Within-Group Cooperation and Between-Group Competition in Contests*

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Abstract

Olson's analysis argues that the free-rider problem makes large groups less effective. In this paper, we challenge this view of group action with a very simple contest game that exhibits a bilateral interplay between intergroup interaction and within-group organization. In a static setting, because of the free-riding incentives, the larger group is disadvantaged in the competition with its rival. When groups interact in a dynamic environment, individuals within each group may be able to achieve tacit cooperation. We then show that the larger group has more chance to enforce within-group cooperation. In accordance with many informal and formal observations, the larger group can thus produce a higher level of collective action.

Keywords: Collective Action, Contest, Within-group cooperation, Between-group competition, Repeated game.

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1 Introduction

Most of economic and political activities involve groups of people with a shared common interest. The effectiveness of a group in carrying out its objective then crucially depends on how it deals with its collective action problem. Olson's (1965) celebrated theory argues that this problem makes large groups less effective. This is because the larger the group, the larger are the free-riding incentives and the smaller is the individual share of group benefit. Olson writes:

> The larger the number of individuals or firms that would benefit from a collective good, the smaller the share of the gains from action in group interest that will accrue to the individual or firm that undertakes the action. Thus, in the absence of selective incentives, the incentive for group action diminishes as group size increases, so that large groups are less able to act in their common interest than small ones. (Olson 1982, 31)

However, the aggregate potency of a group depends both on the level of individual contribution and on the size of the group. Indeed, even though individuals contribute less in large groups than in small groups, it does not necessarily imply that large groups produce lower levels of collective action. A critical factor that drives the aggregate effectiveness of a group is whether the reward of group action is divisible among individuals. Chamberlin, (1974) and McGuire (1974) first pointed out that Olson's thesis of a negative relationship between effective collective action and group size holds when the prize is private but is overturned when the reward of group action is public and not divisible among group members. Esteban and Ray (2001) term Olson's thesis and the generalization of it, the "common wisdom" of group action. But as these authors claim, this view is not really consistent with some informal observations. They write

> For instance, there is a sense in which the received theory runs counter to the old maxim: Divide and conquer. Political entities have applied this rule with surprising universality, but if smaller group are more potent, the division of one's opponent into a number of smaller units would entail more effective opposition. This universality can be reconciled with the traditional argument only if all potential gains are fully public to group members. But that is hardly the case. (Esteban and Ray 2001, 664)

There is an important literature in political science that criticizes Olson's logic and the extensions of it in the economic literature. One of those critics is that interest group membership does not entirely rest on economic-self interest. For example, Moe (1980) argue that there exists many other kinds of incentives such as ideology, moral principles and social pressure that influence both individual membership decision and individual's valuation of contributing to group action. Furthermore, as most political scientists seem to agree, group size is an important resource for ideological, political and other non-economic interest-groups. But size also seems to be an important resource for interest groups with economic concerns such as labor unions or farm lobbies. Indeed, it is well recognized, although there is no consensus on the direction of the causality, that there is a positive relationship between effectiveness and size of unions (see e.g. Checchi and Lucifora, (2002)). In the farming context, scholars also agree that the considerable influence of farmers' unions through the European Common Agricultural Policy is related to their extraordinary capacity to organize broadly at a national level. For instance, Keeler (1996, 134) writes: "In the four most populous EC states the largest farmers' unions alone claims a membership density much higher than all labor unions...As case studies of agricultural politics at the national level make clear, this density is one of the more important "secrets" behind the farm lobby's disproportionate clout".

If the reward of group action is purely public so that a group member's payoff is unaffected by the number of members, the "common wisdom" of group action is actually consistent with the "divide-and-conquer" maxim i.e. the smaller the group, the lower is its aggregate effectiveness. But there are many circumstances in which the collective prize is neither purely public nor purely political or ideological. Quite often, the reward of group action has, at least to some extent, private characteristics so that it can be, to that extent, divided among group members. One just need to remember that an important function of governments is to create and distribute rents through regulation and these rents can be divided both among groups and among individuals. One can also think of the various transfers such as pensions, subsidies or health benefits that are targeted to specific groups. According to the common wisdom, when groups compete for such transfers or for prizes with private economic characteristics, we should observe individuals organized in very narrow interest groups to ward off the free-rider problem and to have the prize divided by a smaller number of individuals. This is also not really conforming to what we observe in a majority of situations. Even though some studies find that smaller groups receive larger transfers, a lot of empirical works find the contrary (e.g., Pincus (1975); Becker (1986); Congleton and Shugart;(1990); Kristov, Lindert and McClelland, (1992); for a survey, see Potters and Sloof, (1996)).

One then needs to understand, how groups and particularly large groups manage to control free-riding and their collective action problem especially in a context where individuals and groups are motivated by private economic considerations. One can think of various ways by which groups can circumvent free-riding. For example, this could be done by implementing costly incentives schemes, by direct monitoring of member actions or by exerting moral or other pressures on them. But these procedures might be very costly to implement especially in large groups. We argue, in this paper, that it is more likely that members in a group tacitly cooperate in pursuing their interest. By "tacitly", we mean that individuals may well find cooperation to be a more fruitful individual strategy than free-riding. Axelrod (1984), in his classical book, explains that cooperation can emerge and stabilize in multiple-participants environments as a result of reciprocal altruism. When agents take account of the probable future response of others to their own behavior, they may find profitable to cooperate anticipating reciprocal cooperation from others. The simplest strategy based on this principle of reciprocal altruism is known as the tit-for-tat strategy in which each player cooperates in the current period if others players cooperated in the previous period. If one player defects in the current period, other players will respond by defection next period. Obviously, this strategy does not make any sense in a one-shot environment. But clearly, groups and group members do not play only once for all; they rather face repeated interactions with each other in the real world.

There is another crucial feature of the collective action problem within groups that we want to emphasize. Most of the collective action theory deals with actions of a single group. In reality, a large number of economic and political activities involve several groups which are in opposition to one another. In essence, the willingness to participate to collective action through interest group membership is driven by the opportunity to pursue an interest that is not universally shared. Therefore, the collective action problem within a group does not only depend on internal attributes and on whether the reward is divisible but also on the interaction between groups. Hence, if groups are in opposition to one another, the ability of a group to attain its objective crucially depends upon its strength relative to that of its antagonists. In turn, group confrontation is likely to affect the internal organization of the groups, most notably in terms of free-riding and cooperative incentives. There are thus double-edged incentives since incentives within groups spill over into the intergroup arena, and between-group competition affect within-group incentives.[1]

The questions we try to answer, in this paper, are the following: How does group interaction affect the ability of the groups to overcome their free-rider problem; hence how does it affect individual behavior and individual incentives within the groups? In turn, how does individual behavior within groups reflect in the competition between groups? For this purpose, we develop

[1] We borrow the term "double-edged incentives" to Persson and Tabellini (1995) who analyze the bidirectional interaction between domestic policy processes and international strategic interactions.

a simple model that exhibits three important features. (1) Collective action is undertaken in a context of competition between groups. (2) The contested prize is purely private. (3) Competing groups have repeated interactions.

Concerning the first feature, we model between-group competition as a contest in which group members make efforts or expenditures to increase their share of a contestable rent. There are two groups of different sizes and all individuals have the same valuation for the rent which is divisible both among groups and among individuals. Aggregate group spending determines the proportion of the rent allocated to the group. Hence, the group share is a public good to the members in a group so that there is a collective action problem within groups. Thereafter, this proportion is shared by the members of the group on an equal division basis.

The fact that the rent is purely private and divisible is a crucial element of our framework. This is in line with Olson's classical analysis where individual benefits of group membership are private and decreasing with the number of members. As a result, in the one-shot game, the larger the group, the lower is the level of collective action because of the free-riding incentives. In our contest model, this is reflected in group shares: the group with fewer members gets, in equilibrium, the larger share of the rent.

Concerning the third feature of our analysis, we analyze the repeated interactions between groups as an infinitely repeated game in which a simple (tit-for-tat) trigger strategy, as described above, is the enforcement mechanism for within-group cooperation. It is well-known that in such models, the cooperative outcome may be achieved if players are sufficiently patient i.e. if the discount parameter is sufficiently large. In our framework, the threshold value of the discount parameter above which cooperation within a particular group can be maintained is endogenously determined as a function of the sizes of the two groups. Moreover, the critical discount factor associated with a group depends upon the organizational properties of the rival group. This is because payoffs under defection, cooperation and non-cooperation depends upon the outcome of the competition between groups and this outcome, in turn, depends upon the organizational properties of the two groups.

We proceed as it follows. We first examine how the critical value of the discount parameter for a given group changes with the number of members in both groups when the status (cooperation or non-cooperation) in the rival group is taken as given. We show that the ability of a group to maintain a cooperative outcome increases as the group grows larger independent of the internal organization (cooperation or non-cooperation) of the rival group. We then characterize the subgame perfect Nash equilibria of the game between the two groups of people. In particular, when there is defection and reversion to the non-cooperative outcome within one group, the enforcement of cooperation within the other group might become a best response.

The main result of the paper is that the cooperative outcome is less difficult to sustain in the larger group. Indeed, if there is some equilibria where there is cooperation within the small group then there is also one where is cooperation within the larger group. In addition, for sufficiently high levels of discount parameters, we show that cooperation can be achieved only within the larger group. One of the important elements that drive these results is that the infinite reversion to the non-cooperative outcome is more costly for the larger group than for the smaller group. This is because the free-rider problem is more severe in this group which is reflected in a lower share of the rent. This is turn makes cooperation less difficult to sustain in the larger group.

Our paper is related to, but differs in its focus from, the large literature on rent-seeking theory. Following the seminal contributions of Tullock (1967, 1980), this literature focuses on the relation between the magnitude of the rents created by different organizations or political systems and the amount of resources wasted by agents in the pursuit of those rents. Various aspects of rent-seeking conflicts have been analyzed. For example, rent-seeking has been studied in contexts such as uncertainty (Hurley and Shogren (1998)), risk aversion (Skarpedas and Gan, (1995)), free entry into the rent-seeking market (Pérez-Castrillo and Verdier, (1992)), intergroup migration (Baik and Lee, (1997)), asymmetric valuations (Nti (1999)) or multistage contests (Gradstein and Konrad, (1999)); see Nitzan (1994) for a survey. But in all these works, each group is acting as a single agent and there is no room for collective action problems. Nitzan (1991) analyzes a contest between several groups in which group members decide voluntarily on the extent of their rent-seeking efforts and the probability of success of a group depends on the sum of efforts of group members. He then shows, for different rules concerning the distribution of the rent within groups, that collective rent-seeking contests induce less dissipation of the rent because of the free-riding incentives. Katz and Tokatlidu (1996) also analyze a model of collective rent-seeking with self-interested agents and show that group size asymmetry acts to reduce rent dissipation.[2] In the present paper, our focus is not on the level of rent dissipation but on the level of collective action that unequally sized groups are able to produce.

[2] In the same spirit, Wärneryd (1998) shows that there is less rent dissipation in a hierarchical (two-stage) rent-seeking contest than in a unified (one-stage) rent-seeking contest.

This paper is also related to the general analysis of tacit collusion in dynamic games. Although, this problem has been extensively analyzed in dynamic oligopoly models, there is much less works in a public economic context. McMillan (1979) first analyzed such a repeated game setting for the private provision of a public good. He shows that, unlike in a static setting, there is not necessarily underprovision of public goods in a dynamic setting. Pecorino (1998) analyzes the effect of an increase in the number of firms on their ability to overcome free-riding in lobbying for tariffs. He shows that increasing the number of firms does not necessarily make the cooperative outcome more difficult to sustain.[3] This is also one of the conclusions of our analysis but in framework in which cooperation in a group not only depends on the internal attributes of that group but also on the internal attributes of the rival groups through intergroup interaction.

Most closely related is the work by Esteban and Ray (2001). They analyze the problem of collective action with multiple groups as a contest game in which the prize for which groups compete has mixed public-private characteristics. The probability of success for a group is public to the members since it depends on the sum of their efforts relative to the aggregate amount of efforts exerted by all groups. Depending on the degree of publicness of the collective prize, they show that if "the marginal cost of effort rises sufficiently quickly" larger groups are more successful than smaller groups. If the individual cost of contributing to group action is quadratic, or more convex, then larger groups are more effective even though the collective prize is purely private. The merit of their analysis is to show that Olson's result and the extensions of it crucially depends on the linearity of cost functions, an assumption that they argue to be unrealistic. However, their analysis is static and there is no scope for cooperation within groups. We present an alternative explanation of the higher potency of larger groups that relies on the incentives to cooperate within competing groups rather than on a technical assumption on the elasticity of the cost of contributing to group action.

We present a simple specification of a contest between two groups in Section 2. We then characterize the single shot equilibrium when members in both groups act non-cooperatively in rent-seeking. In Section 3, we first define the critical value of the discount parameter above which within-group cooperation is maintained. We then calculate the payoffs under cooperation, non-cooperation and defection within a group when the members of the rival group act non-

[3] In another paper (Pecorino, (1999)), he analyzes the ability to cooperate in the private provision of public goods and shows that cooperation can be maintained when the number of contributors goes to infinity.

cooperatively and when they act cooperatively. In Section 4, we first determine the critical value of the discount parameter for each group when the status (cooperation and non-cooperation) within the rival group is taken as given. We then characterize the subgame perfect Nash equilibria of the game between the two groups. Section 5 concludes.

2 The Model

Consider a world with two groups A and B, which have n_A and n_B identical risk neutral members, respectively. We assume that the groups are isolated from each other in the sense that it is prohibitively costly for individuals to move from one group to the other. Such costs may arise from cultural differences, for example differences of language. The government intends to adopt a policy that will provide a rent Y. The only role of the government is precisely to divide this pie among the groups in response to the rent-seeking pressures and lobbying activities of the members of the groups. Following Katz and Tokatlidu (1996), we assume that a group gets a share of the pie equal to the ratio of the sum of the expenditures of its members to the total expenditures. The share of group j is

$$p_j(\mathbf{t}) = \begin{cases} \sum_{i=1}^{n_j} t_{ji} / \left(\sum_{i=1}^{n_A} t_{Ai} + \sum_{i=1}^{n_B} t_{Bi} \right); & \text{if} \quad \sum_{i=1}^{n_A} t_{Ai} + \sum_{i=1}^{n_B} t_{Bi} > 0 \\ 1/2, & \text{otherwise} \end{cases} \tag{1}$$

where $\mathbf{t}$ is the vector of all individual rent-seeking expenditures. The rent acquired by each group is distributed equally among the group members. We also assume that individual preferences are represented by an additively separable utility function. Specifically, individual i in group j, for $j = A, B$, has the following utility

$$u_{ji}(\mathbf{t}) = \frac{p_j(\mathbf{t})\, Y}{n_j} - t_{ji}. \tag{2}$$

We first analyze the one-shot equilibrium outcome in which members in both groups act non-cooperatively in lobbying. Since there is no equilibrium where nobody invests anything, the optimal expenditure of agent i in group A is given by the following first-order condition

$$\frac{\sum_{k=1}^{n_B} t_{Bk}}{\left(\sum_{k=1}^{n_A} t_{Ak} + \sum_{k=1}^{n_B} t_{Bk}\right)^2} \frac{Y}{n_A} = 1. \tag{3}$$

The corresponding condition for an agent in group B is

$$\frac{\sum_{k=1}^{n_A} t_{Ak}}{\left(\sum_{k=1}^{n_A} t_{Ak} + \sum_{k=1}^{n_B} t_{Bk}\right)^2} \frac{Y}{n_B} = 1. \tag{4}$$

Given that members in each group are identical, it is natural to focus on a symmetric equilibrium in which all members in a group make the same level of effort. Let t_A and t_B be the common equilibrium expenditure in group A and group B respectively. The conditions for equilibrium are then

$$\frac{n_B t_B}{(n_A t_A + n_B t_B)^2} \frac{Y}{n_A} = 1 \tag{5}$$

for members of group A, and

$$\frac{n_A t_A}{(n_A t_A + n_B t_B)^2} \frac{Y}{n_B} = 1 \tag{6}$$

for members of group B.

The solution to this system of equations is

$$t_A^{NN} = \frac{n_B}{(n_A + n_B)^2} \frac{Y}{n_A} \tag{7}$$

and

$$t_B^{NN} = \frac{n_A}{(n_A + n_B)^2} \frac{Y}{n_B}. \tag{8}$$

The double upper-script NN denotes a Non-cooperative behavior within *both* groups. By convention, we will use the first and the second upper scripts to indicate the behavior of members within groups A and B, respectively. The share allocated to region A is then

$$p_A^{NN} = \frac{n_B}{n_A + n_B} \tag{9}$$

while the share allocated to region B is $p_B^{NN} = \left(1 - p_A^{NN}\right)$. Hence, the group with fewer members gets the larger share of the pie. Because the share of a group is a public good to the agents in a group, there is a free-rider problem which makes the smaller group more successful. In addition, the larger the group, the smaller is its share of the rent. Finally, it is worth pointing out that not only the larger group ends up with a lower share of the rent but it must divide this share among a larger number of members. The equilibrium utility level of an agent of group A is then

$$u_A^{NN} = \frac{n_B\left(n_B + n_A - 1\right)}{\left(n_{A+}n_B\right)^2}\frac{Y}{n_A}. \tag{10}$$

The equilibrium utility level of an agent of group B is obtained by permuting n_A and n_B. We note that individual utility is falling in the number of members of the home group and increasing in the number of members of the rival group.

3 Trigger Strategies and Within-Group Cooperation

3.1 The Critical Discount Parameter

The objective of this Sub-section is to define the critical discount parameter above which cooperation can be maintained within a given group. Consider an infinitely repeated game in which individuals adopt a simple (tit-for-tat) trigger strategy to maintain within-group cooperation.[4]. Hence, each agent in a group makes the cooperative level of effort in the current period if all group members behaved in a similar manner in the previous period. If any agent defects in the current period, she will trigger the non-cooperative outcome within the group for all subsequent periods. We assume that all agents observe the actions of the others at the end of each period which implies that defections are always detected. In addition, all individuals in both groups have the same discount factor $0 < \delta < 1$.

[4] Friedman (1971) was the first to show that cooperation could be achieved in an infinitely repeated game by using this type of strategy. .

Let an individual's utility be denoted u^C under the cooperative equilibrium and denoted u^N under the non-cooperative equilibrium. The utility reached by an individual who defects from a cooperative equilibrium is denoted u^D. If an agent defects from the cooperative equilibrium, he will get u^D for the current period and u^N in all future periods. If this utility level is larger than the utility level from continued cooperation, then the agent will defect and will trigger the non-cooperative outcome forever. Thus, a necessary condition for maintaining cooperation in rent-seeking under a trigger strategy with infinite Nash reversion is

$$u^D + \sum_{t=1}^{\infty} \delta^t u^N \leq \sum_{t=0}^{\infty} \delta^t u^C \tag{11}$$

Let $\widetilde{\delta}$ be the critical value such that (11) holds with a strict equality. For all $\delta \geq \widetilde{\delta}$, the cooperative equilibrium can be supported, while for $\delta < \delta^*$, cooperation cannot be maintained. Solving for $\widetilde{\delta}$ yields:

$$\widetilde{\delta} = \frac{u^D - u^C}{u^D - u^N} \tag{12}$$

Since $u^D \geq u^C \geq u^N$, the minimum discount factor lies between 0 and 1: $0 \leq \widetilde{\delta} \leq 1$. The higher this critical discount parameter, the more difficult is to sustain cooperation within a group. There are several points worth noting. First, each player in a group will have no incentives to deviate from the punishing response of non-cooperative contribution levels. This threat strategy is therefore self-enforcing since when one member produces at that level, it is optimal for the other members to behave in a similar manner. Second, the payoffs under cooperation, non-cooperation and defection for members in a group will depend not only upon its size but also upon the size and the organizational properties of the rival group. Third, it is well-known that there are many equilibria in this type of infinitely repeated game and we will assume, as is usual, that the Pareto optimal equilibrium from the viewpoint of the group members will be realized.

3.2 Cooperation and the Number of Members

3.2.1 Cooperation in the Other Group

Let consider that at date t, there is cooperation in rent-seeking within both groups. Let t_A and t_B be the common individual rent-seeking effort under within-group cooperation in group A and B, respectively. The share allocated to region A is

$$p_A = \frac{n_A t_A}{n_A t_A + n_B t_B}. \tag{13}$$

The optimal individual expenditure of an agent of group A is given by the following first-order condition

$$\frac{n_B t_B}{(n_A t_A + n_B t_B)^2} Y = 1. \tag{14}$$

The corresponding condition for an agent of group B is

$$\frac{n_A t_A}{(n_A t_A + n_B t_B)^2} Y = 1. \tag{15}$$

It is easily checked that the solution of this system is, for $j = A, B$, $t_j^{CC} = Y/4n_j$ and thereby $p_A^{CC} = p_B^{CC} = 1/2$. The double upper script CC indicates that there is cooperation in rent-seeking within both groups. The equilibrium expected utility level of each agent in each group is

$$u_j^{CC} = \frac{Y}{4n_j}, \qquad j = A, B. \tag{16}$$

Because individuals preferences are represented by a utility function that is additively separable and linear in Y and in rent-seeking activities, within-group cooperation makes each group acting as it was a single agent.

Consider now that in group A, at $t+1$, one agent deviates and contributes nothing while all other agents make the cooperative rent-seeking effort.[5] At that date, members in group B also continue to cooperate in rent-seeking. With one defecting agent, the share allocated to region A at date $t+1$ is $p_A^{DC} = (n_A - 1) / (2n_A - 1)$. The expected equilibrium utility of this agent is therefore

$$u_A^{DC} = \frac{n_A - 1}{2n_A - 1} \frac{Y}{n_A}. \tag{17}$$

The double upper script DC indicates that this agent deviates while all members of the rival group act cooperatively (as well as all other members of the home group). Note that the larger the group, the lower is the individual payoff of defection.

[5] We indeed show in a technical Appendix (available upon request) that the agent who defects optimally cuts its contribution to 0, no matter the internal organization of the rival group.

3.2.2 Non-cooperation in the Other Group

Now consider that at date t, members of group A still act cooperatively but members of group B behave non-cooperatively. Let t_A be the common equilibrium expenditure in group A. The share of that group is

$$p_A = \frac{n_A t_A}{n_A t_A + \sum_{k=1}^{n_B} t_{Bk}} \tag{18}$$

and the share of group B is $1 - p_A$. The optimal individual expenditure of an agent in group A is given by the following first-order condition

$$\frac{n_A \sum_{k=1}^{n_B} t_{Bk}}{\left(n_A t_A + \sum_{k=1}^{n_B} t_{Bk}\right)^2} \frac{Y}{n_A} = 1. \tag{19}$$

The corresponding condition for an agent in group B is

$$\frac{n_A t_A}{\left(n_A t_A + \sum_{k=1}^{n_B} t_{Bk}\right)^2} \frac{Y}{n_B} = 1. \tag{20}$$

The solution of this system of equations is then

$$t_A^{CN} = \frac{n_B}{n_A (n_B + 1)^2} Y \tag{21}$$

and

$$t_B^{CN} = \frac{1}{n_B (n_B + 1)^2} Y \tag{22}$$

where the double upper script CN indicates cooperative and non-cooperative outcomes within group A and B respectively. In equilibrium, the share allocated to region A is then

$$p_A^{CN} = \frac{n_B}{n_B + 1} \tag{23}$$

which is approaching 1 when n_B is large. When members of a group make their lobbying efforts cooperatively, it is as though this group acts as a single agent. The utility of a representative agent in group A is then

$$u_A^{CN} = \left[\frac{n_B}{n_B+1}\right]^2 \frac{Y}{n_A}. \tag{24}$$

This utility level is increasing in n_B. The larger the size of group B, the more severe is the free-rider problem in this group and the larger is the share of group A. This in turn implies a higher individual payoff for members of group A. The utility of a representative agent in group B is

$$u_B^{CN} = \left[\frac{1}{n_B+1}\right]^2 Y. \tag{25}$$

Now, we must characterize the payoff of a defecting agent, at $t+1$, when all other members of group A continue to behave cooperatively and when all members of group B still act non cooperatively. In this case the share allocated to region A is: $p_A^{DN} = n_B\,(n_A-1)\,/\,[n_B\,(n_A-1)+n_A]$. Therefore, payoff under defection is

$$u_A^{DN} = \frac{n_B\,(n_A-1)}{n_B\,(n_A-1)+n_A}\frac{Y}{n_A}. \tag{26}$$

This utility level is decreasing in n_A and increasing in n_B.

4 Maintaining Cooperation and Between-Group Competition

4.1 Partial Analysis

In this subsection, we fix the behavior of members within a group (let say group B) and we examine the difficulty of maintaining cooperation in the other group (group A) as a function of the sizes of the two groups. Thereafter, in the next subsection, we will analyze the equilibrium configurations of the game between the members of both groups.

If there is defection of any agent at date $t+1$ in group A, then members of that group switch, from the date $t+2$, to the non-cooperative outcome forever. Suppose first that members in group B act cooperatively. Using (12), the limit discount factor above which cooperation can be sustained in group A is defined as follows

$$\delta_A^C = \frac{U_A^{DC} - U_A^{CC}}{U_A^{DC} - U_A^{NC}} \tag{27}$$

where the single upper script C denotes Cooperation between members within the *other* group. U_A^{CC} and U_A^{DC} are given by (16) and (17) respectively. U_A^{NC} is given by (25) in which, by symmetry of the model, n_B has been replaced by n_A. (Recall that by convention, the first upper script indicates the internal organization of group A and the second upper script that of group B). Therefore, we have

$$\delta_A^C (n_A) = \frac{(2n_A - 3)(n_A + 1)^2}{4\left[n_A^2 (n_A - 1) - 1\right]}. \tag{28}$$

A similar expression can be found for group B by permuting n_A and n_B. Calculating the derivative of δ_A^C with respect to n_A, we have

$$\frac{\partial \delta_A^C}{\partial n_A} = -\frac{(3n_A - 2)(n_A + 1)\left(n_A^2 - 3n_A + 2\right)}{4\left[n_A^2 (n_A - 1) - 1\right]^2} \tag{29}$$

which is negative for any $n_A \geq 2$.

Suppose now that members in group B act non cooperatively. The limit discount factor above which cooperation can be sustained in group A is now defined as follows

$$\delta_A^N = \frac{U_A^{DN} - U_A^{CN}}{U_A^{DN} - U_A^{NN}} \tag{30}$$

where the single upper script N denotes the Non-cooperative outcome within the *other* group. U_A^{NN}, U_A^{CN} and U_A^{DN} are given by (10), (24), and (26) respectively. We then have

$$\delta_A^N (n_A, n_B) = \frac{(n_A + n_B)^2 \left[n_B (n_A - 2) + (n_A - 1)\right]}{(n_B + 1)^2 \left[n_A (n_A - 1)(n_A + n_B - 1) - n_B\right]} \tag{31}$$

A symmetric expression can be found for group B by permuting n_A and n_B.

Calculating the derivative of δ_A^N with respect to n_A, we have

$$\frac{\partial \delta_A^N}{\partial n_A} = -\frac{\begin{array}{c} n_A n_B \left[n_A (n_B + 1)(n_A - 5) + n_B^2 (n_A - 4) + 7n_B + 8\right] \\ + n_A (n_A - 1)^2 + n_B \left(3n_B^2 - 4n_B - 3\right) \end{array}}{(n_B + 1)^2 \left[n_A (n_A - 1)(n_A + n_B - 1) - n_B\right]^2} < 0. \tag{32}$$

It is immediate to check that the numerator of this expression is always positive for any $n_A \geq 4$ and $n_B \geq 2$. Hence, δ_A^N is decreasing with n_A for any $n_A \geq 4$. Calculating the derivative of δ_A^N with respect to n_B, we have

$$\frac{\partial \delta_A^N}{\partial n_B} = -\frac{\begin{array}{c} n_B^2 \left(n_A^4 - 3n_A^3 + n_A^2 + 4n_A - 3\right) \\ +n_B(n_A^5 - 4n_A^4 + 10n_A^3 - 15n_A^2 + 9n_A - 1) \\ + \left(n_A^5 - 3n_A^4 + 5n_A^3 - 6n_A^2 + 3n_A\right) \end{array}}{(n_B+1)^4 \left[n_A (n_A - 1)(n_A + n_B - 1) - n_B\right]^2} < 0. \tag{33}$$

Again, it is immediate to check that the numerator of this expression is positive for any $n_A \geq 4$ and $n_B \geq 2$. By symmetry, the derivative of δ_A^N will be negative with respect both to n_A and n_B for any $n_B \geq 4$ and $n_A \geq 2$. We will then consider, from now, that the size of both group is at least equal to 4. Thus, we have

Proposition 1 *(i) When the cooperative outcome within the rival group is taken as given, the difficulty of maintaining cooperation in a group depends only on the number of members of that group and is decreasing in that number. (ii) When the non-cooperative outcome within the rival group is taken as given, the difficulty of maintaining cooperation in a group is decreasing in the number of members of both groups.*

From the one-shot analysis of the previous section, we know that the larger the size of a group, the more severe is the collective action problem which is reflected in a lower share of the rent. Hence, we would presume that the ability to maintain cooperation deteriorates as a group expands in size. However, in a dynamic setting, according to the above Proposition, this conjecture is overturned. Furthermore, the difficulty of maintaining cooperation in a group depends on how payoffs under defection, cooperation and non-cooperation evolve has *both* groups grow larger. The one-period unit of payoff is the product of the group's share of the rent by the per-capita value of the aggregate rent Y. When a group becomes larger, the per-capita value of the prize diminishes but the group's share does not change under within-group cooperation. Indeed, when members in a group cooperate, the share of that group is either equal to 1/2 (when there is within-group cooperation in the rival group) or depends only on the number of members of the rival group (when the non-cooperative outcome prevails in the rival group as shown by (23)). When members do not cooperate, however, both the per-capita value of the prize and the group's share decrease as the group becomes larger. Therefore, the cost of infinite reversion to the non-cooperative outcome is increasingly higher with group size independently on the behavior of the members of the rival group. As a result, the ability of a group to maintain cooperation is increasing in its size. In addition, since the share of the group in which there is cooperation is increasing with the size of the rival group in which there is non-cooperation, the larger the size of the rival group, the less difficult is to maintain cooperation in the former group.

It could also be interesting to rank the different discount parameters. Without any loss of generality and for felicity only, let consider that group A is the larger group i.e. $n_A \geq n_B$. By recalling that the upper scripts of the limit discount parameters indicate the organizational properties of the rival group, we can establish

Proposition 2 *When the status within the rival group is taken as given, we have the following ranking (for $n_A \geq n_B$): $0 < \delta_B^N \leq \delta_A^N < \delta_A^C \leq \delta_B^C < 1$. In other words: (i) Cooperation in a group is less difficult to maintain when there is non-cooperation within the rival group than when there is cooperation. (ii) When the cooperative outcome (non-cooperative outcome) within the rival group is taken as given, cooperation is less difficult to sustain in the larger (smaller) group than in the smaller (larger) group.*

Proof. To prove that result, we need to make three comparisons i.e. (i) $\delta_A^C \leq \delta_B^C$; (ii) $\delta_B^N \leq \delta_A^N$ and (iii) $\delta_j^N < \delta_j^C$ (and in particular $\delta_A^N < \delta_A^C$). (i) By symmetry and because δ_j^C (for $j = A, B$) only depends on n_j and is a decreasing function, we have $\delta_A^C \leq \delta_B^C$. (ii) Let note $\Delta = \delta_A^N - \delta_B^N$. After long and painstaking calculus, one can find that $\Delta = n_A n_B \left[\left(n_A^3 - n_B^3\right) + \left(n_A^2 - n_B^2\right) + \left(n_A - n_B\right)\left(2n_A n_B - 1\right)\right] + n_A^2\left(n_A^2 - 1\right) - n_B^2\left(n_B^2 - 1\right)$ which is positive for any $n_A \geq n_B$. Hence, we have $\delta_A^N \geq \delta_B^N$. (iii) Finally, we need to check that $\delta_j^N < \delta_j^C$ for $j = A, B$. Let consider the case of group A. On the one hand, since δ_A^C is decreasing in n_A, δ_A^C reaches its minimum when n_A goes to infinity. Using (28), in the limit we have $\lim\limits_{n_A \to \infty} \delta_A^C = 1/2$. On the other hand, given n_B, the maximum of δ_A^N is obtained when the size of group A is at its minimum i.e. $n_A = 4$. A sufficient condition for the previous inequality to be satisfied is then $\delta_A^N\left(n_A = 4, n_B\right) \leq 1/2$. Using (31), we have $\delta_A^N\left(n_A = 4, n_B\right) = \frac{(n_B+4)^2[2n_B+3]}{(n_B+1)^2(11n_B+36)}$. Using this expression the inequality $\delta_A^N\left(n_A = 4, n_B\right) \leq 1/2$, reduces $7n_B^3 + 20n_B^3 - 29n_B - 60 \geq 0$ which is always satisfied (with strict inequality) for any $n_B \geq 4$. ■

For each group, cooperation is less difficult to sustain when there is non-cooperation within the rival group than when there is cooperation (i.e. $\delta_j^N < \delta_j^C$ for $j = A, B$). This is because the relative benefits of cooperation are significantly more important when the competing group cannot enforce within-group cooperation. In that situation, each group can exploit the free-rider problem within the other group both to sustain cooperation and to extract a large share of the total rent. As shown by (23), the share allocated to a region in which members act cooperatively while members of the other regions act non-cooperatively is approaching 1 as the number of members of the rival group grows larger.

Also, when there is cooperation in rent-seeking within the two groups, each group gets half of the total rent. But the larger the size of a group, the lower is its share of the rent if members behave non-cooperatively while members of the competing group still act cooperatively. Hence, the infinite reversion to the non-cooperative outcome is more costly for the larger group than for the smaller group which in turn makes cooperation less difficult to sustain in the larger group (hence $\delta_A^C \leq \delta_B^C$).

However, when the non-cooperative outcome prevails in the rival group, cooperation is more difficult to sustain in the larger group than in the smaller group. This result is less immediate. On the one hand, the relative benefits of cooperation are more important for the smaller group than for the larger group when members within the rival group act non-cooperatively. This is because, when there is cooperation in a group, its share of the rent is increasing in the size of the rival group in which there is non-cooperation (as shown by (23)). On the other hand, the cost of infinite reversion to the non-cooperative outcome is lower for the smaller group than for the larger group. This is because the larger group, when all individuals within the two groups behave non-cooperatively, gets the lower share of the rent because of the collective action problem. Hence, the relative benefits of cooperation are more important while the relative costs of non-cooperation are less important for the smaller group. The reverse holds for the larger group. Consequently, when there is non-cooperation within the rival group, there exists two opposing forces on the ability to maintain cooperation. According to the above result, the one-period unit of defection is lower than the difference in future payoffs between cooperation and non-cooperation (in present discounted value) for the smaller group than for the larger group (and then $\delta_B^N \leq \delta_A^N$).

4.2 Equilibrium Configurations

We must now characterize the subgame perfect Nash equilibria of the game between the groups of individuals. In particular, when there is defection and reversion to the non-cooperative outcome within one group, the enforcement of cooperation within the other group might become a best response. Hence, when members of the rival group do not cooperate, cooperative incentives in the home group may be enhanced by the possibility that breaking cooperation incitates members of the rival group to cooperate.

It is worth noting out that we focus on a subset of subgame perfect equilibria. Indeed, at a given time, individuals either play their short run best reply to defection by a group number i.e. a non-cooperative level of effort or the group's "pseudo" short run best reply to the switch to the non-cooperative outcome within the rival group i.e. a cooperative level of effort. With these strategies, there are thus four types of equilibria that are stationary on the equilibrium path i.e. cooperation within both groups, non-cooperation within both groups and the two equilibria in which there is cooperation within one group and non-cooperation within the other. In this subsection, we are thus looking for the subgame perfect equilibria that are stationary on the equilibrium path, for every subgame.

For felicity only, let continue to assume that $n_A \geq n_B$. We first analyze the ability to maintain cooperation in the smaller group i.e. group B. Consider that at date t, there is cooperation in rent-seeking activities within both groups. If there is defection of one individual at date $t+1$ in group B, this group from $t+2$ reverts to the one-shot non-cooperative outcome forever. This will not change the behavior of members of the rival group. Indeed, the switch to the non-cooperative outcome in group B increases the relative benefits of cooperation within group A. The relevant discount parameter is therefore the one obtained in the previous subsection i.e. δ_B^C.

Now consider that at date t, the members of group A act non-cooperatively and members of group B act cooperatively. At $t+1$, if one individual of group B deviates, then this group, from $t+2$, reverts to the non-cooperative equilibrium forever. This change in the status of group B may lead to cooperation within group A from the date $t+2$. If $\delta < \delta_A^N$, the switch to the non-cooperative outcome in group B does not have any impact on the behavior of members of group A. They continue to act non-cooperatively. Indeed, recall that δ_A^N is the limit discount parameter above which cooperation can be maintained in group A when the members of group B act Non-cooperatively. If however $\delta \geq \delta_A^N$ then the switch to the non-cooperative outcome within group B could lead to cooperation in group A from the date $t+2$. But because $\delta \geq \delta_A^N \geq \delta_B^N$ defection at the date $t+1$ is not profitable for any members of group B. Therefore, the relevant discount parameter above which cooperation can be maintained in group B is again the one obtained in the previous subsection when the status (non-cooperation) of group A is taken as given i.e. δ_B^N. The threat of the switch to the cooperative outcome in the rival group cannot be exploited to prevent defection within the smaller group i.e. group B.

We now turn to the analysis of the ability to maintain cooperation within group A. Consider that at date t, there is cooperation in rent-seeking activities within both groups. If there is defection of one individual at date $t+1$ in group A, this group from $t+2$ reverts to the one-shot non-cooperative equilibrium forever. This will not change the behavior of the members of the rival group. Indeed, the switch to the non-cooperative outcome within group A increases the benefits of cooperation within group B. The relevant discount factor is therefore the one obtained in the previous subsection i.e. δ_A^C.

Now consider that at date t, members of group B act non-cooperatively and members of group A act cooperatively. At $t+1$, if one individual of group A deviates then this group, from $t+2$, reverts to the non-cooperative equilibrium forever. This change in the status of group A may lead to cooperation in group B from the date $t+2$. If $\delta < \delta_B^N$, the switch to the non-cooperative outcome in group A does not have any impact on the behavior of the members of group B. They continue to act non cooperatively. (Again, δ_B^N is the limit discount parameter above which cooperation can be maintained in group B when members within group A act Non cooperatively). If however, $\delta_A^N \geq \delta \geq \delta_B^N$ then the switch to the non-cooperative outcome in group A may lead, from the date $t+2$, to the cooperative outcome within group B. In that situation, if a member of group A defects, she will earn u_A^{DN} in the current period and u_A^{NC} in all future periods. (Again, recall that the first upper script of payoffs indicates the behavior of members of group A and the second one that of group B). Hence, a necessary condition for maintaining cooperation in group A under a trigger strategy with infinite Nash reversion is now given by

$$u_A^{DN} + \sum_{t=1}^{\infty} \delta^t u_A^{NC} \leq \sum_{t=0}^{\infty} \delta^t u_A^{CN} \tag{34}$$

u_A^{CN} and u_A^{DN} are given by (24) and (26) respectively. u_A^{NC} is given by (25) in which n_B have been replaced by n_A. We then have

$$\delta_A^{N\prime}(n_A, n_B) = \frac{n_B (n_A+1)^2 \left[n_B (n_A-2) + (n_A-1)\right]}{(n_B+1)^2 \left[n_A^2 (n_A n_B - 1) - n_B\right]} \tag{35}$$

$n_A=\lambda n_B$ / n_B	λ=1.25	λ=1.5	λ=2	λ=5	λ=10	λ=100
4	0.126	0.100	0.069	0.016	**-0.001**	**-0.016**
8	0.080	0.066	0.050	0.019	0.009	**-0.001**
20	0.036	0.030	0.023	0.009	0.005	0.000

Figure 1: *The differential between $\delta_A^{N'}$ and δ_B^N (bold numbers represent a higher level of $\delta_A^{N'}$)*

Since the individual payoff within group A is lower when there is cooperation than when there is non-cooperation within group B (i.e. $u_A^{NC} < u_A^{NN}$) this discount parameter is lower than δ_A^N. In other words, the threat of a switch to the cooperative outcome within group B increases the cost of defection within group A which in turn may increase the ability to maintain cooperation within that group.

We need to compare $\delta_A^{N'}$ and δ_B^N. Unfortunately, the derivative of $\delta_A^{N'}$ with respect both to n_A and n_B is indeterminate. Therefore, we rely on numerical simulations to compare $\delta_A^{N'}$ and δ_B^N. Numerically, one can establish that δ_B^N is larger than $\delta_A^{N'}$ as long as group size asymmetry is not too important (see Table 1).[6]

In the following, we then consider that in most cases $\delta_A^{N'} < \delta_B^N$. However, defection within group A can lead to cooperation within group B only if $\delta \geq \delta_B^N$. Therefore, the threat of the switch to the cooperative outcome within group B can be used to prevent defection within group A only if $\delta \geq \delta_B^N$. It follows that the critical factor above which cooperation can be maintained within group A is simply equal to δ_B^N. To summarize, when $n_A \geq n_B$ and group size asymmetry is not too important, we have the following ranking of the relevant discount parameters

$$0 < \delta_B^N \leq \delta_A^C \leq \delta_B^C < 1 \tag{36}$$

We can now characterize the subgame perfect equilibria of this game. Again, in this game the non-cooperative outcome within both groups is always a subgame perfect equilibrium no matter the common discount parameter of all individuals. However, in the following proposition, we just present the equilibria in which cooperation can be achieved within one group or both.

[6] However, in the limit when the larger group grows to infinity, we have $\delta_A^{N'} > \delta_B^N$. This is because, we have $\lim_{n_A\to\infty} \delta_A^{N'} = \frac{1}{1+n_B}$ on the one hand and $\lim_{n_A\to\infty} \delta_B^N = \frac{n_B-2}{n_B(n_B-1)-1}$ on the other. The first limit is larger than the second one.

Proposition 3 *(i) When* $0 \leq \delta \leq \delta_B^N$*, members in both groups act non-cooperatively in rent-seeking. (ii) When* $\delta_B^N \leq \delta \leq \delta_A^C$*, there coexists two equilibria, one in which members of group* A *act cooperatively while members of group* B *act non cooperatively and the reverse situation. (iii) When* $\delta_A^C \leq \delta \leq \delta_B^C$*, members of group* A *cooperate in rent-seeking while members of group* B *do not cooperate. (iv) When* $\delta \geq \delta_B^C$*, there is cooperation in rent-seeking within both groups.*

Proof. We prove the different points in the reverse order. Point (*iv*) is trivial since the critical value of the discount parameter is sufficiently high to maintain cooperation in the smaller group and *a fortiori* in the larger group. We indeed have $\delta \geq \delta_B^C \geq \delta_A^C$. Point (*iii*) is also simple. No matter how member of group B behave, cooperation can always be maintained in group A because $\delta \geq \delta_A^C$. Cooperation in this group does not allow to maintain the cooperative outcome in group B since $\delta \leq \delta_B^C$. Let now consider point (*ii*). Because $\delta \geq \delta_B^N$ and $\delta \leq \delta_A^C$, we have the equilibrium in which members of group B act cooperatively while members of group A act non-cooperatively. We also have the symmetric situation, i.e. members of group A act cooperatively while members of group B act non-cooperatively. This is indeed an equilibrium because as long as $\delta \geq \delta_B^N$, the threat of a switch to the cooperative outcome within group B prevents defection within group A and the maintenance of cooperation within group A prevents cooperation within group B because $\delta \leq \delta_A^C \leq \delta_B^C$. Finally, point (*i*) is straightforward. The discount parameter is too low to prevent cheating from the cooperative outcome in both groups ■

For low discount parameters, cooperation cannot be sustained in either group. In that situation, the smaller group is more effective since it gets a larger share of the rent than the larger group. When the discount parameter is higher and lies in the interval $\left[\delta_B^N, \delta_A^C\right]$, the two symmetric equilibria in which there is cooperation within one group and the non-cooperative outcome in the other group coexist but we cannot determine which equilibrium actually prevails. We could imagine, however, that one of the two groups is formed before the other. In that situation, anticipating the formation of a competing group, members of the original group could enforce and maintain within-group cooperation. Indeed, if members of the first group do not cooperate, members of the following group would be able to enforce the cooperative outcome which would then make cooperation impossible to sustain in the former group. As the discount parameter increases further, the cooperative outcome can be maintained in the larger group but not in the smaller group. As explained earlier, the basic intuition behind that result is that the infinite reversion to the within-group non-cooperative outcome is more costly for the larger group than for the smaller group. Indeed, because of the free-riding incentives, the larger group has much to lose by triggering non-cooperative reversion. Finally, when the discount parameter lies on the interval close to 1, both groups can maintain within-group cooperation.

Since now, we have not discussed about group effectiveness in terms of per-capita payoffs. Even though large groups manage to enforce within-group cooperation, per-capita payoff may be lower than in small groups. Because, the value of the rent is constant, larger groups are disadvantaged since the rent must be shared by a larger number of people. For instance, if members within both groups cooperate, each group gets half of the total rent and individual payoff is lower in the larger group. Now consider the situation in which there is cooperation within the larger group and non-cooperation within the smaller group. Comparing (24) and (25), individual payoff will be higher in the larger group than in the smaller group if $n_A < n_B^2$. Therefore, it might be well possible that larger groups are more effective not only in terms of aggregate levels of collective action but also in terms of per-capita payoff.

Finally, it is important to note that the punishment strategies considered in the present analysis could enforce cooperation not only within groups but also between groups. In that situation, each group would get half of the total rent without making rent-seeking expenditures; each group would then be better off. However, our focus was precisely to analyze the impact of between-group competition on the cooperative incentives within groups as a function of relative sizes.

5 Conclusion

Most collective goods theory emphasizes that large group are less effective because of the free-riding incentives. This is however in sharp contrast to what we observe in many real-world situations. We argue that two crucial features of group action have been neglected so far in the literature which might explain its failure to be consistent with a wide variety of informal and formal observations. First, group action is undertaken within the context of competition between several groups and second, groups have repeated interactions. These two features are sufficient to overturn Olson's argument since it is never the case that large groups are less effective. Further, if groups value the future enough, the larger group can be more effective both in terms of aggregate potency and per-capita payoff.

A critical factor of our analysis is that the two groups compete for a prize which is purely private since it is divisible both among groups and among individuals. It is important to remember that this assumption makes larger groups extremely vulnerable to the free-rider problem.[7] In a static setting, notwithstanding a larger number of claimants, the larger group gets a lower share of the total rent. In a dynamic setting, the predominance of this problem may help the larger group to achieve within-group cooperation and to produce an optimal level of collective action. In other words, the intrinsic disadvantage of large groups might become an asset that makes the threat strategy of infinite reversion to the non-cooperative outcome sufficiently costly to maintain cooperation. It would be both natural and interesting to extend the analysis by considering that the prize for which groups compete has both public and private characteristics. We conjecture that the intrinsic disadvantage of large groups would be attenuated and so their ability to overcome their collective action problem in a dynamic setting.

[7] In a model in which two groups compete for a prize which is purely public and not divisible among groups and among individuals, each group would have a probability 1/2 of getting the prize independent of its relative size. As explained by Katz, Nitzan and Rosenberg (1990), in this type of contest game, the free-rider problem within each group just counterbalances the size of the total prize for the group.

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6 The optimal level of rent-seeking expenditures under defection (Not for Publication)

The purpose of this subsection is to show that when an individual defects from the cooperative outcome, he will cut his contribution to 0. We consider the optimal behavior of a defecting agent within group A when there is non-cooperation within group B on the one hand and cooperation within group B on the other.

Let first consider that there is non-cooperation within group B. When an agent within group A defects from the within-group cooperative outcome, the share allocated to group A is

$$p_A^{DN} = \frac{(n_A-1)t_A^{CN}+t_A^{DN}}{(n_A-1)t_A^{CN}+t_A^{DN}+n_B t_B^{CN}}$$

where t_A^{CN} and t_B^{CN} are given by (21) and (22) in the text and represent the individual expenditure level in group A and B respectively when there is cooperation within group A and non-cooperation within group B. t_A^{DN} is the expenditure level of the agent who defects. This agent optimally chooses t_A^{DN} to maximize

$$u_A^{DN} = \frac{p_A^{DN}Y}{n_A} - t_A^{DN}$$

Using (21) and (22), the optimal expenditure of the defecting agent is given by the first-order condition

$$\frac{n_A(n_B+1)^2Y^2}{\left[n_A(n_B+1)Y+n_A(n_B+1)^2t_A^{DN}-n_BY\right]^2} = 1$$

Simplifying the above expression, we get

$$n_A\left(n_B+1\right)^2 t_A^{DN} = \left[\sqrt{n_A}\left(1-\sqrt{n_A}\right)\left(n_B+1\right)+n_B\right]Y$$

The right-hand term of the above expression in negative when

$$\sqrt{n_A}\left(\sqrt{n_A}-1\right) > n_B/\left(1+n_B\right).$$

A sufficient condition for t_A^{DN} to be equal to 0 is therefore

$\sqrt{n_A}\left(\sqrt{n_A}-1\right) > 1$ which is always satisfied for any $n_A \geq 3$. Therefore, when the non-cooperative outcome prevails within the competing group, the agent who defects from the co-operative outcome within the home group optimally cuts its contribution to 0.

We now consider that there is cooperation within the rival group. When an agent within group A defects from the within-group cooperative outcome, the share allocated to group A is

$$p_A^{DC} = \frac{(n_A-1)t_A^{CC}+t_A^{DC}}{(n_A-1)t_A^{CC}+t_A^{DC}+n_B t_B^{CC}}$$

where t_A^{CC} and t_B^{CC} are equal to $Y/(4n_A)$ and $Y/(4n_B)$ respectively and represent the individual expenditure level in group A and B when there is cooperation within the two groups. t_A^{DC} is the expenditure level of the agent who defects. This agent optimally chooses t_A^{DN} to maximize

$$u_A^{DN} = \frac{p_A^{DC}Y}{n_A} - t_A^{DC}$$

The optimal expenditure of the defecting agent is given by the first-order condition

$$\frac{4n_AY^2}{\left[(2n_A-1)Y+4n_At_A^{DC}\right]^2} = 1$$

Simplifying the above expression, we get

$$4n_At_A^{DC} = \left[1 - 2\sqrt{n_A}\left(\sqrt{n_A} - 1\right)\right]Y$$

The right-hand term is negative for any $n_A \geq 2$. Therefore, when there is cooperation within the rival group, an agent who defects from the cooperative outcome in the home group, cuts its expenditure level to 0.