Open access • Journal Article • DOI:10.1007/S12232-007-0029-Y

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Published on: 01 Jan 2008 - International Review of Economics (Springer-Verlag)

Topics: Conflict management, Conflict resolution research, Conflict avoidance and Conflict resolution

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February 2007

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by

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Paper prepared for the Conference 'Reciprocity, Theories and Facts', February 22-24, 2007, Verbania.

Reciprocity in the Shadow of Threat

Raul Caruso[*]

Abstract

This paper considers a partial equilibrium model of conflict where two asymmetric, rational and risk-neutral opponents evaluate differently a contested stake. Differently from common contest models, agents have the option of choosing a second instrument to affect the outcome of the conflict. The second instrument is assumed to capture positive investments in 'conflict management' - labelled as 'talks'. It will be demonstrated that the asymmetry in the evaluation of the stake does constitute a powerful force influencing agents' behaviour. In particular, (a) whenever the asymmetry in the evaluation of the stake is extremely large there is no room for cooperation and a conflict trap emerges; (b) whenever the degree of asymmetry falls within a critical interval cooperation seems to emerge even if only the agent with the higher evaluation of the stake makes a concession, proportional to the optimal choice of 'talks'; (c) as the evaluations of the stake converge only reciprocal concessions (capturing a kind of strong reciprocity) made by both agents can pave the way for cooperation. In such a case, the existence of reciprocal concessions paves the way for establishing a potential settlement region (PSR) given that both parties can be better off while expending resources in 'talks'. Finally, throughout the paper, the concept of entropy is applied as a tool for the measurement and evaluation of conflict and conflict management.

KEYWORDS: Conflict, Contest, Conflict management, conflict resolution, concessions, reciprocity, asymmetry in evaluation, Statistical entropy, cooperation, integrative systems, 'guns' and 'talks'.

JEL CLASSIFICATION: D7, D74.

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[*]Istituto di Politica Economica, Università Cattolica del Sacro Cuore, e-mail raul.caruso@unicatt.it, Paper prepared for the conference, *Reciprocity, Theories and Facts*, February 22-24, Milano. I warmly thank Luigi Campiglio, Vito Moramarco, Maurizio Motolese, Carsten K. Nielsen, Johan Moyersoen, Nicola Giocoli and Davide Tondani.

RECIPROCITY IN THE SHADOW OF THREAT

Raul Caruso

INTRODUCTION

The basic question of this work is whether a particular form of **strong reciprocity** can favour the establishing of conflict management procedures between rational agents involved in a destructive conflict. In particular, this is the story of two rational agents clashing over the redistribution of a divisible stake. Due to the absence of norms and institutions governing and enforcing the redistribution of the stake they compete by means of positive investments in arms and violent efforts.

In order to better analyse the emergence of conflict management some assumptions about the conflict situation are needed. Then, throughout the paper a conflict interaction is assumed to be: *a destructive interaction which involves strategic interdependent decisions in the presence of coercion and anarchy*. This concept of conflict relies to a large extent upon three main interdependent features: (i) coercion; (ii) anarchy; (iii) wastage of resources.

The first fundamental feature of conflict is the presence of coercion. By coercion, I intend that kind of behaviour that is shaped and influenced by the existence of a credible threat. A credible threat depends upon the potential exploitation of brutal force. Albeit with different approaches, the importance of threat has been brilliantly expounded by John Nash (1953), Thomas Schelling (1960/1966), Kenneth Boulding (1963) and John Harsanyi (1965). The existence of a threat sheds light on the characteristic feature of conflict – namely, that while involved in a conflict the choices of an agent are choices made under coercion. Even though agents have options to make a choice, this is not purely voluntary. Take extortion. In economic terms, it is nothing but a monetary transfer flowing from an individual to another. A shopkeeper under the credible threat of a racketeer has a choice. (S)He could not acquiesce to the extortion. Whatever the outcome of this interaction it would have been a choice under coercion.

The second characteristic feature of conflict is anarchy. By 'anarchy' I simply mean nothing but the absence of rules, norms and institutions governing agents' behaviour. As noted above, it is a *state-of-nature* environment where allocations of resources are determined also through the exploitation of brutal force. Albeit appearing to be a worst case scenario, this does not imply that a conflict cannot be managed or solved. It can be managed and solved only in the presence of endogenous 'rules-of-the-game' governing the interaction. There is no hierarchical way of mediation and conciliation as that provided by states or – broadly speaking – by organised communities.

The third key feature is that conflict is costly and wasteful. Positive expenditures in conflict are irreversible sunk costs. In particular, conflict efforts are interpreted as unproductive activities leading to inefficiencies in economic life. This is in the spirit of the definition provided by Bhagwati

(1982), who proposes a general taxonomy for a broader range of economic activities representing ways of making profit in spite of being directly unproductive, conflicts, contests and rent-seeking can be considered directly unproductive activities (DUP). According to this view, such activities yield pecuniary returns but do not produce goods and services which enter a utility function, either directly or indirectly through increased production or availability to the economy of goods that enter a utility function.

However, conflicts are rarely a simple exploitation of brutal force. Most conflicts involve remarkable bargaining and communication efforts between the antagonists. Beyond violence, as applied when sending actual or potential threats, agents apply other instruments to successfully end any struggle. During a war, for example, the exploitation of actual violence is often interlinked with diplomatic efforts. Diplomatic negotiations are often conducted while troops are deployed on the battlefield. In international interactions, the exploitation of potential or actual violence cannot be disentangled from partial openings and cooperative behaviours. In general they could be labelled broadly as 'conflict management efforts'. What is the nature of such conflict management efforts? By conflict management can be indicated the entire set of joint actions available to the opponents in order to be better off whilst reducing the intensity of conflict. Moreover, what agents pursue while managing the conflict is also the establishing of a certain 'rules-of-the-game' governing the conflict interaction. Given the non-cooperative environment it must be a self-enforcing joint strategy that make parties better off allowing for the emerging of institutions. In a broader view, 'conflict management efforts' can involve a wide spectrum of activities. For expository convenience, consider among others: (i) bargaining; (ii) communication and strategic information transmission; (iii) costly signalling. Alike efforts exerted in offending and hindering other agents' behaviour, efforts exerted to manage or solve the conflict fall within the broader category of unproductive activities. This is not a novelty. Pigou (1921/1929) already enlisted 'bargaining' amongst the sources of inefficiency in public and private sectors of the economy. Using his words "[...]*Of bargaining proper there is little that need be said. It is obvious that intelligence and resources devoted to this purpose, whether on one side of on the other, and whether successful or unsuccessful yield no net product to the community as a whole. [...] these activities are wasted. They contribute to private, but not to social, net product* [...]"[1]

In Caruso (2006a) and Caruso (2007) I borrowed the labelling of the 'Bad Cop and the Good Cop Game' in order to give a simple and appealing depiction of this idea. This paper does constitute an extension of these foregoing works. In particular, this paper aims to study the emergence of a conflict management scenario grounded upon *strong reciprocity*. Here I would recall a definition of strong reciprocity as presented by Gintis (2000). Borrowing his words: *[...]**Homo Reciprocans** exhibits what may be*

[1] Pigou (1929) p. 202-203.

called ***strong reciprocity****, by which we can mean a propensity to cooperate and share with others similarly disposed, even at a personal cost, and a willingness to punish who violate cooperative and other social norms, even when punishing is personally costly[…].*[2] Then, in such a view, the existence and the awareness of punishments shape any reciprocal and strategic behaviour leading to establishing norms and institutions. The idea of strong reciprocity does fit dramatically well with the vigorous argument of 'integrative relationship' and 'grants economy' as presented by Kenneth Boulding (1962/1973). To Boulding, any social system can be divided into three large, overlapping and interacting sub-systems: exchange, threat and integrative system. They do not occur in pure form. All human institutions and relationships involve different combinations of all three. Using Boulding's words: '*the integrative response is that which establishes community between the threatener and the threatened and produces common values and common interest*'[3]. The **integrative system** involves many different concepts. Among individuals, an integrative relationship involves a complex spectrum of feelings, such as respect, love, affection and so on. It also involves other concepts emerging between individuals as well as organisations: legitimacy, status, sense of identity, community etc. etc. In general terms, an integrative system needs to exhibit a convergence and interdependence of utility functions of parties involved. Moreover, the key feature of integrative systems is the existence of 'grants'. In general terms, a grant is supposed to be a unilateral transfer from an individual, a group or a social unit to another. When it occurs, the donor agent does not receive anything in return.

Then, in this paper I model a conflict involving a costly commitment to conflict management between agents. This behaviour is captured by means of the existence of 'grants' or 'transfers' provided, under some conditions, by each agent to the opponent. Hence, they shape a mechanism of reciprocal concessions. However, In such a framework, brutal conflict an threats do not vanish. In the light of the theoretical foundations expounded above any cooperative behaviour grounded on reciprocity will constitute a kind of 'armed cooperation'. But it is reasonable to consider that they do have a different impact on the conflict interaction. This is the rationale of labelling *reciprocity in the shadow of threat*.

Eventually, a key-feature of this work is that agents evaluate differently the stake of the conflict. This is a fundamental and crucial assumption. Investigating how agents form their own beliefs goes far beyond the aim of this work. However, it appears clear that the asymmetry in the evaluations does constitute a really powerful force shaping parties' behaviour. In particular, it is possible to show how agents' choice of fighting and 'negotiating' depend upon the degree of asymmetry in the evaluations. As a simple consideration, recall that the evaluation of the stake can be translated in 'incentive' for all parties involved. Conflict and Conflict

[2] Gintis (2000) p. 262. Emphasis is in the original text. Italics turned into bold.
[3] Boulding (1963a) p. 430.

management can follow the same incentive. On one hand, the higher is the incentive the more brutal is the conflict. On the other hand, the incentive works also in favour of a settlement. That is, in other words, it would mean that agents are more prone to conflict management. This can happen when agents are rational. In fact, as rational agents the parties evaluate the incentives as well as the costs and the benefits of a conflict interaction. In fact, conflict management must be interpreted as a complement of fighting.

The paper is organised as follows. In a first section some formal pillars are presented. In a second section a baseline partial equilibrium model of conflict is expounded. The third paragraph does constitute the 'core' of this work. It presents a model of conflict augmented with conflict management efforts. It underlines under which conditions a potential settlement region can be established. A fourth section is devoted to the issue of measurement. It applies the idea of statistical entropy. Finally, the last section summarises the results and provides suggestions for future research.

CORNERSTONES

In recent economic literature, Jack Hirshleifer pioneered the work on modelling conflict, whose foundations are in Hirshleifer (1987a, 1988, 1989). The economic theory of conflict[4] rests to a large extent upon the assumption that agents involved in conflict interactions have to choose an optimal level of efforts or resources devoted to the unproductive activity of conflict which is necessarily detrimental for welfare. This is central to the theory of conflict as well as to the theory of rent-seeking and contests. Given the partial-equilibrium framework adopted in this work, the analysis produced can be generalized to all these theoretical categories.

What is mainly outlined in recent literature is that while conflict models are usually general equilibrium models, rent-seeking, and contest models are partial equilibrium models. This means that conflict models should involve a trade-off between productive and unproductive activities and the prize (or the rent) of the contest is endogenous. The stake of the conflict is interpreted as a joint production which depends on the productive efforts of the agents. At the same time, the cost function is represented by the foregone production. In such a construction the greater the number of the agents, the greater the 'pie' to be split. In rent-seeking and contest models, the prize (or the rent) is given exogenously. In such a case, even if the number of contestants becomes larger, the rent does not change. Moreover, rent-seeking and contest models can involve unconstrained optimization, whereas conflict models necessarily imply

[4] In more recent years several studies extended Hirshleifer's basic model. See among others: Grossman (1991/1998), Skaperdas (1992), Neary (1997a), Anderton et al. (1999), Garfinkel and Skaperdas (2000), Alesina and Spolaore (2003/2005), Dixit (2004), Spolaore (2004), Caruso (2006b). The literature on the economics of conflict has been recently surveyed and deeply expounded in Garfinkel and Skaperdas (2006).

constrained optimization. Neary (1997b) and Hausken (2005) propose a comparison of conflict and contest models along these lines.

This paper presents a partial equilibrium model of conflict featuring two asymmetric, rational and risk-neutral opponents. It is intended to develop the literature on conflict by tackling three main points:

(i) the existence of a second type of effort (instrument) to win the conflict;
(ii) an asymmetry in the evaluation of the stake of the conflict;
(iii) the existence of reciprocal concessions to favour an agreement between agents.

First, note that the definition of conflict given above has a remarkable formal implication and marks a difference from rent-seeking and contests. Needless to say, in rent-seeking activities, an interest group can voluntarily choose whether or not to participate into the competition for public funds. In a sport contest – e.g. a race – an athlete can decide not to start. By contrast, a conflict interaction in many cases is not a voluntary choice. Agents have to participate into it and cannot give up. Of course, this assumption does exclude the possibility of escape. In formal terms, what is needed is an appropriate mathematical function which does not allow for zero efforts in conflict. Formal cornerstone of contest and conflict literature is the Contest Success Function (henceforth CSF for brevity). [5] The CSF is a mathematical relation that links the outcome of a contest and the efforts of the players. It summarises the relevant aspects of what Hirshleifer defines the *technology* of conflict. It retains the independence of irrelevant alternative property. That is, the outcome of conflict depend only upon the efforts of parties involved. This rules out any impact of a third party.

There are two functional forms of CSF adopted in literature: the *ratio form* and the *logistic form*. Hirshleifer (1989), Baik (1998) and Anderton (2000) analyse the different impact of these two different functional forms for CSF. In the first case, the outcome depends upon the ratio of the efforts applied, whilst in the second case it depends upon the difference between the efforts committed. The main difference between the two functional forms of CSF becomes clear when one agent, say agent 1, puts zero in conflict effort.

In the simplest two-agents case, let $p_i(g_i, g_j)$ denote the probability of winning the contest (or alternatively the fraction of the stake) for agent i with $g_i, g_j, i = 1,2, i \neq j$ indicating the efforts. The probability of winning of agent i is increasing in agent i's efforts and decreasing in the efforts of the other agent. The ratio form of the CSF implies that if one of the two contestants does not exert any positive efforts, the other grabs all the

[5] Selective seminal contributions are by Tullock (1980), O'Keeffe et al. (1984), Rosen (1986) and Dixit (1987). See then Skaperdas (1996) and Clark and Riis (1998) for a basic axiomatization. See also Amegashie (2006).

contested stake, namely $p(g_i,0)=1, \forall g_i \in (0,\infty)$. By contrast, using the logistic form, an agent committing zero effort can achieve some degree of success. If peace and cooperation have to be defined as the absence of violent efforts (with $g_i = g_j = 0$), peace can never occur as an equilibrium under the ratio form of CSF, because either agent would be likely to defect and invest any small positive magnitude in order to raise its fraction of the stake to 100%. Then, the choice of ratio form of the CSF is consistent with the assumption of coercion as a characteristic feature of conflict. Under coercion and credible threat one agent can choose the optimal level of conflict efforts but cannot give up its own irreversible investment. To sum up, while modeling a conflict the existence of threat would not allow for the logistic form of CSF.

Secondly, as presented above, the aim of this paper is that of studying a conflict between two risk-neutral agents that evaluate differently the stake and that can use different instruments in order to pursue their own maximum utility. Therefore, the outcome of the contest will arise from the interaction of such different instruments. In this view, the standard one-instrument models commonly adopted in literature can be considered as a special case of multi-instruments models.

Thus, in the continuation of this work I will interpret the second instrument in a broad view. It is assumed to capture the vast majority of potential *conflict management efforts*. In reality, It can take different shapes. It can involve, among others, elements of communication, negotiation and signalling. Under the assumption of complete information, the second instrument must be perfectly observable. Henceforth, for expository convenience, in the continuation of the work I shall refer to the second instrument as *"talks"* whereas the first instrument will be indicated through the traditional '*'guns"*.[6] Thus to summarise:

(i) the use of a second instrument needs not to be "payoff-irrelevant": it must have a direct impact on both agents' payoffs;
(ii) the second instrument must also be costly. There is no room for *cheap talk*. In fact, what is needed is a "credibility-cost". Under the assumption of complete information, an observable costly effort is also assumed to be credible;
(iii) investments in conflict management must be irrevocable;
(iv) the two instruments must be complements. The outcome depends upon the mixed effect of *'guns'* and *'talks'*

In the theory of contest the use of a second instrument is not a novelty, although such approach has not been developed extensively. Baik and Shogran (1995) study a contest between players with unknown relative ability. Under the assumption of decreasing aversion to uncertain ability, agents are allowed to expend resources in order to reduce such uncertainty

[6] Of course, being in a partial equilibrium framework the classical tradeoff between 'butter' and "guns" is not considered.

through spying. Konrad (2003) enriches a model of rent-seeking considering the interaction between two types of efforts: (i) the standard rent-seeking efforts to improve their own performance in the view of winning a prize; (ii) a sabotaging effort in order to reduce the effectiveness of other agents' efforts. In this model, sabotage is targeted towards a particular rival group and reduces this group's performance. The point of interest is that through sabotage a group can increase its own probability of winning the prize as well as the other contestants'. Thus, the model predicts that sabotage disappears whenever the number of contestants becomes large. Caruso (2005b) presents two different models of contest with two instruments. The analysis is applied to sport contests in order to consider the phenomena of match-fixing and doping. Arbatskaya and Mialon (2005) analyse in depth the equilibrium properties of a two-instruments contest model and compare the results to those attainable in standard one-instrument models. In particular, this paper is close to a model proposed by Epstein and Hefeker (2003), who model a contest where, the use of a second instrument creates an advantage for the player with the higher stake.

Thirdly, this paper can also be linked to the literature of contests with asymmetric evaluations. Hillman and Riley (1989), Nti (1999/2004) analyses the case of a contest where participants evaluate differently the 'prize' – namely the stake. The common results of this contributions show that agents retaining a higher evaluation of the stake exert more efforts in the contest than the low-evaluation participants. In particular, Hillman and Riley show that asymmetric evaluation deters participation by low-evaluation agents.

Eventually, another goal of this paper will be represented by the identification of a *Potential Settlement Region* (henceforth PSR for sake of brevity) as the set of possible peaceful agreements.

THE PURE CONFLICT MODEL

Consider two risk-neutral agents, indexed by $i=1,2$, that are identical in abilities. At the same time they have different evaluations of the contested stake denoted by $x_i \in (0,\infty), i=1,2$. Given the asymmetry in evaluation, it would be possible to write that $x_1 \neq x_2$ where the subscripts indicate the evaluation of agent 1 and agent 2 respectively. In particular, hereafter assume that agent 1 has a higher evaluation than agent 2, namely $x_1 > x_2$. Let $\delta \in (0,1)$ denote the degree of asymmetry between the stakes of the two agents, namely $\exists \delta \in (0,1)\, s.t. x_2 = \delta x_1$. For sake of notational simplicity, throughout the paper I shall use agent 1's evaluation as a kind of numeraire and it will be simply denoted by x.There is common knowledge about such hypotheses.

Under the assumption of risk-neutrality, agents interpret the outcome of the non-cooperative interaction as deterministic. That is, given the assumption of risk-neutrality, agents are indifferent between conflict and sharing a stake in accordance with the winning probabilities. As noted above, the outcome of the conflict is determined through a CSF. The *ratio* form of the CSF used here is:

$$p_i = \frac{g_i}{g_i + g_j} \qquad \text{for } i = 1,2 \text{ and } j \neq i \tag{1}$$

Equation (1) is differentiable and follows the conditions below:

$$\begin{cases} p_1 + p_2 = 1 \\ \partial p_i / \partial g_i > 0 \quad \partial p_i / \partial g_j > 0 \\ \partial^2 p_i / \partial^2 g_i < 0 \quad \partial^2 p_i / \partial^2 g_j > 0 \\ \partial^3 p_i / \partial^3 g_i > 0 \quad \partial^3 p_i / \partial^3 g_j < 0 \end{cases} \tag{1.1}$$

The functional form adopted in equation (1) implies that there is no preponderance of an agent over the other. This is of course a limiting assumption, even if many conflicts fall in this category. Under the assumption of risk-neutrality the outcome of the CSF denotes the proportion of appropriation going to agent i for $i = 1,2$. Eventually, assuming a linear cost for 'guns' the payoff function is given by:

$$\pi_i^{pc}(g_1, g_2) = \frac{g_i}{g_i + g_j} x_i - z_i, i = 1,2, i \neq j \tag{2}$$

Each agent maximizes (2) with respect to g_i. Using $x_2 = \delta x_1$ and suppressing subscripts for notational simplicity, the equilibrium choices of 'guns' (denoted by stars superscripted) are given by[7]:

$$\begin{aligned} g_1^{pc*} &= \frac{\delta}{(\delta+1)^2} x; \\ g_2^{pc*} &= \frac{\delta^2}{(\delta+1)^2} x. \end{aligned} \tag{3}$$

It is clear that $g_1^{pc*} > g_2^{pc*}$ and also that $\partial g_i^{pc*} / \partial x > 0, \partial g_i^{pc*} / \partial \delta > 0, i = 1,2$. Note also that $\partial^2 g_1^{pc*} / \partial^2 \delta < 0$ and $\partial^2 g_2^{pc*} / \partial^2 \delta > 0 \Leftrightarrow \delta < 1/2$. Eventually the payoffs are given by:

[7] As demonstrated in Nti (1999), under constant returns to scale in fighting, a contest with asymmetric valuations has a unique pure strategy nash equilibrium if and only if the sum of the valuations is larger than the higher evaluation, namely $x + \delta x > x$.

$$\pi_1^{pc*} = \frac{1}{(\delta+1)^2} x; \pi_2^{pc*} = \frac{\delta^3}{(\delta+1)^2} x. \qquad (4)$$

Simple to verify that $\pi_1^{pc*} > \pi_2^{pc*}, \partial\pi_i^{pc*} / \partial x > 0, i = 1,2$. Note also that $\partial\pi_1^{pc*} / \partial\delta < 0, \partial^2\pi_1^{pc*} / \partial^2\delta > 0$ and $\partial\pi_2^{pc*} / \partial\delta > 0; \partial^2\pi_2^{pc*} / \partial^2\delta > 0$.

To sum up, both agents exert positive investments in 'guns' which are increasing in the evaluation of the stake. They both get positive payoffs and agent 1, namely the agent with a higher evaluation of the stake, is capable of getting a higher payoff by means of a higher level of 'guns'.

RECIPROCAL CONCESSIONS TO ESTABLISH A POTENTIAL SETTLEMENT REGION (PSR)

As noted above a concession is nothing but a 'grant' in Boulding's language, namely a transfer. Let me assume that such a transfer is measured in the same unit of both the efforts and the contested stake. Then, suppose that such an integrative grant is worth a fraction of the optimal level of resources expended for conflict management. Let $s_1 \in (0,1)$ and $s_2 \in (0,1)$ denote the proportional concessions. A limited assumption is that the latter proportional concessions are treated as exogenously given. I made this choice for analytical and expository convenience. On the other hand, since the concession is worth a fraction of a choice variable it also has an impact on the endogenous outcome.

A simple example can be drawn from International Relations. States invest resources in military expenditures and diplomacy. This does clearly fit with the idea of 'guns' and 'talks'. Take foreign aid. Foreign aid flowing from one state to another commonly falls within the budget of diplomacy. Through foreign aid, the donor state attempts to influence the behaviour of the recipient. In fact, although foreign aid is supposed to be a unilateral transfer provided to address the issues of poverty and development, it is also designed to pursue foreign policy objectives of donor countries.

Thus, consider now the option of a second instrument. Agents commit themselves to the use of a second instrument in order to affect the outcome of the contest. As mentioned above, the basic model presented hereafter follows and partly modifies the one proposed in Epstein and Hefeker (2003). In such a framework the traditional CSF is modified in order to allow for a second instrument. The two instruments are assumed to be complementary to each other. That is, the marginal payoff of an increase in '*guns*' could be enhanced by a simultaneous increase in '*talks*'. Then, the use of the second instrument would strengthen the effect of the first instrument. Eventually the CSF becomes:

$$p_i^{rc} = \frac{g_i(h_i+1)}{g_i(h_i+1) + g_j(h_j+1)}, i = 1,2, i \neq j \qquad (5)$$

and follows the conditions below:

$$\begin{cases} \partial p_i^{rc} / \partial g_i > 0 & \partial^2 p_i^{rc} / \partial g_i < 0 & \partial^3 p_i^{rc} / \partial g_i > 0 \\ \partial p_i^{rc} / \partial g_j < 0 & \partial^2 p_i^{rc} / \partial g_j > 0 & \partial^3 p_i^{rc} / \partial g_j < 0 \\ \partial p_i^{rc} / \partial h_i > 0 & \partial^2 p_i^{rc} / \partial h_i < 0 & \partial^3 p_i^{rc} / \delta h_i > 0 \\ \partial p_i^{rc} / \partial h_j < 0 & \partial^2 p_i^{rc} / \partial h_j > 0 & \partial^3 p_i^{rc} / \partial h_j < 0 \end{cases} \tag{5.1}$$

In particular, the cross partial derivative indicating the complementary relationships between 'guns' and 'talks' is given by:

$$\frac{\partial^2 p_i^{rc}}{\partial g_i h_j} > 0 \Leftrightarrow g_1(h_1+1) - g_2(h_2+1) > 0 \tag{5.2}$$

Eventually, assuming linear cost functions, so that $c'(g_i) > 0, c'(h_i) > 0, c''(g_i) = 0, c''(h_i) = 0$, for both instruments the payoff function for each agent become:

$$\pi_1^{rc}(g_1, g_2, h_1, h_2) = \frac{g_1(h_1+1)}{g_1(h_1+1) + g_2(h_2+1)} x - g_1 - h_1 + s_2 h_2 \tag{6}$$

$$\pi_2^{rc}(g_1, g_2, h_1, h_2) = \frac{g_2(h_2+1)}{g_1(h_1+1) + g_2(h_2+1)} (\delta x) - g_1 - h_1 + s_1 h_1 \tag{7}$$

after the ordinary process of maximization the optimal choices of both agents are:

$$\begin{cases} g_1^{rc*} = \dfrac{\delta^2}{(\delta^2+1)^2} x & h_1^* = \dfrac{\delta^2}{(\delta^2+1)^2} x - 1 \\ g_1^{rc*} = \dfrac{\delta^3}{(\delta^2+1)^2} x & h_2^* = \dfrac{\delta^3}{(\delta^2+1)^2} x - 1 \end{cases} \tag{8}$$

Note that $g_1^{rc*} > 0, g_2^{rc*} > 0$ whereas:

$$h_1^* > 0 \Leftrightarrow x > \frac{(\delta^2+1)^2}{\delta^2}; \tag{9}$$

$$h_2^* > 0 \Leftrightarrow x > \frac{(\delta^2+1)^2}{\delta^3}. \tag{10}$$

That is, in order to have a positive investment in 'talks' the value of the stake must be sufficiently large. Since the two instruments are assumed to exhibit a complementary relationship the incentives to manage the conflict follow those of being involved in a conflict. In other words, the agent with the higher evaluation of the stake has a higher incentive to manage the conflict than his opponent. In order to verify whether the critical points in (8) represent a global maximum, it is possible to consider the Hessian matrices for both agents. In the appendix are reported the results. The analysis shows that $\left(g_1^{rc*}, g_2^{rc*}, h_1^*, h_2^*\right)$ does constitute only a local max.
Eventually the expected payoffs accruing to the agents are:

$$\pi_1^{rc*} = \left(1 - s_2\right) + \frac{\delta\left(\delta^2 s_2 - \delta + 1\right)}{\left(\delta^2 + 1\right)^2} x \tag{11}$$

$$\pi_2^{rc*} = \left(1 - s_1\right) + \frac{\delta^2\left(\delta^3 - \delta + s_1\right)}{\left(\delta^2 + 1\right)^2} x \tag{12}$$

So now observe that $\pi_1^{rc*} > 0$ whereas $\pi_2^{rc*} > 0$ if and only if $s_1 > \delta - \delta^3$. The latter inequality sheds light on a particular aspect. That is, since agent 2 has less incentives to manage the conflict - as shown by (8) – a sufficiently large transfer is needed in order to make it better off and influence its behaviour.

It is also clear that $\partial \pi_1^{rc*} / \partial x > 0, \partial \pi_1^{rc*} / \partial \delta < 0$ and $\partial \pi_1^{rc*} / \partial s_2 > 0 \Leftrightarrow x > \left(\delta^2 + 1\right)^2 / \delta^3$. That is, the payoff of agent 1 is unambiguously increasing in the value of the stake. It is also unambiguously decreasing in the degree of asymmetry in the evaluation of the stake between the contestants. The interesting point is that agent 1's payoff is increasing in the concession provided by the opponent if and only if the value of the stake is sufficiently large. In particular, the latter inequality is also the condition to be fulfilled in order to have a positive value for h_2. This is consistent with the underlying hypothesis of this work. Only when one agent is going to exert positive efforts in 'talks' a concession can take place.

What about agent 2's payoff? Note also that $\partial \pi_2^{rc*} / \partial x > 0 \Leftrightarrow s_1 > \delta - \delta^3, \partial \pi_2^{rc*} / \partial s_1 > 0 \Leftrightarrow x > \left(\delta^2 + 1\right)^2 / \delta^2$, and eventually that $\partial \pi_2^{rc*} / \partial \delta > 0 \Leftrightarrow s_1\left(\delta^2 - 1\right) < \left[\delta\left(\delta^4 + 6\delta^2 - 3\right)\right] / 2$. The first inequality confirms that the payoff of agent 2 is increasing in the value of the stake only when the condition for a positive payoff is fulfilled. The second inequality recalls that only in the presence of a positive investment in 'talks' of agent 1 agent 2's payoff is increasing in the concession. Consider the latter inequality. The LHS is always negative since $s_1 \in (0,1)$ and $\delta \in (0,1)$. Then, the inequality holds if the RHS is positive. In particular, it is always positive if and only if $\delta > 0.68$. That is, there is a critical level $\tilde{\delta}$ such that (a) for $\delta > \tilde{\delta}$ agent 2's payoff is unambiguously increasing in the degree of asymmetry in the evaluation of the stake; (b) for $\delta < \tilde{\delta}$ agent 2's payoff is increasing in the degree of asymmetry in the evaluation of the stake for a particular combination of s_1 and δ.

As noted in the foregoing sections, a potential settlement region is attainable if and only if $h_1^* > 0, h_2^* > 0, \pi_1^{rc*} > 0, \pi_2^{rc*} > 0, \pi_1^{rc*} > \pi_1^{pc*}, \pi_2^{rc*} > \pi_2^{pc*}$. Then recall (4), (11) and (12). Rearranging it is possible to write:

$$\pi_1^{rc*} > \pi_1^{pc*} \Leftrightarrow s_2 > \frac{2\left(\delta^3 - \delta^2 - \delta - 1\right)}{\delta^2\left(\delta + 1\right)^2} \tag{13}$$

and

$$\pi_2^{rc*} > \pi_2^{pc*} \Leftrightarrow s_1 > -\frac{2\delta\left(\delta^3 - \delta^2 - \delta - 1\right)}{\left(\delta + 1\right)^2} \tag{14}$$

Inequalities (13) and (14) shed light on an important point. Also in this case the degree of asymmetry in the evaluation of the stake appears to be as the powerful force driving agents' choices. In particular note that agent 1 has a stricter condition to be fulfilled. However, as the degree of asymmetry in the evaluation of the stake decreases (as $\delta \to 1$) conditions (13) and (14) converge.

Hence, using (10), (11), (12), (13) and (14) as strict equalities and setting an arbitrary value for the contested stake ($x = 100$) it is possible to draw the potential settlement region.

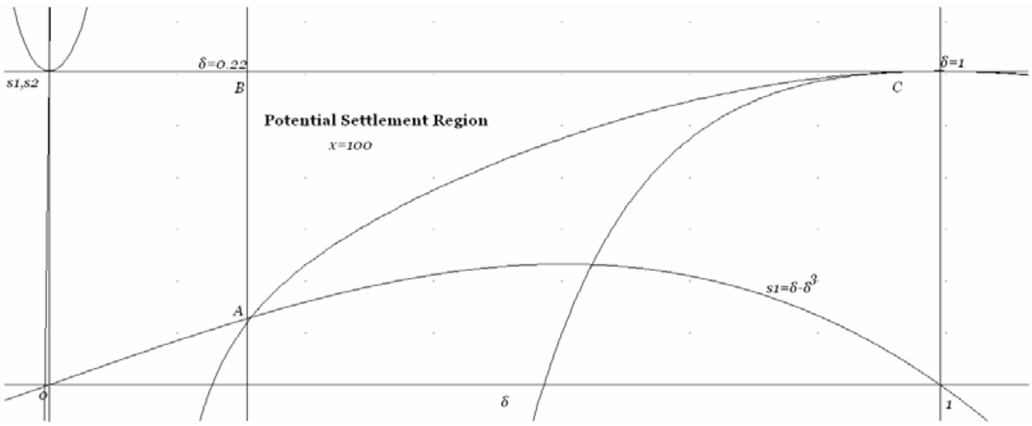

FIGURE 1 – PSR IN THE PRESENCE OF RECIPROCAL CONCESSIONS ($x = 100$)

Figure 1 shows the PSR attainable in the presence of conflict and reciprocal concessions. The PSR is depicted in a parameter space $(\delta, s_i), i = 1,2$. The horizontal axis represents the degree of asymmetry in evaluation of the stake whereas on the vertical axis the value of both s_1 and s_2 are presented.

The PSR is delimited by ABC. The vertical line indicating $\delta = 0.22$ represents the condition (10) for $x = 100$. All the points on the right of line AB fulfil condition (10). Then, no PSR can be established when $\delta \leq 0.22$. Both agents will prefer a pure conflict scenario. In other words the latter condition implies that when the asymmetry in evaluation of the stake is extremely large a PSR is not attainable. In such a case I would say that a *Conflict Trap* emerges.

At the same time, all the points on the left of line AC fulfil condition (14). It is also clear that condition (14) is stricter than (13). Moreover, it is clear that the PSR lies above the curve denoting $s_1 = \delta - \delta^3$. In particular, the latter would guarantee that agent 2' s payoffs are positive. Finally, the area delimited by ABC does constitute the PSR. Loving parsimony, I could say for $x = 100$, only conditions (14) and (12) need to hold.

First, it does appear clear that as the asymmetry in the evaluation of the stake decreases (as $\delta \to 1$) the value of the proportional concessions needed to establish a PSR increase. To better understand the graph, consider a simple numerical example. Set $x = 100$, for $\delta = 0.65$ in order to have a PSR the lower bounds are simply $s_1 > 0.85$ and $s_2 > 0.57$. Again for $\delta = 0.85$ the lower bounds are $s_1 > 0.97$ and $s_2 > 0.96$. The table 1 below presents a simple numerical example.

TABLE 1
Numerical Example

$x = 100$			
δ	s_1	s_2	PSR
0,15	-0.37	27.88*	◇
0.25	0.29	-52.19**	●
0.35	0.5	-6.56**	●
0.5	0.71	-0.65**	●
0.65	0.85	0,57	●
0.75	0.92	0.84	●
0.85	0.97	0.96	●

**rearranging the condition exactly is* $s_2 < 27{,}88$

*** since* s_2 *is assumed to be bounded between zero and one indicating as condition the inequality* $s_2 \geq 0$ *would also suffices.*

There is an interesting point arising from the this example. Consider $s_2 = 0$. Condition (13) reduces to $(\delta^3 - \delta^2 - \delta - 1) < 0$ and then to $\delta < 0.54$. This is the case of an unilateral concession provided by agent 1. That is, when the asymmetry in the evaluation of the stake is sufficiently large a potential settlement region can emerge even if agent 2 is not going to reward the opponent. The intuition behind appears to be simple. Since agent 1 has a higher incentive to conflict, it has also a higher willingness to settle whenever it is able to get a higher payoff. On the other hand agent 1 may tempted to influence agent's behaviour. Moreover, agent 2 - given the hypothesis of common knowledge - as recipient of agent 1' concession, may have an incentive to behave strategically. That is, agent 2, albeit favouring a settlement, may be tempted to work against it expecting to get a monetary transfer. A classical problem of *moral hazard* can emerge. Note that the opposite is not true. In fact if $s_1 = 0$ a PSR is no longer attainable. The agent with the higher evaluation of the stake cannot exploit the benefits of cooperation if it does not commit itself to reward the opponent. In a broader view agent 2 retains an advantage over the opponent. On the other hand, under common knowledge, positive investments in 'talks' ($h_2 > 0$) suffice to signal the agent 2's willingness of not being involved in a pure conflict. Since costly investments in 'talks' have been assumed to be credible another feasible interpretation is that a process of reputation-building can take place. However, regardless of agents 2' willingness to concede agent 1 is also better off. Hence it would be possible to say that there is room for an integrative relationship facilitated only through an unilateral concession if δ falls within a critical interval denoted by $\left[{}_*\delta, \delta^*\right]$ where ${}_*\delta$ is the lower bound given by condition (10) and $\delta^* = 0.54$.

Eventually consider what is the scenario if $\delta > \delta^*$. In the interval $\left(\delta^*, 1\right)$ both agents have to make a positive concession to the opponent. Otherwise there is no room for a PSR. In such a case a mechanism of *strong reciprocity* seems to work. In fact, the contested stake is nothing but the incentive leading the agents to clash as well as to cooperate. A lower disparity makes the pure conflict more profitable and brutal for both agents as clarified through equations (4). Hence the willingness and commitment to settle can be considered credible if and only if: (i) both agents commit themselves to cooperation; (ii) both agents make a concession establishing a relationship of reciprocity. In such a view, a relationship based upon strong reciprocity can be credible and feasible only in the presence of high incentives to conflict. That is, when the asymmetry is not so large a positive reciprocal concession made by agent 2 is needed. Therefore, there is no room for bluffing or moral hazard here.

Finally, note also that the degree of asymmetry cannot equal the proportional concession. That is in order to have a PSR it is necessary that $\delta \neq s_i, i = 1,2$. If $\delta = s_1$ conditions (12) and (14) would not hold simultaneously. In other words, this means that an equal compensation would not pave the way for conflict management. One might ask why this kind of constraint emerges. Being narrative, an adequate compensation would help to manage the conflict much better than an exact equal compensation. Re-writing in formal terms $s_1 > 1 - \delta$.

To sum up, the analysis demonstrated that a PSR is attainable when conditions (9), (10), (13) and (14) hold and in particular that:

(a) there is a critical interval $(0,{}_{*}\delta)$ where an extreme asymmetry in the evaluation of the stake does not allow for any PSR, even if in the presence of major reciprocal concession ($s_1 \cong 1, s_2 \cong 1$). I defined this *Conflict Trap;*

(b) there is a critical interval $[{}_{*}\delta,\delta^{*}]$ such that for $\delta \in [{}_{*}\delta,\delta^{*}]$a PSR is attainable even if $s_2 = 0$. In such a case the agent with the higher evaluation of the stake retains a higher willingness to cooperate. I would call this *Conflict Management under unilateral commitment*.

(c) There is a critical interval $({}_{*}\delta,1)$ such that for $\delta \in ({}_{*}\delta,1)$ a PSR is attainable only in the presence of positive reciprocal concessions. This scenario recalls exactly the title of the paper: *Reciprocity in the shadow of threat*.

MEASURING CONFLICT

Conflict must be susceptible to measurement. In the standard partial equilibrium contest theory the resources expended do constitute the social cost of contest. In rent-seeking literature it is defined as the Rent Dissipation. Then, recall the optimal choices of violent efforts. It would be possible to write that the total cost under pure conflict is:

$$TC^{pc} = g_1^{pc*} + g_2^{pc*} = \frac{\delta}{(\delta+1)}x \tag{15}$$

As noted above, conflict management does constitute an inefficient activity. Thus, the total social deadweight loss imposed by both conflict and conflict management can be decomposed as the sum of the two types of expenditure. Recalling (8) the total cost of conflict when both agents expend efforts in a second instrument is given by:

$$TC^{rc} = g_1^{rc*} + g_2^{rc*} + h_1^{rc*} + h_2^{rc*} = 2\left[\frac{\delta^2 x(\delta+1)}{(\delta^2+1)^2} - 1\right] \tag{16}$$

To give a numerical example, set $x = 100$ and it would be possible to write that $TC^{rc} > TC^{pc} \Leftrightarrow \delta > 0.37$. Then, there is a critical interval $({}_{**}\delta,\delta^{**})$ such that for $\delta \in ({}_{**}\delta,\delta^{**})$ a conflict management scenario imposes a lower social cost than pure conflict. For $x = 100$ such interval is given by $0.22 < \delta < 0.37$, where the lower bound denotes the critical value of δ dictated by condition (10).

Hence, whenever the evaluations are less asymmetric, a scenario of conflict management would be more detrimental for welfare then a pure conflict scenario. However, as noted by Epstein and Hefeker (2003) since agents evaluate the stake differently it is necessary to look at the relative rent dissipation (RRD). It is defined as follows:

$$RRD = \frac{TC}{p_1^* x + p_2^* \delta x} \tag{17}$$

Where p_1^* and p_2^* are exactly (1) and (5) evaluated in equilibrium. Then in case of pure conflict the RRD is given by:

$$RRD^{pc} = \frac{\delta}{\delta^2 + 1} \tag{18}$$

whereas in conflict management it is given by:

$$RRD^{rc} = 2\left[\frac{\delta^2(\delta+1)}{(\delta^2+1)^2} - \frac{1}{x}\right] \tag{19}$$

Then it is possible to compare (18) and (19). The plot below scales the value of the stake against the level of asymmetry in evaluation.

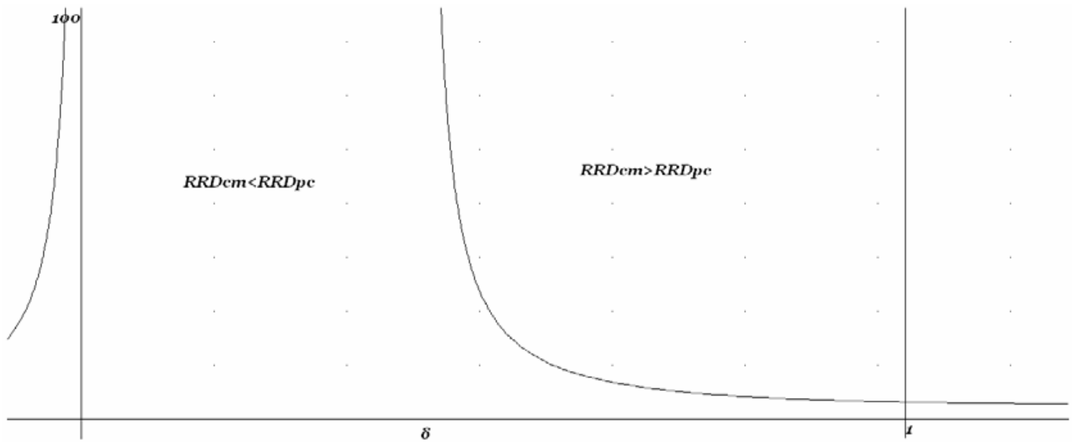

FIGURE 2– RELATIVE RENT DISSIPATION IN PURE CONFLICT AND CONFLICT MANAGEMENT

It is clear that as the evaluations of the stake converge - for a sufficiently large value of x - the RRD in conflict management is higher than in pure conflict scenario. From an economic point of view this would also mean that a conflict management scenario is less efficient than pure conflict.

However, it is clear that such a measurement could be unsatisfactory to analyse the realm of conflicts. If efficiency were a criterium for policy decision no conflict would emerge. Or more paradoxically, no conflict management would emerge. As a result, further analysis is necessary. It would also be reasonable to identify a complementary measure for conflict and conflict management. An appealing idea for a more useful evaluation can be related to those of disorder and randomness. In fact, since conflict is a destructive interaction between two or more parties, it seems reasonable to consider also the degree of uncertainty it spreads. In actual violent appropriative conflicts, uncertainty about the final outcome does clearly constitute a characteristic element that should be considered in developing devices to solve the conflict itself.

A complementary measure of uncertainty as the degree of disorder can be captured through the concept of *statistical entropy*. In communication theory and physical sciences, entropy is commonly adopted as a measure of the degree of disorder, uncertainty or randomness in a system.[8] The famous reference is the work of Shannon and Weaver (1949), which posed the quantitative foundations of information theory. In such a framework, entropy is defined as:

$$E(p_1,\dots,p_n) = -k\sum_{i=1}^{n} p_i \ln p_i, \tag{20}$$

where k is an arbitrary constant which can be set to unity without loss of generality.[9] The greatest disorder would occur when all outcomes have the same probability, i.e. $p_i = 1/n$ for $i = 1,\dots n$. The degree of disorder is given by: $E(1/n,\dots,1/n) = k\ln n$. For instance, in the limiting case of $n = 2$ and $k = 1$ the degree of disorder will be given by $E = \ln(2)$. In order to refine the use of entropy for measurement of conflicts, it would also be useful to introduce the concept of *relative entropy*. Relative entropy is defined as the ratio of the actual to the maximum entropy in a system. That is, it would be useful to recognize the extent to which the degree of disorder approaches the maximum level attainable. In formal terms it is possible to write the relative entropy as: $RE = E / Ln(n)$. Then, relative entropy for pure conflict and conflict management respectively will be:

$$RE^{pc}(p_1^*, p_2^*) = \frac{(\delta+1)\ln(\delta+1) - \delta\ln(\delta)}{(\delta+1)\ln(2)} \tag{21}$$

and

[8] Consider, among others, some applications of entropy to social sciences: the Nobel graduate in physic Dennis Gabor applied entropy to the measurement of social and economic freedom in Gabor and Gabor (1958). Entropy has also been proposed as a measure of competitiveness and diversification in market structure: see Attaran and Zwick (1989) and Horowitz and Horowitz (1968).

[9] The form adopted here is the one presented in Campiglio (1999), ch.4.

$$RE^{rc}\left(p_1^*, p_2^*\right) = \frac{\left(\delta^2+1\right)\ln\left(\delta^2+1\right) - 2\delta^2\ln(\delta)}{\left(\delta^2+1\right)\ln(2)} \quad (22)$$

Figure 3 clearly shows that relative entropy is unambiguously lower in the presence of 'talks'. At the same time, it is worth noting that whenever agents exert positive efforts in conflict management, the system fails to achieve its maximum possible degree of entropy at a relatively lower rate.

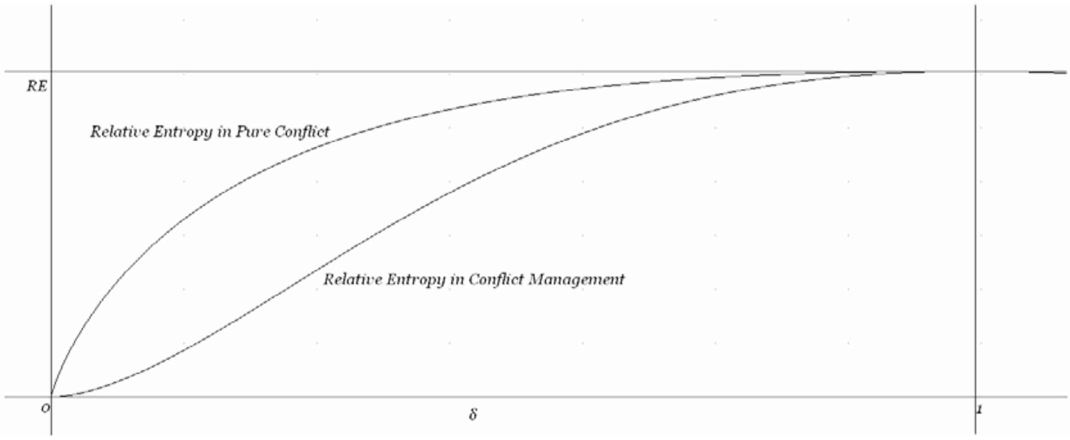

FIGURE 3 – RELATIVE ENTROPY IN PURE CONFLICT AND CONFLICT MANAGEMENT

Although entropy appears to be an appealing concept to evaluate conflicts and contests, some points should be highlighted. First, a remarkable point of interest which would deserve further attention is related exactly to the functional form of CSF adopted. In particular, if entropy is used as a measure of the degree of disorder, it would be clear that it will depend directly on some elements missing in this work (i) the technology of conflict; (ii) the number of contestants; (iii) the abilities of contestants; (iv) the existence of institutional constraints or noises.

The result of this section also raises questions on the trade-off between efficiency losses and the degree of disorder. There could be equilibria where a lower degree of disorder could be attainable with a higher waste of resources. However, the social waste of resources is higher than in a pure conflict scenario. This simple consideration would represent a crucial point for a future research agenda. A trade-off between the loss of resources and the degree of turbulence could clearly emerge.

CONCLUSIONS

This paper considered a partial equilibrium model of conflict with two risk-neutral agents. In particular, the paper analysed the impact of reciprocal concessions on agents' willingness to manage the conflict. By means of a classical comparative statics mechanism, agents are assumed to prefer a conflict management scenario if and only if they are better off making positive expenditures in costly ‘talks’. Otherwise they would prefer being involved in pure conflict. Since the agents evaluate differently the contested stake, there are asymmetric incentives both in fighting and in managing the conflict.

The analysis showed that, when evaluations are sufficiently asymmetric, agent 1 – namely the agent with the higher evaluation of the stake – would be willing to concede a positive fraction of its expenditure in ‘talks’ to the opponent. This kind of commitment is due in order establish a PSR. This mechanism is also incentive-compatible given that both parties can be better off. It is interesting to note how these results can shed new light upon some common insight. In the traditional literature on contest, the agent with the lower evaluation of the stake was indicated as ‘underdog’ (Dixit 1987, Nti, 1999). Such a labelling was grounded upon the consideration that the agent with the higher evaluation is unambiguously favoured to win the contest. Instead, in the framework considered, the agent with the lower evaluation could be favoured. In fact, it can receive a unilateral transfer from the opponent without providing anything in return. On one hand, the transfer can be interpreted by agent 1 as a tool to influence agent 2’ s behaviour. There could be room for some kind of hierarchical structure. On the other hand, the integrative mechanism, based upon unilateral commitment, can also have ambiguous impact. Under the hypothesis of common knowledge, agent 2, the recipient of the concession, can have an incentive to behave strategically: agent 2, albeit favouring a settlement, may be tempted to work against it expecting to get a monetary transfer. As noted above, a classical problem of *moral hazard* can emerge.

However, such a mechanism does not work when the asymmetry in evaluations is extremely large. In such a case a *conflict trap* emerges. That is, no agent is going to make positive expenditures in ‘talks’. They only invest in ‘guns’. The pure conflict scenario is always the preferred option.

By contrast, when the evaluations do not differ so much, no PSR is feasible unless both agents reciprocally reward the opponent by means of a fraction of their own expenditures in ‘talks’. In such a case, both agents are better off if they make positive expenditures in ‘talks’ and a positive concession to the opponent. In such a case, the conflict would be expected to be more destructive. In fact, the lower the asymmetry the bigger is the amount of resources devoted to ‘guns’. Then, a credible commitment to manage the conflict is needed in order to establish a PSR. There is no room for moral hazard or bluffing here. Without any concession provided by agent 2, agent 1 would prefer the pure conflict and it would be the most favoured party. Then, agent 2 also has an incentive to manage the conflict and to make a positive concession to agent 1. Given that, a mechanism of reciprocity can take place only in the shadow threat.

Thus, the main results are summarised below:

a) In the presence of agents with identical abilities and different evaluations of the stake, whenever the evaluations are sufficiently asymmetric, a PSR can be established if and only if the agent with the higher evaluation of the stake is willing to make a proportional concession to the opponent. If the concession enters additively the payoff function of the recipient, both parties can be better off if the degree of asymmetry falls within a range $\left[{}_{*}\delta,\delta^{*}\right]$;

c) As the evaluations of the stake converge, namely for $\delta \to 1$, a PSR is attainable if and only if both agents are willing to make a proportional concession to the opponent. This is the case of *Reciprocity in the shadow of threat.*

d) When the evaluations are extremely asymmetric, namely for $\delta \to 0$, a PSR cannot be attained even if a concession is ensured. Call this *Conflict Trap.*

The results of the paper can be also considered as a contribution to the study of self-enforcing arrangements. In the first case, by means of a credible self-imposed concession, agent 1 is able to influence agent 2's behaviour and lead it to manage the conflict. In the latter it is clear that since both agents concede a positive fraction of their 'talks', the enforcement must be ensured. It is clear that the impact of credibility is also strongly sensitive to the assumption of common knowledge. Therefore, given the limiting assumptions, the PSR can be considered as a credible and incentive-compatible structure. Credibility has been assumed to be related to the cost of conflict management. Since efforts in conflict management – 'talks' - are costly and total outlays are irreversible, they are supposed to be credible. In a broader view, the results can surround a theory of how institutions emerge and evolve. In particular, interpreting institutions as products of conflict management procedures, sheds light upon the (commonly underestimated) role of coercion in their emergence and evolution.

However, the critical issue of the model is the stability of such a solution. In this respect, it is significant that – formally speaking – the optimal choices in the 'conflict management' scenario do not constitute a global max. They do only constitute a local max. In reality, cheating does always constitute an option for participants.

As a novelty of this work, I would also quote the use of the concept of entropy as a tool for measurement of conflict. Following the common neoclassical approach, investing in conflict management would be welfare-immiserizing. In fact, conflict management can also be considered an unproductive activity. Therefore, a pure conflict would be preferable to a scenario where agents invest resources in conflict management. Establishing a PSR would be less efficient than pure conflict. An appealing idea for a more useful evaluation can be related to those of disorder and randomness. In fact, since conflict is a destructive interaction between two or more parties, it seems reasonable to consider the degree of uncertainty it spreads. In actual violent appropriative conflicts, uncertainty about the final outcome does clearly constitute a characteristic element that should be considered while developing policies to solve the conflict itself. It has been shown that the level of entropy also depends on the level of the asymmetry in the evaluation of the stake. In particular, the point of interest is that as the asymmetry in evaluation decreases, the degree of disorder and turbulence increases. In particular, in presence of efforts devoted to conflict management, the degree of disorder is lower.

The aim of this work was to build a general baseline model. Anyway, many elements are still missing in this work. These would pave the way for extension of this work. Consider among others: (i) the impact of different endowments; (ii) an asymmetry in abilities; (iii) an asymmetry in costs structure. In particular, assuming convex costs for conflict could be a more realistic assumption; (iii) risk aversion of contestants; (v) a different protocol of interaction. That is, for example, instead of being maximizing units, agents could be assumed to minimize the 'distance' from an ideal payoff. Different protocols of conflict management are presented in Isard and Smith (1982).

In particular, since it was clear that the powerful force driving agents' behaviour was constituted by the asymmetry in the evaluation, remarkable points deserving further extension are the impact of a larger time horizon and the setting of a learning process. The model expounded in this work is a timeless model. Nevertheless, consider a possible application to a multi-period interaction. Assume for example that a dynamic interaction involves a learning process. Then imagine that such a learning process can modify the asymmetry in evaluation. Consider for example that evaluations of the stake converge over time. Furthermore, you can also imagine that some peculiar features of agents modify (consider among others: production function, access to market, investment in new technologies etc). In such a case, in a future period (say $t+n$), the asymmetry in evaluation can decrease, namely $\delta_{t+n} > \delta_t$. In such a case, according to the results of the model, preferences for conflict or settlement can change. Broadly speaking, a superior information can have an ambiguous impact.

APPENDIX

To check whether the critical points presented in (8) constitute a Nash Equilibrium I have to compute the Hessian matrices for both agents.

I start considering the payoff function of agent 1 evaluated at the critical points for agent 2, namely $\pi_1^{rc}\left(g_1, g_2^*, h_1, h_2^*\right)$. It becomes:

$$\pi_1^{rc}\left(g_1, g_2^*, h_1, h_2^*\right) = \frac{g_1 x\left(\delta^2+1\right)^2\left(h_1+1\right)}{\delta^6 x^2 + g_1\left(\delta^2+1\right)^2\left(h_1+1\right)} + \frac{\delta^3 s_2 x - \left(\delta^2+1\right)^2\left(h_1+s_2+g_1\right)}{\left(\delta^2+1\right)^2}.$$

and the Hessian matrix is given by:

$$H_1 = \begin{pmatrix} \dfrac{\partial \pi_1^{rc}}{\partial g_1 g_1} & \dfrac{\partial \pi_1^{rc}}{\partial h_1 g_1} \\ \dfrac{\partial \pi_1^{rc}}{\partial g_1 h_1} & \dfrac{\partial \pi_1^{rc}}{\partial h_1 h_1} \end{pmatrix} =$$

$$= \begin{pmatrix} -\dfrac{2\delta^6 x^3\left(\delta^4+2\delta^2+1\right)^4\left(h_1+1\right)^2}{\left[\delta^6 x^2 + g_1\left(\delta^4+2\delta^2+1\right)^2\left(h_1+1\right)\right]^3} & \dfrac{\delta^6 x^3\left(\delta^4+2\delta^2+1\right)^2\left[\delta^6 x^2 - g_1\left(\delta^4+2\delta^2+1\right)^2\left(h_1+1\right)\right]}{\left[\delta^6 x^2 + g_1\left(\delta^4+2\delta^2+1\right)^2\left(h_1+1\right)\right]^3} \\ \dfrac{\delta^6 x^3\left(\delta^4+2\delta^2+1\right)^2\left[\delta^6 x^2 - g_1\left(\delta^4+2\delta^2+1\right)^2\left(h_1+1\right)\right]}{\left[\delta^6 x^2 + g_1\left(\delta^4+2\delta^2+1\right)^2\left(h_1+1\right)\right]^3} & -\dfrac{2\delta^6 g_1^2 x^3\left(\delta^4+2\delta^2+1\right)^4}{\left[\delta^6 x^2 + g_1\left(\delta^4+2\delta^2+1\right)^2\left(h_1+1\right)\right]^3} \end{pmatrix}$$

Let H_{1k} denote the k_{th} order leading principal submatrix of H_1 for $k = 1,2$. The determinant of the kth order leading principal minor of H_{1k} is denoted by $\left|H_{1k}\right|$. The leading principal minors alternate signs as follows:

$$\left|H_{11}\right| < 0$$

$$\left|H_{12}\right| > 0 \Leftrightarrow \delta^6 x^2 - 3g_1\left(\delta^8 + 4\delta^6 + 6\delta^4 + 4\delta^2 + 1\right)\left(h_1+1\right) < 0$$

Then I compute the payoff function for agent 2 $\pi_2^{rc}\left(g_1^*, g_2, h_1^*, h_2\right)$,

$$\pi_2^{rc}\left(g_1^*, g_2, h_1^*, h_2\right) = \frac{g_2 \delta x\left(\delta^2+1\right)^2\left(h_2+1\right)}{\delta^4 x^2 + g_2\left(\delta^2+1\right)^2\left(h_2+1\right)} + \frac{\delta^2 s_1 x - \left(\delta^2+1\right)^2\left(h_2+s_1+g_2\right)}{\left(\delta^2+1\right)^2}.$$

and the Hessian matrix is given by:

$$H_2 = \begin{pmatrix} \frac{\partial \pi_2^{rc}}{\partial g_2 g_2} & \frac{\partial \pi_2^{rc}}{\partial h_2 g_2} \\ \frac{\partial \pi_2^{rc}}{\partial g_2 h_2} & \frac{\partial \pi_2^{rc}}{\partial h_2 h_2} \end{pmatrix} =$$

$$= \begin{pmatrix} -\frac{2\delta^5 x^3 (\delta^4 + 2\delta^2 + 1)^4 (h_2 + 1)^2}{\left[\delta^4 x^2 + g_2 (\delta^4 + 2\delta^2 + 1)^2 (h_2 + 1)\right]^3} & \frac{\delta^5 x^3 (\delta^4 + 2\delta^2 + 1)^2 \left[\delta^4 x^2 - g_2 (\delta^4 + 2\delta^2 + 1)^2 (h_2 + 1)\right]}{\left[\delta^4 x^2 + g_2 (\delta^4 + 2\delta^2 + 1)^2 (h_2 + 1)\right]^3} \\ \frac{\delta^5 x^3 (\delta^4 + 2\delta^2 + 1)^2 \left[\delta^4 x^2 - g_2 (\delta^4 + 2\delta^2 + 1)^2 (h_2 + 1)\right]}{\left[\delta^4 x^2 + g_2 (\delta^4 + 2\delta^2 + 1)^2 (h_2 + 1)\right]^3} & -\frac{2\delta^5 g_2^2 x^3 (\delta^4 + 2\delta^2 + 1)^4}{\left[\delta^6 x^2 + g_2 (\delta^4 + 2\delta^2 + 1)^2 (h_2 + 1)\right]^3} \end{pmatrix}$$

Also in this case, let H_{2k} denote the k_{th} order leading principal submatrix of H_2 for $k = 1,2$. The determinant of the kth order leading principal minor of H_2 is denoted by $|H_{2k}|$. The leading principal minors alternate in sign as follows:

$$|H_{21}| < 0$$

$$|H_{22}| > 0 \Leftrightarrow \delta^4 x^2 - 3g_2 (\delta^8 + 4\delta^6 + 6\delta^4 + 4\delta^2 + 1)(h_2 + 1) < 0$$

since the Hessian matrices are not negative semidefinite it is necessary to deepen the analysis in order to show whether the critical points represent a global max. Then I compute the limits of both agents' payoffs. For the first agent we have:

$$\lim_{h_1 \to 0} \pi_1^{rc}(g_1, g_2^*, h_1, h_2^*) = \frac{g_1 x (\delta^4 + 2\delta^2 + 1)^2}{\delta^6 x^2 + g_1 (\delta^4 + 2\delta^2 + 1)^2} + \frac{\delta^3 s_2 x - (\delta^4 + 2\delta^2 + 1)(s_2 + g_1)}{\delta^4 + 2\delta^2 + 1}$$

$$\lim_{h_1 \to \infty} \pi_1^{rc}(g_1, g_2^*, h_1, h_2^*) = -\infty$$

$$\lim_{g_1 \to \infty} \pi_1^{rc}(g_1, g_2^*, h_1, h_2^*) = -\infty$$

$$\lim_{g_1 \to 0} \pi_1^{rc}(g_1, g_2^*, h_1, h_2^*) = \frac{\delta^3 s_2 x - (\delta^4 + 2\delta^2 + 1)(s_2 + h_1)}{\delta^4 + 2\delta^2 + 1}$$

and for agent 2:

$$\lim_{h_2 \to 0} \pi_2^{rc}(g_1^*, g_2, h_1^*, h_2) = \frac{\delta g_2 x (\delta^4 + 2\delta^2 + 1)^2}{\delta^4 x^2 + g_2 (\delta^4 + 2\delta^2 + 1)^2} + \frac{\delta^2 s_1 x - (\delta^4 + 2\delta^2 + 1)(s_1 + g_2)}{\delta^4 + 2\delta^2 + 1}$$

$$\lim_{h_2 \to \infty} \pi_2^{rc}(g_1^*, g_2, h_1^*, h_2) = -\infty$$

$$\lim_{g_2 \to \infty} \pi_2^{rc}\left(g_1^*, g_2, h_1^*, h_2\right) = -\infty$$

$$\lim_{g_2 \to 0} \pi_2^{rc}\left(g_1^*, g_2, h_1^*, h_2\right) = \frac{\delta^2 s_1 x - \left(\delta^4 + 2\delta^2 + 1\right)\left(s_2 + h_2\right)}{\delta^4 + 2\delta^2 + 1}$$

therefore for both agents it would be necessary to check for $h_i = 0, g_i = 0, i = 1,2$. Consider first the payoff function of agent 1:

$$\pi_1^{rc}\left(g_1, g_2^*, 0, h_2^*\right) = \frac{g_1 x\left(\delta^4 + 2\delta^2 + 1\right)^2}{\delta^6 x^2 + g_1\left(\delta^4 + 2\delta^2 + 1\right)^2} + \frac{\delta^3 s_2 x - \left(\delta^4 + 2\delta^2 + 1\right)\left(s_2 + g_1\right)}{\delta^4 + 2\delta^2 + 1}$$

Maximize $\pi_1^{rc}\left(g_1, g_2^*, 0, h_2^*\right)$ with respect to g_1 and let g_1^{**} denote the optimal choice. As usual set $x = 100$ and it would be possible to demonstrate that $\pi_1^{rc}\left(g_1^{**}, g_2^*, 0, h_2^*\right) < \pi_1^{rc}\left(g_1^*, g_2^*, h_1^*, h_2^*\right) \Leftrightarrow \delta < 0.68$.

Then, it is clear that the critical points presented in (8) do no constitute a Nash Equilibrium.

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