics and confidence building.

The three figures in corollary 2 show that the (C, C) equilibrium occurs when societal costs of conflict are high, while the (F, F) equilibrium occurs when societal costs of conflict are low. For $\rho \geq \alpha$, the (F, C)–area contains the (C, F)–area. This reflects the larger attraction the fighting option has for the smaller group: if it wins the conflict, the spoils will be divided among fewer individuals. Foreign intervention, by decreasing ρ can limit the size of the (F, C)–area, but will at the same time increase the (C, F)–area.

Not all the areas in the graphs occur for all possible parameter configurations. Which areas occur depends on whether the coordinates of the δ_H^*'s are between 0 and 1. This, in turn, crucially depends on the value of c/Y.

Corollary 3 *Comparative static effects of c/Y:*

(a) If $c/Y = 0$, (F, F) is always an equilibrium. If $\pi_o^L > 0$ and $\pi_o^K > 0$, there exist strictly positive values of (δ_1, δ_2) for which (C, C) is also an equilibrium. In this area there will be mixed strategy equilibria of type (a).

(b) If c/Y increases, the pure strategy area in which (C, C) occurs expands, and the area in which (F, F) occurs contracts.

(c) A necessary and sufficient condition to rule out the (F, F) equilibrium in pure strategies is $c/Y > \min\left\{\frac{\rho}{\alpha}, \frac{1-\rho}{1-\alpha}\right\}$.

(d) A necessary and sufficient condition for the (C, C) equilibrium to be a BN equilibrium in pure strategies for all δ_1 and δ_2 in $[0, 1]$ is that:

$$\frac{c}{Y} \geq \max\left\{\frac{(1-\pi_o^L)\rho}{\alpha} + \frac{(1-\alpha)\pi_o^L}{\alpha}, \frac{(1-\pi_o^K)(1-\rho)}{(1-\alpha)} + \frac{\alpha\pi_o^K}{(1-\alpha)}\right\}.$$

Part (a) of corollary 3 is no surprise: with zero private costs of conflict the situation in which both groups will choose to fight will be an equilibrium, irrespective of the other parameter values. Cooperation is also an equilibrium, provided that societal costs of conflict are sufficiently high. Part (b) is also intuitively clear. Increased private costs of conflict make fighting less attractive. This enlarges the area in which cooperation occurs and shrinks the conflict area. Part (c) shows that we can only rule out the conflict equilibrium if private costs of conflict are above a certain threshold level. Part (d) shows that private costs of conflict need to be above another threshold level to make the cooperative equilibrium a BN equilibrium for all values of (δ_1, δ_2).

Corollary 4 *If there exists a (C, C) equilibrium and there is no (F, F) equilibrium in pure strategies, then the (C, C) equilibrium is the unique pure strategy equilibrium.*

The restriction on c/Y in corollary 3 (d) ensures that the cooperative equilibrium is a BN equilibrium for all the parameter values we consider. The restriction on c/Y in corollary 3 (c) ensures that the fighting equilibrium will not be a BN equilibrium in that parameter space. So we know that, if both hold simultaneously, the (C, C) equilibrium is the only pure strategy equilibrium.

4 Effectiveness of intervention

4.1 Effects on mixed BN equilibria and on the partitioning curves

The comparative static properties of the mixed BN equilibria are easy to derive. They are listed in the next corollary. A '+' ('−') means that the probability increases (decreases) and a '0' means that the probability remains unchanged.

Corollary 5 *Effects of third party intervention on the mixed strategy equilibria:*

(a) *Effect on* $p^L_{c\|o}$			***(b)*** *Effect on* $p^K_{c\|o}$		
	type of equilibrium			*type of equilibrium*	
	(a)	*(b) and (c)*		*(a) and (c)*	*(b)*
π^L_o	-	-	π^L_o	*0*	*0*
π^K_o	*0*	*0*	π^K_o	-	-
c/Y	-	+	c/Y	-	+
δ_1	+	-	δ_1	+	-
δ_2	+	-	δ_2	+	-
ρ	+	-	ρ	-	+

From corollary 5, it follows that the only effects of intervention that do not depend on the type of mixed strategy equilibrium are those of trust building. Notice that an increased belief that the other player is of the 'good' type decreases the probability that a player cooperates. The reason is that, if the other player cooperates, it is possible to gain by fighting. If a player's belief that the other is of the opportunistic type increases, the expected gains from fighting increase, inducing him to decrease the probability of cooperation. This is an important conclusion: in areas where mixed strategy equilibria occur, confidence building decreases the probability that players opt for a cooperative strategy. The effect of all other policy measures on the probability that players cooperate depends on the type of mixed strategy equilibrium. The reason for this can be seen in equation (3). In a mixed strategy equilibrium of type (a), $\delta_2 > \delta_{2,K1}$ and $\delta_2 < \delta_{2,K2}$. From inequalities (1) and (2), the coefficient in front of $[1 - p^L_{c|o}\pi^L_o]$ is positive, and the coefficient in front of $[p^L_{c|o}\pi^L_o]$ is negative. An increase in c/Y decreases both the first and the second coefficient (making the second coefficient more negative). To ensure that equality (3) holds, the weight attached to the first term has to increase and the weight attached to the second term must decrease. Therefore $p^L_{c|o}$ has to decrease. If the mixed strategy equilibrium is of type (b), the signs of the terms in front of $[1 - p^L_{c|o}\pi^L_o]$ and $[p^L_{c|o}\pi^L_o]$ switch, leading to the opposite conclusion. This holds true irrespective of the parameter change considered. Consequently, to predict the effect of boycotts and power politics, we need to know the values of the parameters of the economy, since they determine the type of mixed strategy equilibrium that might occur. Therefore, in the next section, we only mention the possible types of mixed strategy equilibria for the corresponding cases. The comparative statics can then be derived using corollary 5.

The partitioning of the $\delta_1 \times \delta_2$–space, allows for a straightforward analysis of the effects of boycotts on the BN equilibria in pure strategies. Boycotts sanctioning any deviation from cooperation (strong boycotts) lower δ_1, boycotts sanctioning only when both players fight (weak boycotts) lower δ_2.

The effects of changed trust and power are more difficult to analyze. Their analysis requires the following lemmas that tell us how the different curves are affected by changes in beliefs and power.

Lemma 2 *Effects of beliefs on the critical value functions.*

- *An increase in π_o^L only rotates the $\delta_{2,K2}$–curve clockwise through the point δ_K^*.*
- *An increase in π_o^K only rotates the $\delta_{2,L2}$–curve clockwise through the point δ_L^*.*

Lemma 3 *Effects of power on the critical value functions. An increase in ρ has the following effects:*

- *the $\delta_{2,K1}$–curve shifts down-wards;*
- *the $\delta_{2,L1}$–curve shifts up-wards;*
- *the $\delta_{2,K2}$–curve rotates counterclockwise through the point $\left(\frac{\alpha}{\pi_o^L}\left[\pi_o^L + \frac{c}{Y}\right], 0\right)$;*
- *the $\delta_{2,L2}$–curve rotates clockwise through the point $\left(\frac{1-\alpha}{\pi_o^K}\left[\pi_o^K + \frac{c}{Y}\right], 0\right)$;*
- *δ_K^* shifts vertically down;*
- *δ_L^* shifts vertically up.*

Comparing the results in the two lemmas leads to the conclusion that the effect of trust on the curves is quite simple, while the effects of power are much more complicated. The following sections, however, show that the consequences for areas in the $\delta_1 \times \delta_2$–parameter space where the different pure strategy equilibria occur are more straightforward for power politics. Before analyzing the full complexity of the generic cases, we consider two specific cases: the symmetric case and the proportional power case.

4.2 The symmetric case

The simplest case to analyze is the symmetric case. Here $\delta_{2,KX} = \delta_{2,LX}$ for $X = 1, 2$. This situation has two interesting properties. First, not surprisingly, and very specific for this symmetric case, is that the (C, F)– and the (F, C)–areas coincide. The area will not be empty if $\pi_o^K = \pi_o^L \neq 0$ and generates a mixed strategy equilibrium of type (b). Second, if $\pi_o^K = \pi_o^L \neq 0$, lemma 1 (b) implies that there exists an area northwest of $\delta_K^* = \delta_L^*$ with a mixed strategy equilibrium of type (a). Figure 4 depicts this situation.

Corollary 6 gives the comparative static effects of changes in the parameter values (i.e. implications of the different intervention possibilities) on the equilibrium areas and the types of mixed strategy equilibria that can occur. From here on, a '+' ('−') means that the area increases (decreases), a '0' means that the area remains unchanged, and a '?' indicates that the impact on the area is ambiguous.

Corollary 6 *Symmetry: $\alpha = \rho = 1/2$ and $\pi_o^K = \pi_o^L$.*

(a) Size of the pure strategy equilibria areas:

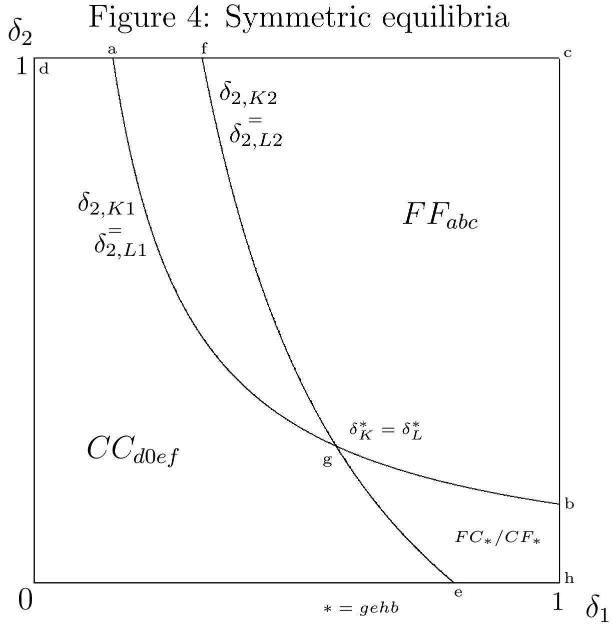
	(F, F)	(C, C)	(F, C)	(C, F)
π_o^L	0	-	+	0
π_o^K	0	-	0	+
$\rho\uparrow$	-	-	+	-
$\rho\downarrow$	-	-	-	+

(b) Types of mixed strategy equilibria:

To the northwest of $\delta_K^* = \delta_L^*$, the equilibrium in mixed strategies is of type (a), to the southeast of $\delta_K^* = \delta_L^*$ it is of type (b). No equilibria of type (c) are possible.

Corollary 6 (a) shows that increases in trust not necessarily enhance cooperation in a symmetric society. Some societies that were cooperative before an increase in π_o^L become dominant societies afterwards, with the group that has increased trust, group K, dominant. For K, the expected utility of cooperation if L cooperates, has become smaller than the expected utility of fighting. The effect of a marginal change in π_o^L on the expected utility of cooperation is reflected by $[Y]$, the effect on the expected utility of fighting by $\left[\frac{1}{\alpha}\delta_1 Y - \frac{\rho}{\alpha}\delta_1\delta_2 Y\right]$. Since $\delta_2 < \delta_{2,K1}$, and, after the increase in π_o^L, δ_2 is larger than $\delta_{2,K2}$, we have from the combined equivalences (1) and (2) that the latter effect is larger than the former. The intuition for this effect is similar to the intuition for the negative effect of increased trust on the mixed strategy equilibria (see the discussion following corollary 5). Finally, note that a simultaneous increase in π_o^K and π_o^L expands the (C, C)–area to the northwest of δ_K^*, but contracts the

Figure 4: Symmetric equilibria



(C, C)–area to the southeast of δ^*_K. Hence, even the effect of increased mutual trust on the (C, C)–area is ambiguous.

Increasing the power of group K decreases the areas in which otherwise a conflict society or a fully integrated society comes about. These societies might now become stratified, with group K dominant. The (C, F)–area has decreased and is now a strict subset of the (F, C)–area. The reason for these changes is twofold: the increase in ρ increases the expected advantage of fighting for group K and decreases the expected advantage of fighting for group L. Note also that the shrinkage of the (C, F)–area implies that the mixed strategy area shrinks.

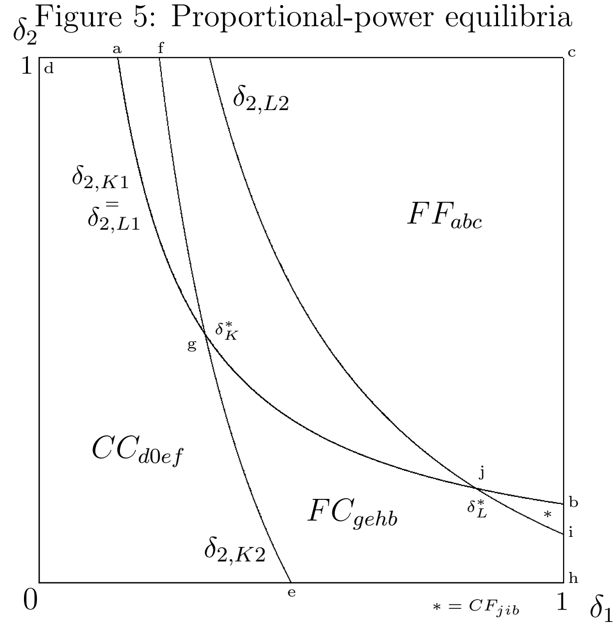
Finally, here too, the effects of boycotts are easily analyzed: strong boycotts decrease δ_1 and can always lead to a (C, C) equilibrium, while weak boycotts will not always achieve this. They will only lead to a (C, C) equilibrium if δ_1 is sufficiently low.

4.3 The proportional power case

Consider now a game between two groups of unequal size with proportional power: $\rho = \alpha$, so that $\delta_{2,K1} = \delta_{2,L1}$. We also maintain the assumption that $\pi^L_o = \pi^K_o$, which implies that the point where the $\delta_{2,K2}$–curve cuts the δ_1–axis lies below the point where the $\delta_{2,L2}$–curve cuts the axis, so that $\delta_{2,K2}$ is smaller than $\delta_{2,L2}$. Figure 5 depicts this situation.

Comparison with the symmetrical situation shows some interesting features. First, for given parameter values, both continue to have the same $\delta_{2,K1} = \delta_{2,L1}$–curve. Hence the area in which the (F, F) equilibrium results is the same. Second the $\delta_{2,K2}$–curve

Figure 5: Proportional-power equilibria



is shifted to the left, the $\delta_{2,L2}$–curve to the right. The leftward shift of $\delta_{2,K2}$ makes the (C,C)–area smaller. Third, the (F,C)– and (C,F)–area no longer coincide. The (F,C)–area strictly contains the (C,F)–area. In that sense, the smaller group is more aggressive. The incentive causing this is the fact that, if the smaller group becomes dominant in a stratified society, it divides the cake between fewer individuals, so that each member of the group obtains more. Fourth, as before, mixed strategy equilibria are found in the areas where the (C,C)– and (F,F)–areas or the (F,C)– and (C,F)–areas overlap. The size of these overlapping areas has decreased compared to the symmetric equilibrium. Corollary 7 lists the comparative static effects.

Corollary 7 *Proportional Power :* $\alpha = \rho < 1/2$ *and* $\pi_o^K = \pi_o^L$.

(a) Size of the pure strategy equilibria areas:

	(F,F)	(C,C)	(F,C)	(C,F)
π_o^L	*0*	*?*	*+*	*0*
π_o^K	*0*	*?*	*0*	*+*
$\rho \uparrow$	-	-	+	-
$\rho \downarrow$	-	+	-	+

(b) Types of mixed strategy equilibria: To the northwest of δ^*_K*, the equilibrium in mixed strategies is of type (a), to the southeast of* δ^*_L *it is of type (b). No equilibria of type (c) are possible.*

Corollary 7 shows that in asymmetric societies characterized by proportional power, we find that an increased belief that the other group is of the opportunistic type does not necessarily enhance cooperation. Some fully integrated societies become stratified with the group with increased belief dominant.

An increase in the power of the smaller group negatively affects this group's cooperative behavior, and increases the range of economies in which it becomes dominant. Contrary to the symmetric case, a decrease in ρ now has a positive effect on the size of the (C, C)–area. This suggests that it is possible to offset the advantage of the small group by changing the balance of power in favor of the larger group. Decreasing ρ, however, also increases the (C, F)–area. This is due to two effects: some (F, F) and (F, C) societies become (C, F) societies.

4.4 The generic cases

The effects of changes in beliefs and power in the generic cases are often only determined under specific conditions. We use the condition ($\boldsymbol{i}$), saying that the $\delta_{2,K2}$– and $\delta_{2,L2}$–curves do not intersect, to determine some effects and we refer to the respective generic cases as *G1*, *G2* and *G3*.

We use this condition in corollary 8.

Corollary 8 *Generic cases:*

(a) Size of the pure strategy equilibria areas:

	(F, F)	(C, C)	(F, C)	(C, F)
π_o^L	*0*	*?*	*G1: -* / *otherwise: ?*	*0*
π_o^K	*0*	$\boldsymbol{i}$*: 0* / *otherwise: ?*	*0*	*G1: ?* / *G2 and 3: -*
ρ	*G1: +* / *G2 and 3: -*	$\boldsymbol{i}$*: -* / *otherwise: ?*	+	-

(b) Types of mixed strategy equilibria:

In generic cases 2 and 3, no mixed strategy equilibrium of type (c) are possible.

The effects in corollary 8 clearly confirm the previous results. However, they also show that decreasing symmetry in the model, increases ambiguity in the results.

Definition 2 *For notational convenience, we define the following variables:*

$R_1 = \pi_o^L \left(\frac{\delta_1}{\alpha} - 1\right);$ $\qquad R_2 = \pi_o^K \left(\frac{\delta_1}{1-\alpha} - 1\right);$

$R_3 = \left[\frac{c}{Y} + \pi_o^L \left(1 - \frac{\delta_1}{\alpha}\right)\right] \frac{\alpha}{(1-\pi_o^L)\delta_1\delta_2};$ $\qquad R_4 = 1 - \left[\frac{c}{Y} + \pi_o^K \left(1 - \frac{\delta_1}{1-\alpha}\right)\right] \frac{1-\alpha}{(1-\pi_o^K)\delta_1\delta_2}.$

Corollary 9 discusses whether a certain third party intervention can, with strictly positive private costs of conflict, but irrespective of other parameter values, guarantee that there exists a (C, C) equilibrium[8].

Corollary 9 *Potential to achieve a fully integrated society ($c > 0$) when both players are opportunistic:*

(a) A strong boycott (reduction of δ_1) can always ensure that there exists a (C, C) equilibrium for all parameter values.

(b) A weak boycott (reduction of δ_2) can ensure the existence of a (C, C) equilibrium if and only if $c/Y \geq \max\{R_1, R_2\}$.

(c) Manipulation of group power (changing ρ) can ensure the existence of a (C, C) equilibrium if and only if $c/Y \geq \max\{R_1, R_2\}$ and

$$\frac{c}{Y} \geq \frac{(1-\pi_o^L)(1-\pi_o^K)\delta_1\delta_2 + \alpha(1-\pi_o^K)(R_1) + (1-\alpha)(1-\pi_o^L)(R_2)}{\alpha(1-\pi_o^K) + (1-\alpha)(1-\pi_o^L)}.$$

To ensure the possibility of a (C, C) equilibrium, ρ has to be changed in such a way that $R_4 \leq \rho \leq R_3$.

(d) Manipulation of trust (changing π_o^L and π_o^K) can ensure the existence of a (C, C) equilibrium if and only if:

$$\frac{c}{Y} \geq \max\left\{\min\left\{\frac{\delta_1}{\alpha} - 1, \frac{\rho\delta_1\delta_2}{\alpha}\right\}, \min\left\{\frac{\delta_1}{1-\alpha} - 1, \frac{(1-\rho)\delta_1\delta_2}{1-\alpha}\right\}\right\}$$

π_o^L must be increased if $\min\left\{\frac{\delta_1}{\alpha} - 1, \frac{\rho\delta_1\delta_2}{\alpha}\right\} = \frac{\delta_1}{\alpha} - 1$, and it must be decreased otherwise. Similarly, if $\min\left\{\frac{\delta_1}{1-\alpha} - 1, \frac{(1-\rho)\delta_1\delta_2}{1-\alpha}\right\} = \frac{\delta_1}{1-\alpha} - 1$, π_o^K must be increased, and it must be decreased otherwise.

Parts (a) and (b) of corollary 9 follow from equations (1) and (2). δ_1 and δ_2 enter equation (1) symmetrically and manipulation of δ_1 and δ_2 can always guarantee that, given that L fights, the expected advantage of cooperation for K is larger than of fighting. In equation (2), the effect of δ_1 on the left-hand side of the second inequality is always negative, but the sign of the effect of δ_2 is not determined. Moreover, when $\delta_1 = 0$, we see that the left-hand side is positive, but when $\delta_2 = 0$, this need not be the case. Therefore, manipulation of δ_1 can guarantee that the expected advantage of cooperation for K is larger than of fighting, given that L cooperates, while manipulating δ_2 cannot guarantee this.

[8] Ruling out that $c = 0$ eliminates the case described in corollary 2 (a), so that there always exists an area where (C, C) is the unique equilibrium.

To understand parts (c) and (d), note that to allow for the fully integrated society to be an equilibrium outcome, we must have that $\delta_2 \leq \delta_{2,K2}$, which means that the left-hand side of the second inequality in expression (2) has to be positive. This cannot be guaranteed for all values of $c/Y > 0$, by solely manipulating ρ or π_o^L.

From corollary 9 (a) and (b) it is straightforward to see that the strong boycott has more potential than the weak boycott: to make a cooperative equilibrium possible, no restrictions on the costs of fighting (c/Y) are needed. Similarly, we can infer from corollary 9 (b) and (c) that a weak boycott has more potential than manipulating the balance of power: for the manipulation of ρ to make (C, C) a possible equilibrium one more restriction needs to hold. Comparing the effectiveness of weak boycotts and power politics to the manipulation of trust leads to ambiguous results: it highly depends on the parameter values of the economy. Strong boycotts, however, since no restrictions on c/Y are necessary, are more effective than trust manipulation.

From an international–policy point of view, it is not only interesting to know when the respective intervention types will manage to make cooperation an equilibrium strategy, it is also important to know whether these intervention types will manage to exclude the (F, F) equilibrium. Corollary 10 shows the ability of the respective interventions to exclude mutual fighting as a BN equilibrium for all parameter values.

Corollary 10 *Potential to rule out a conflictual society ($c > 0$) when both players are opportunistic:*

(a) Both types of boycott can ensure that the fighting equilibrium, (F, F), is no equilibrium outcome of the game.

(b) The manipulation of the balance of power can ensure that the fighting equilibrium, (F, F), is no equilibrium outcome of the game if and only if $\frac{c}{Y} > \delta_1\delta_2$.

(c) It is not possible to exclude the (F, F) equilibrium by manipulating trust levels.

The preceding discussion sums up as follows: boycotts have to be strengthened to make cooperation possible, their impact is fairly easy to predict. Manipulation of the balance of power, "power politics", is more tricky, but its effects are still quite easy to predict: ρ has to be manipulated in such a way that it lies between R_4 and R_3, and these constraints depend on the parameters of the economy. Moreover, the right manipulation of ρ can decrease the size of the (F, F)–area. To determine the way power has to be manipulated to accomplish this, we only need to know whether the small group has, relative to its size, inferior (generic case 1) or excessive power (generic cases 2 and 3). Furthermore, it seems fair to state that the manipulation of trust is very delicate: while it is commonplace to assume that positive beliefs foster cooperation and negative beliefs may lead to conflict, we find that the support for this statement is limited in our model. First of all, the impact of beliefs on the occurrence of a fully integrated society is highly context-specific and can go either way.

If condition $\boldsymbol{i}$ holds, an increase in π_o^L will eliminate the (C, C)–equilibrium for some societies to the south east of δ_K^*, and create a (C, C)–equilibrium for some societies to the north west of δ_K^*. Small differences in parameter values in the neighborhood of δ_K^* can determine what the consequences are of confidence building in an economy. Second, an increase in π_o^K has either no effect (if condition $\boldsymbol{i}$ holds) or an adverse effect on the size of the (C, C) equilibrium. Third, part (b) of corollary 8 provides an exhaustive list of the mixed strategy equilibria that can not occur. It implies that it is impossible to rule out the existence of mixed strategy equilibria of type (a) and (b). We know from corollary 5 that increased trust always decreases the probability that a player chooses to cooperate, while the effect of power changes will be different for mixed strategy equilibria of type (a) and (b). Finally, corollary 9 and 10 show us that by merely manipulating trust, it is impossible to 'enforce' cooperation by both parties: it is possible to ensure that (C, C) is *a* BN equilibrium, but since changes in beliefs have no effect on the size of the (F, F)–area it is not possible to ensure that (C, C) is *the only* BN equilibrium. We believe that this result casts serious doubts on the usefulness or at least attractiveness of trust manipulation as an intervention tool for third parties in conflict prevention.

Moreover, provided that third party intervention aims at eliminating all non-cooperative behavior, we can, because of corollary 4, use corollary 9 and 10 to postulate an unmistakable effectiveness-ranking in the four intervention types we have considered.

Corollary 11 *The strong boycott which punishes all non-cooperative behavior constitutes an effective intervention tool, no matter what the cost of fighting is. Second comes the weak boycott, followed by power politics. Finally, confidence building seems to be the least effective intervention tool.*

In order to exclude the fighting equilibrium and to make mutual cooperation a BN equilibrium, the respective intervention types require different restrictions on the cost of fighting. With corollary 9 listing the conditions for the interventions to make mutual cooperation an equilibrium outcome and corollary 10 listing the conditions for the intervantions to exclude the fighting equilibrium, we have for each intervention type two conditions which have to be fulfilled. By comparing the strongest condition of the respective interventions, we can easily show that the strong boycott is most effective, followed by, first, the weak boycott, then power politics and, finally, confidence building.

5 Conclusion

In this paper we use a simple game theoretic model to analyze what outside parties such as the United Nations can do to prevent a civil conflict within a country. We focused on the potential effects of boycotts, trust building and power politics and ignored problems of implementation of these interventions. Admittedly, implementation problems can be huge, but we argue that, if in the absence of such problems an intervention lacks potential, we probably should not even consider its implementation anyway.

Boycotts can be of two types: strong boycotts sanction any non cooperative behavior while weak boycotts only sanction joint non cooperative behavior. Only the former type of boycott can, irrespective of the costs of conflict, always ensure that cooperation is an equilibrium strategy for both parties. The reason is obvious.

Obviously, with costs of conflict rising above a certain level, each policy measure has the potential to ensure that cooperation is an equilibrium strategy for both players. However, for low costs of conflict (costs below a certain threshold), our model shows that weak boycotts and the manipulation of, respectively, the balance of power and confidence building, don't have the potential to ensure that both players cooperate, irrespective of the other parameters that characterize the economy.

The effects of weak boycotts are easiest to analyze. They have the potential to prevent that society becomes conflictual, but unless costs of conflict are high enough, they can not guarantee that a fully integrated society is always an equilibrium.

Power politics can also prevent that societies will be conflictual and can ensure that the fully integrated society is an equilibrium if private costs of armaments are larger than a certain threshold (a higher threshold that for the weak boycott). To know which shift in the balance of power of opposing groups must be established to decrease the range of parameters for which society is conflictual, we have to know whether the small group has, relative to its size, inferior or excessive power. From all the interventions we considered, confidence building seems to be the least feasible and predictable one. Societies that are conflictual will be so, irrespective of the level of trust that exists between its groups. Their effects on the size of the different equilibrium areas are context specific. Moreover, what is sometimes needed to establish cooperation between both groups is a decrease in trust. If a group believes that it is very likely that the other group will cooperate, a group can be induced to fight to reap the rewards of becoming the dominant group in society. Under such circumstances, a decreased trust in the cooperative nature of the other group can establish cooperation.

Based on these results, a clear hierarchy of the intervention measures appears: strong boycotts, weak boycotts, power politics and confidence building. Strangely enough though, in contemporary international politics, confidence building seems to be a far more popular intervention policy than boycotts are. We show, however, that a strong boycott is the more predictable and more effective policy measure to prevent conflict and non cooperative behavior of opposing groups. Hence, this paper clearly pleads for a reappraisal of boycotts in conflict prevention.

6 Appendix: Proofs

Proof of theorem 1:

(a) First we consider equilibria in pure strategies. Player K will cooperate (fight) if and only if the expected advantage of cooperating is larger (smaller) than the expected advantage of fighting:

$$\begin{aligned}
&\pi^L_{c|o}\pi^L_o u_K(C,C) + \left[1-\pi^L_{c|o}\pi^L_o\right] u_K(C,F) \\
&\qquad \geq\ (\leq)\ \pi^L_{c|o}\pi^L_o u_K(F,C) + \left[1-\pi^L_{c|o}\pi^L_o\right] u_K(F,F) \\
\Leftrightarrow\quad & \pi^L_{c|o}\pi^L_o\left[Y-\frac{1}{\alpha}\delta_1 Y + c\right]\ \geq\ (\leq)\ \left[1-\pi^L_{c|o}\pi^L_o\right]\left[\frac{\rho}{\alpha}\delta_1\delta_2 Y - c\right]. \qquad (4)
\end{aligned}$$

For player L we obtain a similar result:

$$L \text{ chooses } C\,(F) \Leftrightarrow$$

$$\pi^K_{c|o}\pi^K_o\left[Y-\frac{1}{1-\alpha}\delta_1 Y + c\right] \geq (\leq) \left[1-\pi^K_{c|o}\pi^K_o\right]\left[\frac{1-\rho}{1-\alpha}\delta_1\delta_2 Y - c\right]. \qquad (5)$$

A first equilibrium is the cooperative equilibrium: $\pi^L_{c|o} = \pi^K_{c|o} = 1$. With K choosing C and $\pi^L_{c|o} = 1$, (4) requires that:

$$\begin{aligned}
& \pi^L_o\left[Y-\frac{1}{\alpha}\delta_1 Y + c\right] \geq \left[1-\pi^L_o\right]\left[\frac{\rho}{\alpha}\delta_1\delta_2 Y - c\right] \\
\Leftrightarrow\quad & \pi^L_o\left[Y-\frac{1}{\alpha}\delta_1 Y\right] + c \geq \left[1-\pi^L_o\right]\frac{\rho}{\alpha}\delta_1\delta_2 Y \\
\Leftrightarrow\quad & \delta_2 \leq -\frac{\pi^L_o}{\left(1-\pi^L_o\right)\rho} + \frac{\alpha}{\left(1-\pi^L_o\right)\rho\delta_1}\left[\pi^L_o + \frac{c}{Y}\right] \equiv \delta_{2,K2}.
\end{aligned}$$

Similarly, with L choosing C and $\pi^K_{c|o} = 1$, (5) yields

$$\delta_2 \leq -\frac{\pi^K_o}{\left(1-\pi^K_o\right)(1-\rho)} + \frac{1-\alpha}{\left(1-\pi^K_o\right)(1-\rho)\delta_1}\left[\pi^K_o + \frac{c}{Y}\right] \equiv \delta_{2,L2}.$$

A second equilibrium is the fighting equilibrium: $\pi^L_{c|o} = \pi^K_{c|o} = 0$. In this case statements (4) and (5) show that the sign of the inequalities has to be reversed. Reversed inequality (4) with $\pi^L_{c|o} = 0$ requires:

$$0 \leq \left[\frac{\rho}{\alpha}\delta_1\delta_2 Y - c\right] \quad\Leftrightarrow\quad \delta_2 \geq \frac{\alpha}{\rho}\frac{1}{\delta_1}\frac{c}{Y} \equiv \delta_{2,K1}.$$

Similarly, the reversed inequality (5) with $\pi^K_{c|o} = 0$ requires that:

$$\delta_2 \geq \frac{1-\alpha}{1-\rho}\frac{1}{\delta_1}\frac{c}{Y} \equiv \delta_{2,L1}.$$

In the third pure strategy equilibrium, group K fights, while group L cooperates: $\pi^K_{c|o} = 0$ and $\pi^L_{c|o} = 1$. It is easy to verify that this requires $\delta_2 \geq \delta_{2,K2}$ and $\delta_2 \leq \delta_{2,L1}$. The final equilibrium in pure strategies is the one in which group K cooperates and group L fights. This happens if and only if $\delta_2 \geq \delta_{2,L2}$ and $\delta_2 \leq \delta_{2,K1}$.

(b) The expected utility of player K when his strategy is $p^K_{c|o}$ is:

$$\begin{aligned} E(u) &= p^K_{c|o}\pi^L_{c|o}\pi^L_o Y \\ &\quad + \left(1 - p^K_{c|o}\right)\left[\pi^L_{c|o}\pi^L_o\left[\frac{1}{\alpha}\delta_1 Y - c\right] + \left(1 - \pi^L_{c|o}\pi^L_o\right)\left[\frac{\rho}{\alpha}\delta_1\delta_2 Y - c\right]\right]. \end{aligned}$$

Mixed strategy equilibria are interior solutions. Therefore, they satisfy the first order condition:

$$\frac{\partial E(u)}{\partial p^K_{c|o}} = \pi^L_{c|o}\pi^L_o\left[Y - \frac{1}{\alpha}\delta_1 Y + \frac{\rho}{\alpha}\delta_1\delta_2 Y\right] - \left[\frac{\rho}{\alpha}\delta_1\delta_2 Y - c\right] = 0.$$

This yields:

$$\pi^L_{c|o}\pi^L_o\left[Y - \frac{1}{\alpha}\delta_1 Y + \frac{\rho}{\alpha}\delta_1\delta_2 Y\right] = \left[\frac{\rho}{\alpha}\delta_1\delta_2 Y - c\right]. \tag{6}$$

Equating $\pi^L_{c|o}$ to $p^L_{c|o}$ and solving expression (6) yields $p^L_{c|o} = \frac{1}{\pi^L_o}\frac{\rho\delta_1\delta_2 - \alpha\frac{c}{Y}}{\alpha - \delta_1 + \rho\delta_1\delta_2}$. The result for $p^K_{c|o}$ can be obtained in a similar way. The probabilities $p^L_{c|o}$ and $p^K_{c|o}$ have to lie between zero and one.

First consider $p^L_{c|o}$. If $\rho\delta_1\delta_2 - \alpha\frac{c}{Y} > 0$, we must have $\pi^L_o(\alpha - \delta_1 + \rho\delta_1\delta_2) > \rho\delta_1\delta_2 - \alpha\frac{c}{Y}$ for $p^L_{c|o} < 1$ (note that the combination of the two inequalities ensures that $p^L_{c|o} > 0$). Thus,$\delta_2 > \delta_{2,K1}$ and $\delta_2 < \delta_{2,K2}$ ensure that $0 < p^L_{c|o} < 1$. If $\delta_2 < \delta_{2,K1}$ and $\delta_2 > \delta_{2,K2}$, we also have $0 < p^L_{c|o} < 1$. Now, consider $p^K_{c|o}$. A similar reasoning shows that $0 < p^K_{c|o} < 1$ holds if either $\delta_2 > \delta_{2,L1}$ and $\delta_2 < \delta_{2,L2}$, or $\delta_2 < \delta_{2,L1}$ and $\delta_2 > \delta_{2,L2}$.

Proof of corollary 1 From theorem 1 (b), mixed strategy equilibria can, in principle, arise in three cases. First, in areas where 1 (i) and 2 (i) hold true. In that case the necessary and sufficient conditions of the same theorem, part (a) for pure strategy equilibria of type (C, C) and (F, F) are satisfied. Second, in areas where 1 (ii) and 2 (ii) hold true, the conditions for pure strategy equilibria of type (F, C) and (C, F) are met. Third, in areas where 1 (ii) and 2 (i) hold true, none of the conditions for pure strategy equilibria are met. This is the mixed strategy equilibrium of type (c). Note that we can drop the case where conditions 1 (i) and 2 (ii) are satisfied simultaneously. Condition 1 (i) requires that $\delta_1 > \alpha (1 + (c/Y))$ while condition 2 (ii) requires that $\delta_1 < (1 - \alpha) (1 + (c/Y))$. Since $\alpha \leq 1 - \alpha$, these two conditions are irreconcilable.

Proof of lemma 1 Parts (a) and (b) follow from simple differentiation of the critical value functions given in definition 1 with respect to δ_1. (c) follows directly from the definitions of the critical value functions and their derivatives with respect to δ_1. To verify (d), for $H = K$ and L, substitute the δ_1–coordinate of δ_H^* in the equations for $\delta_{2,HX}$ $(X = 1, 2)$ to obtain the δ_2–coordinate of δ_H^*. (e) follows directly from the definitions of $\delta_{2,K1}$ and $\delta_{2,L1}$. To establish (f), equate the expressions for $\delta_{2,K2}$ and $\delta_{2,L2}$. There is a unique value for δ_1 solving this equation.

Proof of corollary 2 The shape of the curves is the same in all three cases and follows directly from lemma 1 (a). (d) says that the curves for each player H cross at δ_H^*, and (b) says that the $\delta_{2,H2}$–curve crosses the $\delta_{2,H1}$–curve from above.

Case 1: Since $\alpha \leq 1/2$, from lemma 1 (d), the δ_1–coordinate of δ_K^* is smaller than the corresponding coordinate for δ_L^*. From the same lemma, $\rho \leq 1/2$ implies that the δ_2–coordinate of δ_K^* is larger than the corresponding coordinate of δ_L^*. Part (e) of that lemma implies that the $\delta_{2,K1}$–curve lies above the $\delta_{2,L1}$–curve.

Case 2: Due to the fact that $\alpha \leq 1/2$, lemma 1 (d), implies that the δ_1–coordinate of δ_K^* is smaller than the corresponding coordinate for δ_L^* and $\rho \leq 1/2$ implies that the δ_2–coordinate of δ_K^* is larger than the corresponding coordinate of δ_L^*. Part (e) of that lemma implies that the $\delta_{2,K1}$–curve lies below the $\delta_{2,L1}$–curve.

Case 3: $\alpha \leq 1/2$ implies, by virtue of lemma 1 (d), that the δ_1–coordinate of δ_K^* is smaller than the corresponding coordinate for δ_L^* and $\rho \geq 1/2$ implies that the δ_2–coordinate of δ_K^* is smaller than the corresponding coordinate of δ_L^*. Part (e) of that lemma implies that the $\delta_{2,K1}$–curve lies below the $\delta_{2,L1}$–curve.

Proof of corollary 3

(a) If $c/Y = 0$, the $\delta_{2,K1}$– and $\delta_{2,L1}$–curve coincide with the δ_1-axis, so that for all non-negative values of $\delta_2 \geq \delta_{2,K1}$ and $\delta_2 \geq \delta_{2,L1}$. From theorem 1 (a),

(F,F) is always an equilibrium. From lemma 1 (d), it follows immediately that $\delta_K^* = (\alpha, 0)$ and $\delta_L^* = (1-\alpha, 0)$ if $c/Y = 0$. With $0 < \alpha \leq 1/2$ and $\pi_o^L \neq 0$ and $\pi_o^K \neq 0$, the $\delta_{2,K2}$– and $\delta_{2,L2}$–curves are negatively sloped, so that there will always exist values of (δ_1, δ_2) that lie below the $\delta_{2,K2}$– and $\delta_{2,L2}$–curve and for which (C,C) is an equilibrium.

(b) From definition 1, it is clear that increases in c/Y push up each player's $\delta_{2,H1}$– and $\delta_{2,H2}$–curves, so that the (C,C)–area expands and the (F,F)–area contracts.

(c) From theorem 1 (a) and lemma 1 (a), we know that no (F,F) equilibrium will occur if the point $(1,1)$ lies outside the (F,F) area, that is, if:

$$\begin{aligned} 1 < \delta_{2,K1}(1,\alpha,\rho,c/Y) \quad & \mathit{or} \quad 1 < \delta_{2,L1}(1,\alpha,\rho,c/Y) \\ \Leftrightarrow 1 < \frac{\alpha}{\rho}\frac{c}{Y} \quad & \mathit{or} \quad 1 < \frac{1-\alpha}{1-\rho}\frac{c}{Y} \\ \Leftrightarrow \frac{c}{Y} > \frac{\rho}{\alpha} \quad & \mathit{or} \quad \frac{c}{Y} > \frac{1-\rho}{1-\alpha}. \end{aligned}$$

So, to rule out the (F,F) equilibrium, it is necessary and sufficient that:

$$\frac{c}{Y} > \min\left\{\frac{\rho}{\alpha}, \frac{1-\rho}{1-\alpha}\right\}.$$

(d) From theorem 1 (a) and lemma 1 (a), we know that there exists a (C,C) equilibrium for all the parameter configurations within the $\delta_1 \times \delta_2$–space if the point $(1,1)$ lies inside the (C,C) area. That is, if $1 \leq \delta_{2,K1}(1,\alpha,\rho,c/Y)$ and $1 \leq \delta_{2,L1}(1,\alpha,\rho,c/Y)$:

$$\Leftrightarrow \left\{ \begin{array}{lll} 1 & \leq & -\frac{\pi_o^L}{(1-\pi_o^L)\rho} + \frac{\alpha}{(1-\pi_o^L)\rho}\left[\pi_o^L + \frac{c}{Y}\right] \\ 1 & \leq & -\frac{\pi_o^K}{(1-\pi_o^K)(1-\rho)} + \frac{1-\alpha}{(1-\pi_o^K)(1-\rho)}\left[\pi_o^K + \frac{c}{Y}\right]. \end{array} \right.$$

$$\Leftrightarrow \left\{ \begin{array}{lll} \frac{c}{Y} & \geq & \frac{(1-\pi_o^L)\rho}{\alpha} + \frac{(1-\alpha)\pi_o^L}{\alpha} \\ \frac{c}{Y} & \geq & \frac{(1-\pi_o^K)(1-\rho)}{1-\alpha} + \frac{\alpha\pi_o^K}{1-\alpha}. \end{array} \right.$$

So, there exists a (C,C) equilibrium for all the parameter configurations if and only if:

$$\frac{c}{Y} \geq \max\left\{\frac{(1-\pi_o^L)\rho}{\alpha} + \frac{(1-\alpha)\pi_o^L}{\alpha}, \frac{(1-\pi_o^K)(1-\rho)}{(1-\alpha)} + \frac{\alpha\pi_o^K}{(1-\alpha)}\right\}.$$

Proof of corollary 4 We know that:

- For $\delta_2 < \delta_{2,K1}$ player K will cooperate if L fights. Similarly, for $\delta_2 < \delta_{2,L1}$ player L will cooperate if K fights.
- For $\delta_2 \leq \delta_{2,K2}$ player K will cooperate if L cooperates. Similarly, for $\delta_2 \leq \delta_{2,L2}$ player L will cooperate if K cooperate.

From theorem 1:

- $\delta_2 \leq \min\{\delta_{2,K2}, \delta_{2,L2}\}$ implies that $\delta_2 \leq \delta_{2,K2}$ AND $\delta_2 \leq \delta_{2,L2}$; and,
- $\delta_2 < \max\{\delta_{2,K1}, \delta_{2,L1}\}$ implies that $\delta_2 < \delta_{2,K1}$ OR $\delta_2 < \delta_{2,L1}$.

With $\delta_2 < \delta_{2,K2}$, $\delta_2 < \delta_{2,K1}$ implies that K always cooperates; with $\delta_2 < \delta_{2,L2}$, $\delta_2 < \delta_{2,L1}$ implies that L always cooperates. Hence, either K always cooperates, which induces L to cooperate, or L always cooperates, which induces K to cooperate. Note furthermore that we use the assumption that if a player is indifferent between his two strategy choices, he will cooperate.

Consequently, irrespective of the other player's strategy, a player will always cooperate: the (C, C) equilibrium is indeed the only BN equilibrium.

Proof of corollary 5 Comparative static results. The intuition we gave in section 4.1 can be derived formally:

$$\begin{aligned}
\frac{\partial p^L_{c|o}}{\partial \pi^L_o} &= -\frac{p^L_{c|o}}{\pi^L_o} < 0 \quad \text{and} \quad \frac{\partial p^L_{c|o}}{\partial \pi^K_o} = 0. \\
\frac{\partial p^L_{c|o}}{\partial\,(c/Y)} &= \frac{-\alpha}{\pi^L_o(\alpha - \delta_1 + \rho\delta_1\delta_2)}. \\
\frac{\partial p^L_{c|o}}{\partial \delta_1} &= \frac{\alpha}{\pi^L_o\,(\alpha - \delta_1 + \rho\delta_1\delta_2)^2}\left(\delta_2 - \frac{c}{\rho(Y+c)}\right). \\
\frac{\partial p^L_{c|o}}{\partial \delta_2} &= \frac{\rho\delta_1}{\pi^L_o\,(\alpha - \delta_1 + \rho\delta_1\delta_2)^2}\left(\alpha\left[1 + \frac{c}{Y}\right] - \delta_1\right). \\
\frac{\partial p^L_{c|o}}{\partial \rho} &= \frac{\delta_1\delta_2}{\pi^L_o\,(\alpha - \delta_1 + \rho\delta_1\delta_2)^2}\left(\alpha\left[1 + \frac{c}{Y}\right] - \delta_1\right).
\end{aligned}$$

Clearly, the impact of changes in c/Y, δ_1, δ_2 and ρ is ambiguous: for $\delta_1 < [1 + c/Y]$ and $\delta_2 > c/[\rho(Y + c)]$, which is the area northwest of δ^*_K (cf. lemma 1), $\partial p^L_{c|o}/\partial(c/Y)$ is negative, while southeast of δ^*_K, $\partial p^L_{c|o}/\partial(c/Y)$ is positive. For $\delta_2 > c/[\rho(Y + c)]$ (north of δ^*_K) $\partial p^L_{c|o}/\partial\delta_1$ is positive; south of δ^*_K, $\partial p^L_{c|o}/\partial\delta_1$ is negative. Similarly, for $\delta_1 < [1 + c/Y]$ (west of δ^*_K) both $\partial p^L_{c|o}/\partial\delta_2$ and $\partial p^L_{c|o}/\partial\rho$ are positive. East of δ^*_K, both are negative.

Proof of lemma 2. Definition 1 implies that $\delta_{2,K1}$ and $\delta_{2,L1}$ are independent of π_o^H. $\delta_{2,K2}$ is independent of π_o^K and $\delta_{2,L2}$ is independent of π_o^L. Part (d) of lemma 1 shows that the δ_H^*'s are independent of expectations. It is easy to show that:

$$\frac{\partial \delta_{2,K2}}{\partial \pi_o^L} \geq (\leq)\, 0 \Leftrightarrow \delta_1 \leq (\geq)\, \alpha \left[1 + \frac{c}{Y}\right];$$
$$\frac{\partial \delta_{2,L2}}{\partial \pi_o^K} \geq (\leq)\, 0 \Leftrightarrow \delta_1 \leq (\geq)\, (1-\alpha) \left[1 + \frac{c}{Y}\right].$$

Consequently, when expectations change, the $\delta_{2,H2}$–curves rotate around the point δ_H^*. If π_o^L increases, the $\delta_{2,K2}$–curve rotates clockwise around δ_K^*. Similarly, if π_o^K increases, the $\delta_{2,L2}$–curve rotates clockwise around δ_L^*.

Proof of lemma 3. It is clear from definition 1 that the $\delta_{2,K1}$–curve shifts downwards as a result of an increase in ρ, while the $\delta_{2,L1}$–curve shifts up. Differentiation of the expressions for $\delta_{2,K2}$ and $\delta_{2,L2}$ with respect to ρ yields:

$$\frac{\partial \delta_{2,K2}}{\partial \rho} \geq (\leq)\, 0 \Leftrightarrow \delta_1 \geq (\leq)\, \frac{\alpha}{\pi_o^L} \left[\pi_o^L + \frac{c}{Y}\right];$$
$$\frac{\partial \delta_{2,L2}}{\partial \rho} \geq (\leq)\, 0 \Leftrightarrow \delta_1 \leq (\geq)\, \frac{1-\alpha}{\pi_o^K} \left[\pi_o^K + \frac{c}{Y}\right].$$

The $\delta_{2,K2}$–curve cuts the $\delta_2 = 0$ line for a value of $\delta_1 = \frac{\alpha}{\pi_o^L}\left[\pi_o^L + \frac{c}{Y}\right]$. The $\delta_{2,K2}$–curve is downward sloping (see lemma 1 (a)), so that $\delta_1 < \frac{\alpha}{\pi_o^L}\left[\pi_o^L + \frac{c}{Y}\right]$, hence, $\frac{\partial \delta_{2,K2}}{\partial \rho} < 0$, so that if ρ increases, the $\delta_{2,K2}$–curve rotates counterclockwise around the point $\left(\frac{\alpha}{\pi_o^L}\left[\pi_o^L + \frac{c}{Y}\right], 0\right)$. Similarly, the $\delta_{2,L2}$–curve cuts the $\delta_2 = 0$ line when $\delta_1 = \frac{1-\alpha}{\pi_o^K}\left[\pi_o^K + \frac{c}{Y}\right]$. The $\delta_{2,L2}$–curve is downward sloping (see lemma 1 (a)); $\delta_1 < \frac{1-\alpha}{\pi_o^K}\left[\pi_o^K + \frac{c}{Y}\right]$ and $\frac{\partial \delta_{2,L2}}{\partial \rho} > 0$, so that if ρ increases, the $\delta_{2,K2}$–curve rotates clockwise around the point $\left(\frac{1-\alpha}{\pi_o^K}\left[\pi_o^K + \frac{c}{Y}\right], 0\right)$.

The effects on δ_H^* follow directly from lemma 1 (d).

Proof of corollary 6

(a) Size of the pure strategy equilibria areas:

If π_o^L increases, $\delta_{2,K2}$ tilts clockwise away from $\delta_{2,L2}$ (lemma 2). The result is that the size of the (C, C)–area decreases and the size of the (F, C)–area increases. If π_o^K increases, $\delta_{2,L2}$ tilts clockwise away from $\delta_{2,K2}$ (lemma 2), shrinking the size of the (C, C)–area and increasing the size of the (C, F)–area.

An increase in ρ affects all curves – see lemma 3. The upward shift in $\delta_{2,L1}$ decreases the size of the (F, F)–area. This upward shift, together with the counterclockwise rotation of $\delta_{2,K2}$, leads to an increase in the size of the (F, C)–area. The counterclockwise rotation of $\delta_{2,K2}$ decreases the size of the (C, C)–area. Due to the clockwise rotation of the $\delta_{2,L2}$–curve and the downward shift of the $\delta_{2,L1}$–curve, the (C, F)–area decreases.

(b) Types of mixed strategy equilibria:

Under symmetry, $\delta_{2,K1} = \delta_{2,L1}$ and $\delta_{2,K2} = \delta_{2,L2}$. From lemma 1, the $\delta_{2,H2}$–curve is steeper than the $\delta_{2,H1}$–curve. To the northwest of $\delta_L^* = \delta_K^*$, we thus have $\delta_2 \leq \delta_{2,H2}$ and $\delta_2 \geq \delta_{2,H1}$, so that because of theorem 1, we have both a (C, C) and (F, F) equilibrium, and therefore, due to corollary 1, a mixed strategy equilibrium of type (a). To the southeast of $\delta_L^* = \delta_K^*$, we thus have $\delta_2 \geq \delta_{2,H2}$ and $\delta_2 \leq \delta_{2,H1}$, so that because of theorem 1, we have both a (C, F) and (F, C) equilibrium, and therefore, due to corollary 1, a mixed strategy equilibrium of type (b). For type (c) equilibria, the inequalities between δ_2 and $\delta_{2,KX}$ and between δ_2 and $\delta_{2,LX}$ must be reversed, which is not possible since $\delta_{2,KX} = \delta_{2,LX}$.

Proof of corollary 7

(a) Size of the pure strategy equilibria areas:

Lemma 2 describes how the different curves are affected. An increase in π_o^L rotates the $\delta_{2,K2}$–curve clockwise around δ_K^*, which has an ambiguous effect on the (C, C)–area and increases the size of the (F, C)–area. Increasing π_o^K has a similar effect on the $\delta_{2,L2}$–curve: it expands the (C, F)–area but has an ambiguous effect on the (C, C)–area.

The upward shift of $\delta_{2,L1}$ shrinks the (F, F)–area, the counterclockwise rotation of $\delta_{2,K2}$ diminishes the (C, C)–area, and the changes in these curves increases the (F, C)–area. The downward displacement of the $\delta_{2,K1}$–curve and the clockwise rotation of the $\delta_{2,L2}$–curve reduce the size of the (C, F)–area.

(b) Types of mixed strategy equilibria:

In this case, we have that $\delta_{2,K1} = \delta_{2,L1}$.

From lemma 1, the $\delta_{2,K2}$–curve is steeper than the $\delta_{2,K1}$–curve. To the northwest of δ_K^*, we thus have $\delta_2 \leq \delta_{2,K2}$ and $\delta_2 \geq \delta_{2,K1}$. Since $\delta_{2,K1} = \delta_{2,L1}$, with π_o^L and π_o^K different from zero, at least part of the area to the northwest of δ_K^* lies within the area where $\delta_2 \leq \delta_{2,L2}$ and $\delta_2 \geq \delta_{2,L1}$, so that, due to corollary 1, the equilibrium has to be a mixed strategy equilibrium of type (a).

To the southeast of δ_L^*, $\delta_2 \leq \delta_{2,L2}$ and $\delta_2 \geq \delta_{2,L1}$. Since $\delta_{2,K1} = \delta_{2,L1}$, with π_o^L and π_o^K different from zero, at least part of the area to the southeast of δ_L^* lies within the area where $\delta_2 \geq \delta_{2,K2}$ and $\delta_2 \leq \delta_{2,K1}$, so that, due to corollary 1, the equilibrium has to be a mixed strategy equilibrium of type (b).

For type (c) equilibria, the inequalities between δ_2 and $\delta_{2,K1}$ and between δ_2 and $\delta_{2,L1}$ must be reversed, which is not possible since $\delta_{2,K1} = \delta_{2,L1}$.

Proof of corollary 8

(a) Size of the pure strategy equilibria areas:

We briefly sketch a proof of the corollary. Increasing ρ lowers the position of the $\delta_{2,K1}$–curve and raises the position of the $\delta_{2,L1}$–curve. In generic case 1, this increases the size of the (F, F)–area, while in generic cases 2 and 3 it has the opposite effect. The downward shift of $\delta_{2,K1}$ and clockwise rotation of $\delta_{2,L2}$ decrease the size of the (C, F)–area. The upward shift of $\delta_{2,L1}$ and the counterclockwise rotation of the $\delta_{2,K2}$–curve increases the size of the (F, C)–area. The way the (C, C)–area is affected depends crucially on whether the $\delta_{2,K2}$– and $\delta_{2,L2}$–curves intersect or not. If they do not intersect, increasing ρ decreases the size of the (C, C)–area. Otherwise, the effect will be ambiguous.

Beliefs only affect the position of the $\delta_{2,H2}$–curves. The size of the (F, F)–area does not depend on these curves. The (F, C)–area is independent of the $\delta_{2,L2}$–curve, so changes in π_o^K have no effect. Equivalently, changes in π_o^L do not affect the (C, F)–area. Consider the effect of changing π_o^L in generic case 1. Since the (F, C)–area lies to the south east of δ_K^*, the counterclockwise rotation of $\delta_{2,K2}$ will decrease the size of the (F, C)–area. If condition $\boldsymbol{i}$ holds true, the same counterclockwise rotation makes the effect on the (C, C)–area ambiguous. It is only if $\boldsymbol{i}$ does not hold true, and the $\delta_{2,L2}$–curve cuts the $\delta_{2,K2}$–curve below δ_K^* that the effect of π_o^L on the (C, C)–area can be signed. It will then be positive.

(b) Types of mixed strategy equilibria:

Take generic case 2 and 3: $\rho > \alpha$ implies that $\delta_{2,K1} < \delta_{2,L1}$. Consequently, condition 1 (ii) and 2 (i) from theorem 1 cannot hold simultaneously. Mixed strategy equilibria of type (c) are thereby ruled out.

Proof of corollary 9 For an equilibrium to be fully integrated, we need that:

$$\begin{cases} \delta_2 \le -\frac{\pi_o^L}{(1-\pi_o^L)\rho} + \frac{\alpha}{(1-\pi_o^L)\rho\delta_1}\left[\pi_o^L + \frac{c}{Y}\right]; \\ \delta_2 \le -\frac{\pi_o^K}{(1-\pi_o^K)(1-\rho)} + \frac{1-\alpha}{(1-\pi_o^K)(1-\rho)\delta_1}\left[\pi_o^K + \frac{c}{Y}\right]. \end{cases}$$

$$\Leftrightarrow \begin{cases} \left[\left(1-\pi_o^L\right)\rho\delta_2 + \pi_o^L\right]\frac{\delta_1}{\alpha} - \pi_o^L \le \frac{c}{Y}; \\ \left[\left(1-\pi_o^K\right)(1-\rho)\delta_2 + \pi_o^K\right]\frac{\delta_1}{1-\alpha} - \pi_o^K \le \frac{c}{Y}. \end{cases} \tag{7}$$

(a) The left-hand side of the inequalities in (7) are increasing in δ_1. This means that we can, at best, reduce δ_1 to 0. In that case the restrictions in equation (7) become: $(c/Y) \ge \max\left\{-\pi_o^L, -\pi_o^K\right\}$, which, with both c and Y being greater than 0, is always satisfied.

(b) Analogously, the left-hand side of both inequalities in (7) are increasing in δ_2. This means that we can, at best, reduce δ_2 to 0. The restrictions in equation (7) then become: $\frac{c}{Y} \geq \max\{R_1, R_2\}$.

(c) Obviously, the impact of changing ρ is different for K and L: the left-hand side of the first inequality of equation (7) (player K) is increasing in ρ, while the left-hand side of the second inequality of equation (7) (player L) is decreasing in ρ.

To find the restrictions on ρ we rearrange (7):

$$\begin{cases} \rho \leq \left[\frac{c}{Y} + \pi_o^L \left(1 - \frac{\delta_1}{\alpha}\right)\right] \frac{\alpha}{(1-\pi_o^L)\delta_1\delta_2} \equiv R_3 \\ \rho \geq 1 - \left[\frac{c}{Y} + \pi_o^K \left(1 - \frac{\delta_1}{1-\alpha}\right)\right] \frac{1-\alpha}{(1-\pi_o^K)\delta_1\delta_2} \equiv R_4. \end{cases}$$

This results in the following restrictions on ρ: $R_4 \leq \rho \leq R_3$, which, since $0 \leq \rho \leq 1$, is equivalent to requiring that:

$$\begin{cases} R_3 \geq 0 & \Leftrightarrow \quad \frac{c}{Y} \geq R_1 \\ R_4 \leq 1 & \Leftrightarrow \quad \frac{c}{Y} \geq R_2 \\ R_3 \geq R_4 & \Leftrightarrow \quad \frac{c}{Y} \geq \frac{(1-\pi_o^L)(1-\pi_o^K)\delta_1\delta_2 + \alpha(1-\pi_o^K)(R_1) + (1-\alpha)(1-\pi_o^L)(R_2)}{\alpha(1-\pi_o^K) + (1-\alpha)(1-\pi_o^L)}. \end{cases}$$

Rearranging terms allows us to see that the third condition can be written as: $\frac{\alpha(c/Y - R_1)}{1-\pi_o^L} + \frac{(1-\alpha)(c/Y - R_2)}{1-\pi_o^K} \geq \delta_1\delta_2$.

(d) First we rewrite (7):

$$\begin{cases} \pi_o^L \left(\frac{\delta_1}{\alpha}(1 - \rho\delta_2) - 1\right) \leq \frac{c}{Y} - \rho\delta_2\frac{\delta_1}{\alpha}; \\ \pi_o^K \left(\frac{\delta_1}{1-\alpha}(1 - (1-\rho)\delta_2) - 1\right) \leq \frac{c}{Y} - (1-\rho)\delta_2\frac{\delta_1}{1-\alpha}. \end{cases} \tag{8}$$

Now, depending on the size of α relative to δ_1, we get four cases:

– With $\frac{\alpha}{\delta_1} \geq 1 - \rho\delta_2$ and $\frac{(1-\alpha)}{\delta_1} \geq 1 - (1-\rho)\delta_2$, both left-hand sides in (8) are negative. So optimally, we can put $\pi_o^L = \pi_o^K = 1$, which gives us the following restrictions on c/Y:

$$\begin{cases} \frac{c}{Y} \geq \frac{\delta_1}{\alpha} - 1; \\ \frac{c}{Y} \geq \frac{\delta_1}{1-\alpha} - 1. \end{cases}$$

– With $\frac{\alpha}{\delta_1} \geq 1 - \rho\delta_2$ and $\frac{(1-\alpha)}{\delta_1} < 1 - (1-\rho)\delta_2$, the first left-hand side in (8) is negative and the second is positive. So optimally, we can put $\pi_o^L = 1$ and $\pi_o^K = 0$, which generates the following restrictions on c/Y:

$$\begin{cases} \frac{c}{Y} \geq \frac{\delta_1}{\alpha} - 1; \\ \frac{c}{Y} \geq \frac{(1-\rho)\delta_1\delta_2}{1-\alpha}. \end{cases}$$

– With $\frac{\alpha}{\delta_1} < 1 - \rho\delta_2$ and $\frac{(1-\alpha)}{\delta_1} \geq 1 - (1-\rho)\delta_2$, the first left-hand side in (8) is positive and the second is negative. So optimally, we can put $\pi_o^L = 0$ and $\pi_o^K = 1$, which generates the following restrictions on c/Y:

$$\begin{cases} \frac{c}{Y} \geq \frac{\rho\delta_1\delta_2}{\alpha}; \\ \frac{c}{Y} \geq \frac{\delta_1}{1-\alpha} - 1. \end{cases}$$

– With $\frac{\alpha}{\delta_1} < 1 - \rho\delta_2$ and $\frac{(1-\alpha)}{\delta_1} < 1 - (1-\rho)\delta_2$, both left-hand sides in (8) are positive. So optimally, we can put $\pi_o^L = \pi_o^K = 0$, which generates the following restrictions on c/Y:

$$\begin{cases} \frac{c}{Y} \geq \frac{\rho\delta_1\delta_2}{\alpha}; \\ \frac{c}{Y} \geq \frac{(1-\rho)\delta_1\delta_2}{1-\alpha}. \end{cases}$$

Note that:

$$\frac{\alpha}{\delta_1} \geq (\leq) 1 - \rho\delta_2 \quad \Leftrightarrow \quad \frac{\delta_1}{\alpha} - 1 \leq (\geq) \frac{\rho\delta_1\delta_2}{\alpha}$$

and that:

$$\frac{1-\alpha}{\delta_1} \geq (\leq) 1 - (1-\rho)\delta_2 \quad \Leftrightarrow \quad \frac{\delta_1}{1-\alpha} - 1 \leq (\geq) \frac{(1-\rho)\delta_1\delta_2}{1-\alpha},$$

so that we can always guarantee the existence of a (C, C) equilibrium if and only if:

$$\frac{c}{Y} \geq \max\left\{\min\left\{\frac{\delta_1}{\alpha} - 1, \frac{\rho\delta_1\delta_2}{\alpha}\right\}, \min\left\{\frac{\delta_1}{1-\alpha} - 1, \frac{(1-\rho)\delta_1\delta_2}{1-\alpha}\right\}\right\}.$$

Proof of corollary 10 In order to rule out the fighting equilibrium, we need that:

$$\begin{aligned} & \delta_2 < \delta_{2,K1} \quad \text{AND} \quad \delta_2 < \delta_{2,L1} \\ \Leftrightarrow\ & \delta_2 < \frac{\alpha}{\rho}\frac{1}{\delta_1}\frac{c}{Y} \quad \text{AND} \quad \delta_2 < \frac{1-\alpha}{1-\rho}\frac{1}{\delta_1}\frac{c}{Y} \\ \Leftrightarrow\ & \frac{c}{Y} > \frac{\rho\delta_1\delta_2}{\alpha} \quad \text{AND} \quad \frac{c}{Y} > \frac{(1-\rho)\delta_1\delta_2}{1-\alpha}. \end{aligned} \tag{9}$$

(a) The right-hand side of the inequalities in (9) are increasing in δ_1 (and in δ_2). This means that we can, at best, reduce δ_1 (δ_2) to 0. In that case the restrictions in equation (9) become: $\frac{c}{Y} > \max\{0, 0\}$, which, with both c and Y being greater than 0, is always satisfied.

(b) The right-hand side of the first inequality in (9) is linearly increasing in ρ, while the right-hand side of the second inequality is linearly decreasing in ρ. Since these equations always cross for a value of ρ between 0 and 1, the restriction in equation (9) is minimal for ρ^*:

$$\frac{\rho^* \delta_1 \delta_2}{\alpha} = \frac{(1-\rho^*)\delta_1 \delta_2}{1-\alpha}.$$

Since this will occur when group power is proportional to group size, $\alpha = \rho^*$, the restriction in (9) becomes:

$$\frac{c}{Y} > \delta_1 \delta_2.$$

(c) Obviously, the impact of changing π will have no consequences: the necessary conditions to rule out the fighting equilibrium are unaffected by the level of trust.

Proof of corollary 11 Due to corollary 4 we find necessary and sufficient conditions for each type of intervention to impose the (C, C) equilibrium as the only equilibrium in pure stratеties by combining the corresponding conditions in corollary 9 and 10.

(a) From corollary 9 (a) and corollary 10 (a) we know that a strong boycott can always ensure that (C, C) is a BN equilibrium, and (F, F) is not.

(b) From corollary 9 (b) and corollary 10 (a) we know that a strong boycott can ensure that (C, C) is a BN equilibrium and (F, F) is not if $c/Y \geq \max\{R_1, R_2\}$.

(c) From corollary 9 (c) and corollary 10 (b) we know that a strong boycott can ensure that (C, C) is a BN equilibrium and (F, F) is not if:

$$c/Y > \max \quad \begin{cases} R_1; \\ R_2; \\ \frac{(1-\pi_o^L)(1-\pi_o^K)\delta_1\delta_2 + \alpha(1-\pi_o^K)(R_1) + (1-\alpha)(1-\pi_o^L)(R_2)}{\alpha(1-\pi_o^K) + (1-\alpha)(1-\pi_o^L)}; \\ \delta_1 \delta_2. \end{cases}$$

(d) From corollary 10 (c) we know that confidence building is ineffective in excluding the (F, F) equilibrium, which implies that it is the least effective intervention tool in excluding all non-cooperative behavior.

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