FINAL REPORT
Breaking the Dynamics of Emotions and Fear in Conflict and Reconstruction

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In accordance with the Memorandum of Understanding signed among the five partner organization and the SNIS Rules and Procedures for Submitting Reports and Working Papers, this report summarizes the activities and research work conducted in the framework of the SNIS-funded Breaking the Dynamics of Emotions and Fear in Conflict and Reconstruction Project (October 1, 2010 – June 30, 2012).

This final report presents in conformity with the structure given in the research plan the following three research steps: (1) a generic computational dynamic model (2) a neuroscience experimental research and (3) empirical data.

Step 1: Elaborating a Generic Dynamic Model of Conflict and Cooperative Behavior

This generic model builds on previous research by Luterbacher et al. (2005) and Chichilnisky (2009a and 2009b) Chichilnisky et al. (2000). The objective of the model is first to combine some of the various strands of theory that have been used to explain conflict: Among those the contributions by Bhavnani and Backer (1999) and Bhavnani et al. (2011) appears to be particularly elaborate because they are trying to build on previous formulations developed by political scientists on ethnic conflict. The emphasis of that earlier work by Fearon and Laitin (1996) and Lohman (1993) is centered on information questions. Conflict will be initiated or amplified by information circulating mostly within one group and directed against the other. Misperceptions about the other group can lead to armed violence. To this Bhavnani et al. (2011) add a particular concern about the location of conflict and how violence is territorially determined and influenced by social distance, a notion based upon Kalyvas's (2008) pioneering work. Without denying the importance of information questions, territoriality and social distance in the generation of armed conflict, one can nevertheless legitimately ask about the importance of other factors. Quite a few authors (Andre and Plateau 1998, Homer-Dixon 1994, Collier and Hoeffler 2000) have pointed out the importance of resource issues in explaining conflict at least as a long-term factor. Information issues raised by Bhavnani and Backer (2000) and Bhavnani et al. (2011) are considered without reference to a specific context. However, context matters and in several cases of conflict both domestic and international fear appears to be a powerful motivator for extreme behavioral responses in general and for conflict and violence in particular. Such behavioral responses appear irrational at the outset and cannot usually be explained through standard models of decision making such as expected utility as shown convincingly by Chichilnisky (2006)[1]. Quite clearly, fear is also closely linked to rumor and thus often to false information transmissions. Moreover, fear has a tendency then to build

[1] She suggests an alternative axiomatization of utility theory in order to account for attitudes involving fear of catastrophes.

upon itself and to influence thus conflict dynamics: Fear of the other will lead to suppress the other violently, which will then in reaction draw more people who feel threatened to rally toward him as much as opponents will rally against him. Fear and other "emotional" factors in conflict such as a feeling of injustice are precisely what neuroscience research has emphasized. How can one now tie all these aspects together?

A numerical agent based model will provide numerical solutions, which can then be confronted and calibrated with empirical data.

Basic Economic Relations

We formulate the model in terms of an agent-based perspective. We take this approach while we remain able to explore some of the relations we want to emphasize with purely analytical methods. We postulate a utility function for a representative agent i as: $u_i\ (x_i, \sum_{j=1}^{N} g_i) = exp(\alpha\ -1/x_i + -1/ \sum_{j=1}^{N} g_i)$ (1)

Where x_i is a private good and g_i a public or collective good and α an adjustment parameter.

If we make the assumption that all representative agents in a society are identical, an equilibrium can be expressed by a symmetrical allocation among all N agents of the society (there is only one such equilibria as mentioned by Dasgupta and Heal 1979: 42). If all agents in society maximize utility in the same way i does, based upon some expectation they have on how much of the collective good every other agent produces or purchases, a particular kind of Nash equilibrium obtains for the society in question, which we will call a *society market or anarchic equilibrium*. In other words, if every agent anticipates the purchase or production of the amount of collective good $\hat{g}$ by every other agent, for agent i, the problem is then to maximize:

$exp\{a\ -1/x_i + -1/[g_i + (N-1)\ \hat{g}]\}$ (2) which is just a reformulation of utility function (1) with the assumptions enumerated above.

Maximizing (2) is subject to the budget constraint established as follows: Assume that initially agents have one unit of the private good x_i, and none of the collective good g_i. Agents are however able to convert the private good into the collective good at a rate p^s. If $s = 1$, the private good can be transformed into the collective good proportionally, if $s < 1$, the conversion takes place more than proportionally, if $s > 1$, less than proportionally. If, for instance, g_i stands for national defense, then s represents a measure of society's ability to mobilize resources for war (the lower is s, the greater the possibility to mobilize resources). Moreover, assume that i saves a certain amount of x_i for investment, a proportion h which will be accounted for in the budget constraint.

Agent i in society g can therefore maximize u_i as defined in (2) subject to the budget constraint:

$$p^s g_i + (1+h)\ x_i \leq 1 \quad (3)$$

Maximizing (2) subject to (3) leads to the following equilibrium values for x_i and g_i, i.e. and $\hat{g}$:

$$\hat{x} = \frac{N}{\sqrt{h+1}(\sqrt{p^s} + N\sqrt{h+1})} \quad \text{and} \quad \hat{g} = \frac{1}{\left(\sqrt{p^s} + N\sqrt{h+1}\right)\sqrt{p^s}} \qquad (4)$$

These are not Pareto optimal as not enough quantities of the private good are converted into the public good. It is easy to compute Pareto optimal values by treating the public good as if it were a private good and going through the same optimization process as before. On gets then:

$$\tilde{x} = \frac{\sqrt{N}}{\sqrt{h+1}(\sqrt{p^s} + \sqrt{N}\sqrt{h+1})}, \quad \tilde{g} = \frac{1}{\left(\sqrt{p^s} + \sqrt{N}\sqrt{h+1}\right)\sqrt{p^s}} \qquad (5)$$

From there we can now calculate the distance between the Pareto optimal solution and the "anarchic" equilibrium situation as:

$$\sqrt{p^s}\sqrt{h+1}\frac{(\sqrt{N}-1)^2}{N} \succ 0 \qquad (6)$$

This distance can also be called E, the externality in the use of resources that has not been internalized through the full use of a public good. We will make use of the concept later on. A further quantity to be computed is the short-term advantage an agent gets from overuse, z, which can be expressed by the difference in the amount of private good she gets from the anarchic equilibrium as opposed to the Pareto optimal situation. z is then for positive values of the square roots:

$$z = \frac{\sqrt{N}\sqrt{p^s}(\sqrt{N}-1)}{p^s\sqrt{h+1} + N(h+1)\sqrt{N}\sqrt{h+1}) + \sqrt{N}\sqrt{p^s} + N\sqrt{p^s} + \sqrt{N}h\sqrt{p^s} + Nh\sqrt{p^s}} \geq 0 \qquad (7)$$

As can be seen z is positive provided N>1. With N = 1, Pareto optimal and anarchic equilibrium are trivially equivalent as they should be in the limit case.

Through time, dynamic equations can now determine evolutions of the variables x and N and thus also E and z. N's evolution can be determined via a dynamic population equation:

$\frac{dN}{dt} = (\beta - \delta)N$ (8), where β represents a birth (eventually plus or minus migratory balance) and δ a death rate.

To get at the dynamic of private goods within a society we can first define a capital increase rate, in the following way:

$$\frac{dK}{dt} = Nhx_i - \rho K \quad (9).$$

Where ρ represents an amortization rate.
We can now determine Nx_i through a production function such as:

$$Nx_i = exp\{\zeta - \gamma/K - \eta/wN\} \quad (10).$$

Where ζ, is an adjustment parameter and γ, and, η are elasticities of capital and labor with respect to production.

We will assume here that only a proportion *w* of the *N* agents are involved in production. This proportion to be specified below represents the number of agents involved in productive activities as opposed to fighting.

Fighting Propensity

The objective of the model is to explain a representative agent's choice between producing and joining fighting forces in an unstable country. This perspective can help understand under which conditions the emergence of a society with competing warlords (as it sometimes occurs in developing countries) is more or less likely than the building of a politically stable and economically developed society. Moreover, we will try to link the question of the warlord competition to the issue of natural resources. We start from the following assumptions:

Assumption 1: We assume initially a society with *N* identical individuals, who can be symbolized by *one representative politico-economic agent*. N.B. This is a standard assumption which is usually included either in purely theoretical but also agent based models.

Assumption 1a: The above assumption will be modified in a second step in such a way that the society will be divided into groupings of *N, M* and *U* individuals which stand for coalition kernels of factions *N,* and *M* and a considerable quantity of uncommitted bystanders *U* (an "ocean" of uncommitted individuals). A coalition model based upon the development of oceanic game models of coalitions will be used (more on this below).

Assumption 2: The representative politico-economic agent has the choice of how much time he wants to allocate for producing and how much for fighting. In our model this will be represented by a *decision to optimize* by using a certain proportion of his time to produce, and thus to contribute to a stable political regime, and by using the remaining time proportion to the establishment of a "warlord society" through fighting.

Assumption 3: The individual choice of the representative agent is linked to the *aggregate decision of the society*. If our representative politico-economic agent achieves a higher expected value by fighting and vice-versa, we can expect that this outcome will eventually hold for the society as a whole. We can draw an analogy here to Schelling's binary decisions in an aggregate framework: the decision by one individual is conditioned by what all others are doing. To clarify this aspect: each individual agent is influenced by all the others in their individuality.

We can draw an analogy here to Schelling's (1971, 1979) binary decisions in an aggregate framework: the decision by one individual is conditioned by what all others are doing. So for instance if everybody drives to work it makes sense from an individual point of view to take public transportation because the roads are crowded. However, if most people take public transportation it is again worth driving. As shown by Moulin (1986), this condition can lead to stable or unstable Nash equilibria at the level of the whole society.

Assumption 4: Every agent is a *producer/fighter* and at the same time a *consumer*. The framework is the one of an economy, in which initially no trade with the outside is taking place but then eventually the economy opens up to trade.

Assumption 5: We assume that if the agent becomes a fighter, he can already make an *initial gain* at the beginning of the period by exploiting some natural resources or by getting a reward, which might be emotional or a mix of emotional and economic values. By contrast, becoming a producer demands an *initial commitment*, an investment, which is usually longer than any commitments the fighter has to make. This initial investment can be, for example, the cost of education or in a more agricultural society the cost of creating tools/machines for further development of productive activity. So while it is true that even a fighter has to make some initial commitments stricto sensu, lato sensu this one is usually much shorter than an investment to produce. The fighter in this sense is much closer to a gambler in his attitude.

We can show that want to find the level of producing/fighting, which maximizes the utility of a representative agent. The model is initially a static, one-period model, in which the representative agent is a utility-maximizer who chooses an individually optimal level of producing and fighting (a mathematical result using this perspective is included in the Appendix. This assumption will eventually be changed for a dynamic formulation. Moreover, we can combine this with a coalition formation behavior which although implicit in the notion of social distance and communication (or absence their of used by Bhavnani et al. 2011 and Fearon and Laitin 1996 and Lohman 1993) is never explicitly represented in all the formulations and theories about domestic conflict.

Assumption 5: We assume that if the agent becomes a fighter, he can already make an *initial gain* at the beginning of the period by exploiting some of the natural resources. By contrast, becoming a producer demands an *initial commitment*, an investment. This initial investment can be for example the cost of education, or in a more agricultural society the cost of creating tools/machines for further development of productive activity.

Assumption 6: We assume that the only choice made in this society is one between fighting and producing activities. We thus ignore for the moment the question of how Warlords emerge or how they organize their armies. We assume that in an environment where lots of people are willing to fight or where our representative agent devotes most of his time to fighting the emergence of warlords capable of organizing armed bands is more likely. Our model presents thus necessary but not sufficient conditions for organized internal conflict.

We want to find the level of producing/fighting, which maximizes the utility of a representative agent. The model is here a static, one-period model, in which the representative agent is a utility-maximizer who chooses an individually optimal level of producing and fighting.

The representative agent has the following aforementioned utility function:

(11) $u_{wf} = \int_{i=1}^{n} c_i^D dc$, where c_i^D is the demanded amount of a variety of the only consumption good.

For convenience, all goods produced under a regime of "warlord" or "stable political regime" production can be seen as varieties of one single good, where each of them gives an identical level of utility to the representative agent[2].

As our locally non-satiated representative agent is at the same time the only producer and consumer in our competitive economy, and as all relative prices are positive, the aggregate demand for every variety of our commodity must equal its aggregate supply. Since we have only one agent, and by assumption initially no international trade takes place, we get:

(12) $c_i^D = c_i^S$, where c_i^S is the produced (and supplied) amount of commodity i.

As the utility function is strictly monotonic in all varieties of the consumption good, and the agent basically consumes what he produces, we can focus, in our analysis, exclusively on the production function of the goods. In order to maximize his utility, our agent simply maximizes production.

Every variety c_i^S has an identical production function, akin to the utility function 1.3 presented earlier:

(13) $c_i^S = \exp(a - \frac{\theta}{w} - \frac{\pi}{q})$

where a=parameter, w=part of time endowment allocated for producing, q=part of time endowment allocated for fighting, θ=parameter expressing the gain of producing, π=parameter expressing the gain of fighting.

This production function exhibits at first increasing then decreasing returns with respect to the arguments p and q. This expresses the plausible assumption that initial increases in the levels of respectively fighting or producing activities will generate more than proportional returns in the production good c_i^S but then eventually, with further increases of p and q, less than proportional output will appear. If everything that is produced is consumed agent i has simply the utility function $u_{iwf} = c_i^S$. This utility function is similar to the S-curve preference functions we introduced earlier. This production/utility function is subject to the constraint:

[2] As opposed to the previous utility function, which referred to the choice between public and private goods, this one refers to the choice between fighting and producing and is thus labeled u_{wf}. The two utility functions are obviously linked, a fact that we will evoke below.

(14) $(1-b)q + (1+k)w \leq 1-t+k$ *with* $t>>b$

By definition, $w + q \leq 1$ since both variables represent parts of a total endowment. However, the initial commitment (analogous to a tax) for becoming a producer, which we call k, and b, the initial gain (analogous to a subsidy) of turning a producer into a fighter, will also affect the endowment as a whole[3]. The "subsidy" to the fighter has to be usually more than compensated through a tax on the total endowment, t, which is assumed to be considerably greater than b. Similarly, the commitment taken by a producer, k, which is a net contribution to the total endowment, has to be accounted for. All these considerations are represented in the constraint (14)[4].

Thus, we assume that there are two ways of producing a particular good. Either the agent can choose the "stable political regime" production technique under which he has to make an initial commitment in order to get a higher return in the long-run or he can choose the "warlord" production technique, which refers to the low-technology capability of exploiting natural resources in areas controlled by the armed forces and gets an initial boost from the switch to fighting.

The terms θ and π correspond to the elasticity of producing and fighting, or to put it differently, to the impact of a marginal change in the amount of production and fighting time on the output.

The link between the outputs of the two rival production techniques is summarized in equation (15). The decision taker is myopic and only takes the short- and medium-run into account. As he ignores the future externalities of over-exploitation, he has incentives to extract more than the social optimum of natural resources:

(15) $\theta = \pi(1-\phi) + x_i$

Where $\varphi = -y\,E + z$

where x_i =ordinary production in case of producing, z=short-run gain of over-exploitation, E=externality of the overuse of the natural resources (positive number), y=extent up to which the externality can be internalized if the agent is a producer (number between 0 and 1).

It is a priori difficult to determine whether $\theta > \pi$ or $\pi > \theta$, as the latter, π, benefits in the short-run from the gains of the over-exploitation of natural resources (z) and as the former θ implies regular production and efficiency gains from the better internalization of the externality. The short-run gains from overuse correspond to the increased quantity of natural resource exploitation, whereas the gains of better internalization of the natural resources correspond to a higher sale price (as less is produced) and to a more efficient exploitation of natural resources. We will first

[3] The framework of the constraint is inspired by Dasgupta and Heal's (1979) similar reasoning for the case of public goods.

[4] We can see from this budget constraint how we could overcome the restriction posed in Assumption 6 and make our model necessary and sufficient for the explanation of war lord activities: the war lord is the one who organizes the taxation of resources to distribute the initial subsidy to fighters.

assume that the overuse of natural resources is quite an important factor and that accordingly θ is smaller than π.

The values of x and y depend on the following factors (by assumption property rights protection and the possibility of joining an international cartel become only real options in the case of the "stable political system" production technique).

(16) $x = x(\overset{+}{p_M}, \overset{+}{p_P})$ and

(17) $y = y(\overset{+}{p_P})$ and

(18) $p_M = p_M(\overset{+}{p_P})$ and

where p_M = probability that an international cartel of producers of the natural resource takes place (number between 0 and 1), p_P= Probability that the rule of law and the property rights are protected (number between 0 and 1).

We can see in equation (16) that if the representative agent chooses to be a producer rather than a fighter, a gain due to the internalization of the externality, yE, is possible, if an international cartel of the producers of the particular natural resource takes place or if the property rights are better protected than in the warlords-case. An international cartel fights the price depressing-effect and restricts the quantity (less overuse) to keep prices high[5]. A good level of property rights protection assures a more efficient exploitation of natural resources.
In addition, as described by equation (17), a high level of property rights protection may also favor the "regular" production x_i .
Equation (18) stresses furthermore that a society with a certain control of the quantity produced (due to the protected property rights) is more likely to form an international cartel with other similar societies.

Using (13) and (14), we get the following production maximization problem:

(19) $\underset{w,q}{Max} \ \exp(a - \frac{\theta}{w} - \frac{\pi}{q})$ subject to $(1-b)q + (1+k)w \leq 1-t+k$, and from (15) after transformation $\pi = \frac{\theta - y}{1-\varphi}$

This can be expressed by the following Lagrangian:

(20) $L = \exp(a - \frac{\theta}{w} - \frac{\pi}{q}) + \lambda(1 + k - t - (1-b)q - (1+k)w) + \mu(\pi - \frac{\theta - y}{1-\phi})$

Calculating the partial derivatives of L with respect to w, q, λ, μ (the first-order conditions) gives us equation (21) after rearrangement:

[5] Empirical cases of such international cartels include the OPEC or the coffee cartel until the 1990s.

(21) $$\frac{\pi}{q^2} = \frac{\theta}{\frac{(1+k-t-(1-b)q)^2}{(1+k)^2}}$$

After rearranging (21), we can distinguish two possible equilibria (all other possibilities violate the restriction $0 \le q \le 1$), which we obtain by taking the square root on both sides. We get:

(22) $$q_1 = \frac{1-t+k}{1-b+\sqrt{\frac{\theta}{\pi}}(1+k)}$$ and

(23) $$q_2 = \frac{1-t+k}{1-b-\sqrt{\frac{\theta}{\pi}}(1+k)}$$

As expected, a higher b and a higher k result in a higher chosen level of fighting activity, since the first partial derivatives of (22) and (23) with respect to b are:

(24) $$\frac{\partial q_1}{\partial b} = \frac{1+k-t}{(1-b+(k+1)\sqrt{\frac{\theta}{\pi}})^2}$$ and

(25) $$\frac{\partial q_2}{\partial b} = \frac{1+k-t}{(1-b-(k+1)\sqrt{\frac{\theta}{\pi}})^2}$$

These are always positive, provided $t < 1+k$. In addition, it can also be shown that the first partial derivatives of q_1 and q_2 with respect to k are positive. They are:

(26) $$\frac{\partial q_1}{\partial k} = \frac{1-b+t\sqrt{\frac{\theta}{\pi}}}{(1-b+(k+1)\sqrt{\frac{\theta}{\pi}})^2}$$ and

(27) $$\frac{\partial q_2}{\partial k} = \frac{1-b-t\sqrt{\frac{\theta}{\pi}}}{(1-b-(k+1)\sqrt{\frac{\theta}{\pi}})^2}$$

The equations (26) and (27) are always positive if $1 \ge b + t\sqrt{\frac{\theta}{\pi}}$.

Interesting consequences appear, when θ and π, the elasticities of producing and fighting, or to put it differently, the impact of a marginal change of the amount of production and fighting activity on the output, are considered.

In the case of the "good" equilibrium q_1 (where q is low), an increase in θ decreases q (the partial derivative of q with respect to θ is always negative). This seems intuitive for a situation, where incentives work properly. By contrast, for the

"bad" equilibrium q_2, the so-called "fighting warlords" trap, a greater value of θ actually *increases* q (the partial derivative of q with respect to θ is always positive). The equilibrium value q_2 is a "high" conflict outcome, where a great proportion of the population has an incentive to engage in fighting rather than producing through more conventional means. This means, that when fighting is generalized in our model, even an increase in the elasticity of traditional production will not only leave the situation unchanged but will push an even higher proportion of the population into fighting. The society in question is then caught in what can be called a "fighting warlords trap".

However this process has a limit, which is given by the ratio $\frac{\theta}{\pi}$. If θ is greater than π, then the denominator of the fraction which determines q_2 becomes negative and thus q_2 itself is negative, which contradicts our assumptions. Thus, if $\theta > \pi$ only the q_1 solution is possible. The ratio $\frac{\theta}{\pi}$ constitutes thus a bifurcation which establishes the possibility or not of such a "fighting warlords" trap. In other words, a massive increase in θ through a better internalization of the natural resource externality or a greater capacity to produce without fighting will make the "warlord trap" equilibrium impossible.

Thus, the higher the profits made with natural resources under a stable political system regime relative to those made under a system of competing warlords are, the less likely is the latter to occur. Also a higher value of the regular production (exclusive of natural resources) makes the emergence of a liberal democracy more likely.

Further, higher probabilities of an international cartel for the natural resource, *Pm*, and of an operating property rights protection and rule of law system, *Pp*, increase the likelihood of a liberal democracy outcome by increasing x_i and y in equation (15). On the other hand, higher immediate gains from fighting, b, and higher initial commitments for producing, k, increase both the risk of civil war.

If the immediate gains from natural resources, b, have a clearly negative impact on the democratization and the establishment of the rule of law, the impact of depends π on the values of several other parameters. To deal with those, recall that equation (15) expresses θ in terms of π: .

This relation illustrates the idea that if the gains of the natural resource exploitation technology under a regime of warlordism, π, are bigger than the gains of production in a stable political system, θ, it is because of the bigger quantity of natural resources exploited, due to overuse. This point is also made, as mentioned, in Chichilnisky (1994).

Clearly, these bigger gains from the warlordism exploitation technology are not sustainable in the long-run, because of the negative impact of over-exploitation. From an evolutionary point of view the gain from exploiting natural resources, π, should approach zero in the long-run.

It is interesting to see what the implications of extreme values of π are on the level of q. If we replace θ by its value defined in relation (15) we get the following equations:

$$(28)\quad q_1 = \frac{1-t+k}{1-b+\sqrt{\frac{\pi(1-z+yE)+x_i}{\pi}}(1+k)}$$

$$(29)\quad q_2 = \frac{1-t+k}{1-b-\sqrt{\frac{\pi(1-z+yE)+x_i}{\pi}}(1+k)}$$

For a very small q, we would get in the square root, which is in the denominator of the above fractions, almost just the standard (as opposed to the resource) production, x_i , divided by a very small number, which would result in the value of the square root becoming increasingly large. We have thus:

$$(30)\quad \lim_{\pi\to 0} q = 0$$

By contrast, as π approaches infinity, x_i/π becomes very small within the square root, which leaves:

$$(31)\quad \lim_{\pi\to\infty} q = \frac{1-t+k}{(1-b)\pm\sqrt{(1-z+yE)}(1+k)}$$

Thus, within the framework of the present model, a very low level of natural resources decreases the risk of a civil war outcome to close to zero, whereas for medium and high levels of natural resources we obtain higher levels of q. But the relationship between π and q is not monotonous. These implications are in accord with the empirical findings of Collier and Hoeffler (1998).

Coalition Behavior

Our coalition type game is based upon the notion of "oceanic games", a concept introduced by Milnor and Shapley (published 1978 but elaborated earlier in a RAND paper) and then further developed by Straffin (1977). If a society is divided up into coalition kernels N and M (for instance two opposing factions) and a large number of uncommitted bystanders U, the coalition dynamic can result in bystanders joining either N or M based either on uncommitted's evaluation of the probability of N or M overtaking the other faction (i.e. join the likely winner) or conversely on the fear that such a perspective might actually occur (defend the possible loser for fear of the likely winner). We thus rejoin the considerations made earlier about emotional aspects of mobilization for conflict. Once coalitions are established, mobilization of their respective strengths in numbers can occur, social distance between them will increase and then conflict and violent clashes can occur. These will be simulated with territorial and information issues introduced.

Clearly, the coalition perspective, which can reiterate some aspects of the emotional factors in conflict, shows how confrontations can be influenced and enhanced by their own dynamics. In other words, conflict begets conflict as more and more individuals are drawn into it. This is in our view the main value added of the present

approach: Whereas other conceptions stay at a relatively static level, our vision leads to an endogenous possible amplification (or for that matter reduction) of conflict.

In order to model how violence and conflict can break out, one can conceive of sets of potential coalitions of fighters whose numbers will grow as a result of the advantage of joining such a group as opposed to staying neutral or uncommitted. Suppose we have group n and group m opposed to each within the N population. For n we can express this in the following way:

$$\frac{\partial A(n)}{\partial n} \geq \frac{A(u)}{u} \quad (32)$$

In other terms, it is worth joining a group of n potential fighters if the advantages $A(n)$ where n represents the number of fighters within group N are greater that those $A(u)$ of remaining uncommitted (u). The advantages of remaining uncommitted tend to diminish as the total number of fighters increase. So if we assume that the advantages of joining increase logarithmically with an expansion in the number of a group's committed fighters and that the advantages of staying within the uncommitted group u diminish linearly with the percentage of fighters in the society q. So that we have then:

$$\frac{\partial \chi \ln(n)}{\partial n} = \frac{A - (qN)}{N - (n + m)} \quad (33)$$ and thus n:

$$n = \frac{\chi(N - m)}{A - qN + \chi} \quad (34)$$

Similarly we should have for m:

$$\frac{\partial \xi \ln(m)}{\partial m} = \frac{B - (qN)}{N - (n + m)} \quad (35)$$ and finally m is:

$$m = \frac{\xi N(A - qN)}{(B - qN)(A - qN + \chi) + \xi(A - qN)} \quad (36)$$

These give us values for evolving n_s and m_s.

Combat Model

Combat equations can now be written in the following way if one assumes that n corresponds to insurgents and m to the dominant group:

$$\frac{dcombn}{dt} = par11(par1n - par2combncombm) \quad (37)$$

$$\frac{dcombm}{dt} = par11(-par3\,n + par4\,m) \quad (38)$$

$$\frac{dn}{dt} = par5\,n - par6\,par7\,nm \quad (39)$$

$$combn = par9n \quad (40)$$

$$combm = par10m \quad (41)$$

$$par6 = \begin{cases} 1 \; if \; (par8combm - combn) < 0 \\ 0 \; otherwise \end{cases} \quad (42)$$

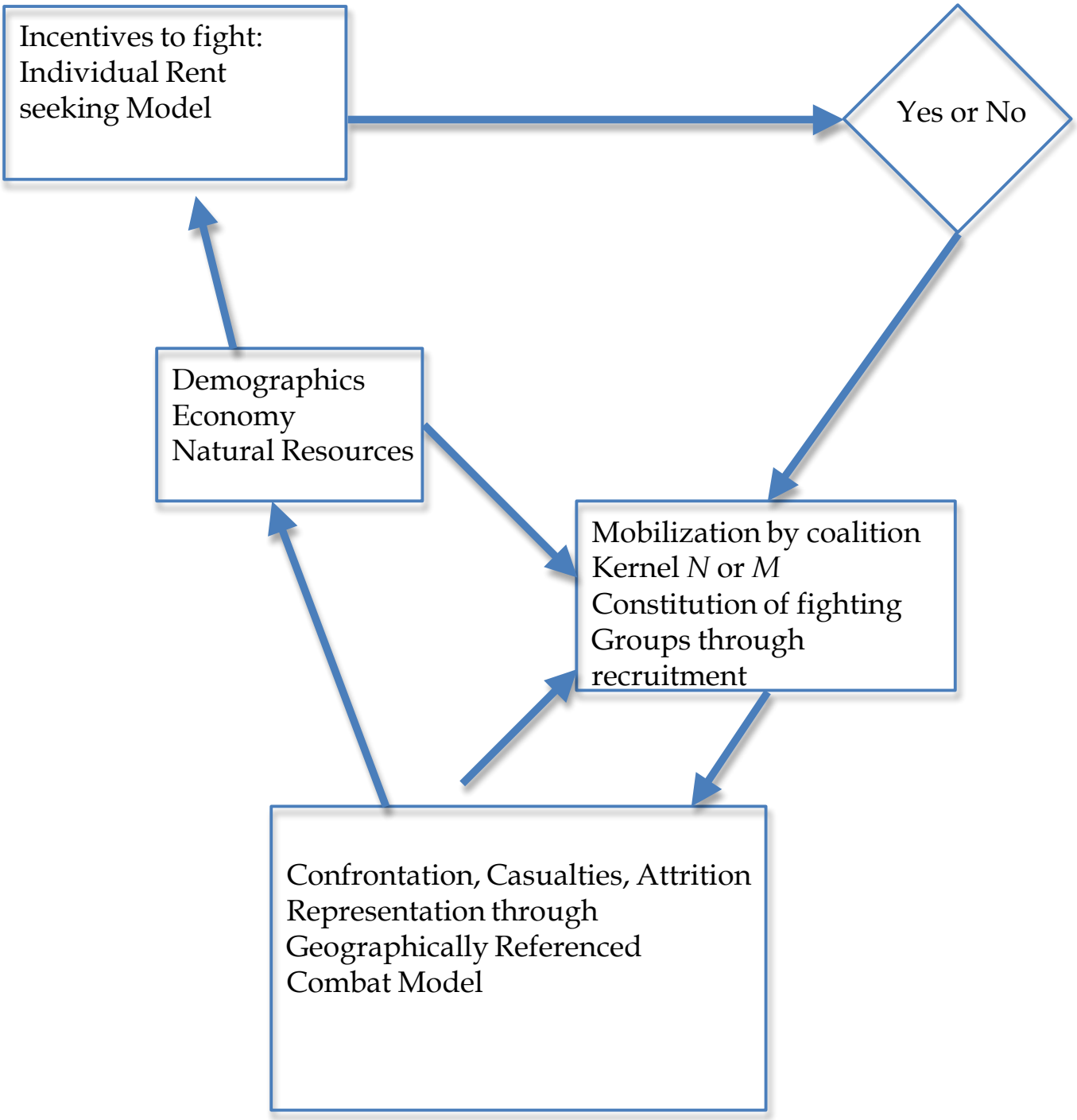
$$par11 = \begin{cases} 1 \; if \; q_1 \; and \; q_2 > q^* \\ 0 \; otherwise \end{cases} \quad (43)$$

(37) is a Deitchman-Lanchester equation describing dispersed combat with replacement. This corresponds to a situation where a dominant group blankets an area to hit insurgents. *combn* and *combm* are variables representing combatants of *n* and *m* respectively. They are defined in (40) and (41) as proportions of the larger groups *n* and *m*. In dispersed combat, losses depend on chance encounters (product) of combatants, *par*2 is a parameter expressing kill likelihoods in a encounter; *par*1 represents a replacement parameter where a fraction of n replaces *n*'s losses. (38) is a Lanchester concentration equation since insurgents can target dominant combatant groups in a concentrated way through ambushes. (39) expresses the notion that an insurgent group can be targeted through intimidation and massacres that will affect its total population directly (without the intermediary of combat). This situation is now extant in Syria for instance. Relation (42) represents conditions under which massacres and intimidations will occur: essentially when one group of combatants is numerically strong enough to threaten seriously the domination of the more powerful group. Fear of a strong change in the balance of power should then trigger massacres. The parameter *par*6 indicates that this will occur when the combatants of the insurgent group reaches a certain size determined by *par*8: For instance if group *n* combatants reach parity or superiority over group *m* fighters. Finally *par*11 represents a logical switch which specifies that fighting will only start whenever q_1 and q_2 are greater than a minimal threshold level q^*.

Clearly, the coalition perspective, which can reiterate some aspects of the emotional factors in conflict, shows how confrontations can be influenced and enhanced by their own dynamics. In other words, conflict begets conflict as more and more individuals are drawn into it. This is in our view the main value added of the present approach: Whereas other conceptions stay at a relatively static level, our vision leads to an endogenous possible amplification (or for that matter reduction) of conflict.

This model can lead to conflict escalation and stable societal conflict traps. On the other hand, we show also that such situations are basically inefficient and that in fact any unequal situation within society that is not compensated by transfers from the more powerful or wealthier to poorer segments of society is inefficient. This particular result illustrates the neuroscience finding that increased inequality in a social hierarchy favors conflict. To show how the conflict dynamics can work in our framework, we will use the following scheme:

Fig. 1


Incentives to fight:
Individual Rent
seeking Model
Yes or No
Demographics
Economy
Natural Resources
Mobilization by coalition
Kernel *N* or *M*
Constitution of fighting
Groups through
recruitment
Confrontation, Casualties, Attrition
Representation through
Geographically Referenced
Combat Model

Some of these conclusions will be illustrated below with the help of our simulation model.

Simulation Model Construction

The relations presented above can now be coded in a simulation model, which is for the moment written in the context of the SPARE system developed at the Graduate Institute. This system allows us to write directly dynamic relations and recursive algebraic equations. Once the model is formulated different scenarios suggested by the mathematical analysis done above can be investigated. In particular, the kind of coalition behavior, which can amplify conflict behavior, can be analyzed in this way. The simulation model is subdivided into basic economic relations, fighting incentive relations, coalition behavior and combat equations. In principle the model can be regionalized to various geographical entities depending on the availability of data such as macroeconomic and demographic variables at the regional and sub-regional levels. Here is the transcription of the model script:

```
>DYNAMIC CONFEMOT
*
***
T=T$
*
*
*
*
** BASIC ECONOMIC EQUATIONS
E=(SQRT(P**S)*SQRT(H+1)*(SQRT(TPOP)-1)**2)/TPOP
*
Z=AC*SQRT(TPOP)*SQRT(P**S)*(SQRT(TPOP)-1)/DZ
DZ=SQRT(H+1)*((P**S)+SQRT(TPOP)*TPOP*(H+1)+SQRT(P**S)*SQRT(H+1)*(1+SQ
RT(TPOP)))
POP.=(BETH-ALPH)*POP
TPOP=POP+CMBPN
K.=NXI*H-RHO*K
NXI=EXP(ZET-GAM/K-ETH/(TPOP-COMBN-COMBM))
*
*FIGHTING INCENTIVE EQUATIONS
Q1=(1-TA+KA)/((1-BA+SQRT(THETA/PI)*(1+KA))**2)
*Q2=(1-TA+KA)/((1-BA-SQRT(THETA/PI)*(1+KA))**2)
W1=(1-TA+KA-(1-BA)*Q1)/(1+KA)
*W2=(1-TA+KA-(1-BA)*Q2)/(1+KA)
W=W1
Q=Q1
PI=(THETA-XI)/(1-PHI)
PHI=-Y*E+Z
XI=NXI/(TPOP-COMBN-COMBM)
*COALITION FORMATION
N=(CHI*(CMBPN-M))/(A-Q*CMBPN+CHI)
M=MNUM/MDEN
MNUM=(XSI*POP*(A-Q*POP))
```

```
MDEN=(B-Q*POP)*((A-Q*POP+CHI)+XSI*(A-Q*POP))
*COMBAT EQUATIONS
COMBN.=PAR12*(PAR1*CMBPN-PAR2*COMBN*COMBM)
COMBM.=PAR12*(-PAR3*COMBN+PAR4*M)
CMBPN.=PAR5*N-PAR13*PAR7*N*M
CMBDA.=PAR14*DAP-PAR15*CMBDA*COMBM
DAP.=PAR16*DAP
DIF= PAR8*COMBM-COMBN
PAR13=CONSTR(PAR6,0.,1.)
PAR6= -(COMPR(DIF)-1.)
DIF2=QSTAR-Q
PAR11=-(COMPR(DIF2)-1.)
PAR12=CONSTR(PAR11,0.,1.)
FATC=PAR2*COMBN*COMBM+PAR3*COMBN
FATR=SPDATA('SSUDFAT',1,T,1)
SKR=SPDATA('SKAP',1,T,1)
SGDPR=SPDATA('SUDGDP',1,T,1)
FATDA=SPDATA('DARFAT',1,T,1)
*
>TABLE SUDKAPF 14
** SUDAN
*
** Capital
*
* Year, Gross Capital Formation (Current US$)
*
1997, 1842.188771
1998, 2019.309493
1999, 1795.718978
2000, 2268.306236
2001, 2350.344857
2002, 2913.713655
2003, 3548.193382
2004, 4878.059608
2005, 7910.129356
2006, 1073.7583769
2007, 1419.3621761
2008, 1509.3313711
2009, 1376.2365863
2010, 1447.1931660
*
>TABLE SUDGDP 14
1997 11681.198236
1998, 11250.216339
1999, 10682.045000
2000, 12366.140066
2001, 13362.328043
2002, 14975.626178
2003, 17780.302167
2004, 21684.761535
2005, 27386.699507
```

2006, 36393.186004
2007, 46533.234127
2008, 58032.057416
2009, 54633.362294
2010, 62045.783133
*
>TABLE SSUDFAT 14
** Fatalities
*
* Year, fatalities South Sudan
*
1997, 0.007000
1998, 0.005000
1999, 0.003000
2000, 0.002000
2001, 0.001000
2002, 0.001000
2003, 0.001000
2004, 0.000200
2005, 0.000090
2006, 0.000750
2007, 0.000445
2008, 0.000171
2009, 0.002500
2010, 0.000986
>TABLE DARFPOP 2
** DARFUR
*
** Population
*
* Year, Population
*
1997, 3.
2008, 6.2
>TABLE SKAP 14
** SUDAN
*
** Capital Stock
*
* Year, Capital Stock (based on current US$)
*
1997, 30091.540680
1998 31242.034061
1999, 32346.959127
2000, 33840.724293
2001, 35325.819827
2002, 37295.665038
2003, 39796.924845
2004, 43519.885578
2005, 50105.753851
2006, 59244.442592

```
2007, 71592.826257
2008, 84788.293078
2009, 96720.337482
2010, 10940.0954002
*
>TABLE DARFAT 6
** DARFUR
*
** Direct Conflict Deaths
*
* Year, Fatalities (PRIO)
2003, 0.005000
2004, 0.000603
2005, 0.001000
2006, 0.002718
2007, 0.001289
2008, 0.001466
>initial
T$MIN=1997.;T$MAX=2020.
D$NPOINT=52.
PAR1=0.0001
PAR2=0.018
PAR3=0.034
PAR4=0.1
PAR5=0.03
PAR7=0.000000002
PAR8=0.07
PAR14=0.03
PAR15=0.0002
PAR16=0.028
QSTAR=0.15
P=0.5
S=0.8
H=0.23
POP=35.
BETH=0.003
ALPH=0.001
K=30091.54
RHO=0.01
ZET=15.2
GAM=70000.
ETH=150.
TA=0.25
KA=0.13
BA=0.1
THETA=3500.
Y=12.
CHI=1.0
A=42.
XSI=0.001
B=50.
```

COMBN=0.14
COMBM=0.11
CMBPN=7.
AC=100.
DAP=3.
CMBDA=0.14

N.B. The dynamic (differential) equations are represented by a dot following a left hand side defined variable. All the other relations are algebraic recursive, which allows for total simultaneity but can then also propagate instabilities quite quickly. The stabilization of the model in terms of representative parameters took quite some time. It can now be used for a progressive approximation of the model to real historical data points. Data present in the tables are for the Sudan. These were important because they allowed for a rough calibration of the model in terms of real historical series at least in terms of basic economic and demographic relations. However, more precise calibration will still take some more time. Scenario simulation examples are given at the end of the report.

Data Issues

Data validation of our approach touches on the question of how to relate data that are at least in part gathered at a macro level with our originally micro-level approach. There are two answers to this: the first is that if, according to our model overwhelming incentives to fight exist within a society the probability of casualties from conflict should be higher at the aggregate level and thus actual observed casualties and other conflict indicators should be greater. Conversely, if incentives to fight diminish observed casualties and conflict indicators should also decrease.

Step 2: Conducting Neuroscience Experimental Research Partner EPFL

We have addressed a number of key questions at a basic level of complexity in rodents with the goal of providing insights about key elements affecting social interactions and, hence, helpful to identify important elements to be implemented in the modeling part of the project.

The questions that were addressed with the rodent approaches were:

1. What is the impact of stress and fear on aggression and conflict resolution?
2. What is the impact of cooperative behavior related to both generalized and direct reciprocity on conflict resolution?
3. Can the experience of cooperative behavior modulate behavior in an animal model of retaliation?
4. What physiological mechanisms underlie the impact of stress on conflict dynamics and retaliation related behavior?

These questions have been addressed both experimentally and by examining the related literature. The main findings are summarized below:

What is the impact of stress and fear on aggression and conflict resolution?

We have investigated the aggression level and dominance hierarchy established between two male rats when stress (a fear-induction experience) is given to one of the two rats in the contest. In our model, a social hierarchy established by two male rats during a first encounter is not maintained one week later. If one of the two rats is stressed, the stressed rat becomes subordinate and the hierarchy that is formed is maintained. In addition, we have evaluated the role of 'intrinsic stress' (i.e., high anxiety trait) in the formation of the social hierarchy and found that high anxiety trait predicts (60-75%) the development of social subordination when the contest is hold with a low anxious individual.

Thus, we have shown that stress can have a deleterious impact in individuals' position in the social scale, as well as increasing social inequality.

What is the impact of cooperative behavior related to both generalized and direct reciprocity on conflict resolution?

As indicated in the project proposal, we have addressed this question by consulting the relevant literature. We have extended the search to the literature related to evolutionary perspectives in leadership, dominancy, and conflict resolution (van Vugt et al., 2006; Herman et al., 2008; Harcout et al., 2009a, 2009b,, 2010; King et al., 2009; Johnstone and Manica, 2011).

These are the key elements that we have extracted based on the literature and our own reflection and that we deemed essential to deal with conflict resolution:

- Alternation on the access to disputed resources can be a way to resolve conflicts before they have gotten into high escalation levels.
- Escalated conflicts are linked to strong emotions and negative emotional memories. Resolution of conflict might be benefited by a change in 'intrinsic' motivation in the respective parties (e.g., responsibility of achieving peace for the future of next generations), reducing the emphasis on aspects related to 'extrinsic' motivation (competition with the other party).
- Bringing a change in intrinsic motivation not only to leaders (top-down), but also to the group (bottom-up).
- Fostering cooperation on the bases (i.e., respective groups) from each party through external reward, as a way to reduce negative emotionality.
- Given the strong influence of fear and emotion, the negotiation framework should include a basis to deal with free-riders that can boycott the agreement process.
- Biological roots can be in the basis of individual and group variations in dominance behaviors, aggression, and antisocial punishment. Understanding these biological mechanisms can be a way to deal with difficult conflict resolution.

Can the experience of cooperative behavior modulate behavior in an animal model of retaliation?

To address this issue, we have started investigating the modulatory role of different personality-like traits in the establishment of social hierarchies. Individual differences in the amount of anxiety were apparent when we tested Wistar rats in a test that measures animals' anxiety, the elevated plus maze (EPM; Fig. 1, left panel). We further showed that anxiety trait is highly predictive for social dominance; highly anxious (HA) animals tend to become submissive during an encounter when

matched for weight to low anxious (LA) conspecifics as apparent from both total duration of offensive behavior (Fig. 1, right panel).

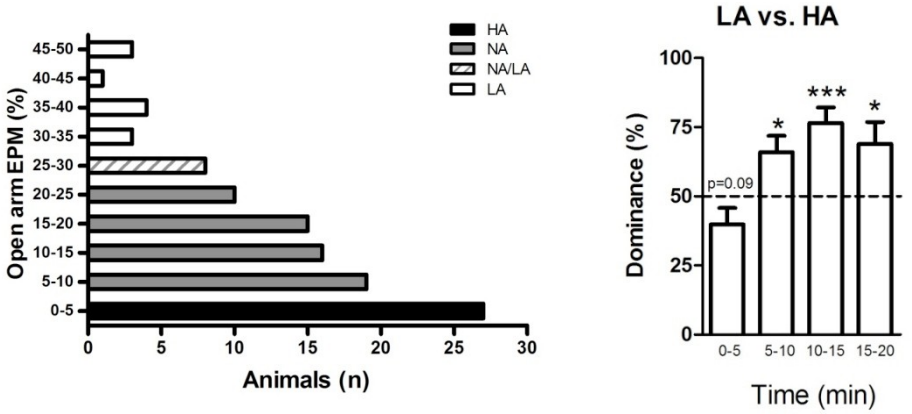


Figure 1. Left panel: Rats' distribution into different anxiety groups. Right panel: Dominance in percentage. HA: high anxiety; LA: low anxiety; NA: normal anxiety.

Systemic administration of the anxiolytic drug Diazepam (known better by its commercial name, Valium) reduces anxiety on the EPM (Fig. 2, left panel) while it enhances dominancy (absolute and relative) in HA rats (Fig. 2, right panel).

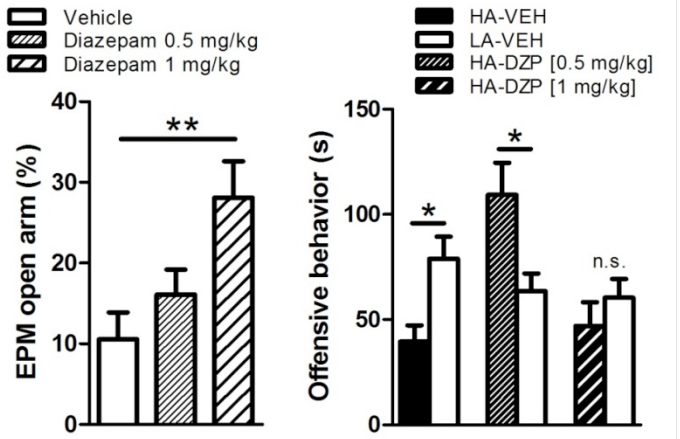


Figure 2. Left panel: Effect of different diazepam (DZP) doses given systemically in the elevated plus maze (EPM). Right panel: Offensive behaviors in HA-LA interactions when the HA animal is injected with DZP. HA: high anxiety; LA: low anxiety. VEH: vehicle.

These findings indicate a very strong role for anxiety-like personalities in the resolution of social conflicts linked to the establishment of hierarchies. They also show that anxiolytic drugs can change the outcome of a social encounter. Altogether, these observations provide key information to interpret dynamics of social interactions. Future studies should try to evaluate the translational value of these findings for human interactions.

What physiological mechanisms underlie the impact of stress on conflict dynamics?
In order to investigate whether stress effects in the long-term establishment and expression of the social hierarchy are mediated by the so called 'social neuropeptides' oxytocin and vasopressin, we have investigated changes in the expression level of the receptors for each of these neuropeptides (i.e., *Otr* and *V1aR* receptor genes) in brain regions relevant for the mediation of social behaviors and aggression (plasma levels are in quite a low range and not so informative). We found

that the potentiation of a social hierarchy induced by stress is accompanied by social status-, region- and time-specific changes in the expression of *Otr* and *V1aR* mRNA in the medial amygdala and lateral septum. Results from pharmacological experiments designed to mimic the observed changes in gene expression by micro-infusing specific antagonists suggested roles for the OTR in the medial amygdala during the initial stages of the long-term establishment of a subordinate status and for the V1aR in the lateral septum during the expression of this phenotype. These findings highlight roles for these two neuropeptide systems in the mechanisms through which stress facilitates the long-term establishment of a social hierarchy.

Thus, we have learnt that the oxytocin and vasopressin systems are implicated in the impact of stress on social hierarchies. The following paper has been published (with SNIS included in acknowledgements):

Timmer M., Cordero M.I., Sevelinges Y. and Sandi C. (2011) Evidence for a role of oxytocin and vasopressin 1a receptors in the long-term establishment of dominance hierarchies. Neuropsychopharmacology 36(11):2349-2356.

Step 3: Empirical Data Gathering

In the first months of the project, the data collection efforts focused on the conflict variable and on testing the ground for the proposed case studies. The three datasets identified in the project proposal have been tracked down, relevant data extracted, and its operational value to the research project assessed. Most importantly, a considerable volume of empirical material has been gathered on the conflicts in Israel/Palestine, Afghanistan, and Sudan, contacts with experts at international organizations and NGOs established, and a data gap analysis conducted. In the following months of the project, one case study has been added, Lebanon. This means that four case studies have finally been picked up from the initial list of cases in the research proposal: Israel-Palestine (an interstate conflict), Afghanistan, Lebanon and Sudan (intrastate conflicts with strong international involvement). Conflict datasets have been set up for all four, with an initial focus on fatalities but also including statistics on migration, demography, poverty, and economic development. In the first months of the project, the data collection efforts focused indeed on the conflict variable. The articles "Conflict, Environment, and the Dynamics of Fear" and "Unfolding Tragedies: Explaining and Predicting Future Environmental Scarcities and Conflicts" build on the complex relations between "natural resources, demography and institutions" to understand the existence of conflict. Besides conflict data, the research compiled in the last months of the project deals with sociological and economic data with a specific focus on three elements: ethnic groups and their settlement patterns, demographic data (especially population density) and natural resources.

Case Studies: background

Based on the resources provided by the UCDP Conflict Encyclopedia (www.ucdp.uu.se/database) and the BBC country profiles database, here is a quick overview of latest developments for each area of conflict.

In Afghanistan, after the multinational coalition led by the United States ousted the Taleban from power in 2001, a democratic system was established in 2002 and a new Afghan constitution established in 2004. However, the situation remains highly unstable because Taleban insurgents continue their actions: the Afghan government's authority is difficult to establish beyond Kabul.

Regarding the Israeli-Palestinian conflict, Israeli forces and settlers left the Gaza Strip in 2005 but there has been an intensification of the economic blockade of the area after Hamas took control in June 2007. Israel launched an attack at the end of 2008 to counter rocket attacks. The main issues regarding the peace process are the status of Jerusalem, Jewish settlements and the question of Palestinian refugees. Intrastate conflicts have also taken place among Palestinians with confrontations between Hamas and Fatah since 2006.

In Lebanon, the fragile equilibrium defined after independence which gives the president's seat to a Maronite Christian, the prime minister position to a Sunni Muslim and the speaker of parliament position to a Shia Muslim is at heart of the different internal and external tensions plaguing the country. Following the end of theCivil War, Israeli forces withdrew in 2000 and Syrian in 2005 after the assassination of former Prime Minister Rafik Hariri. However, the Shiite Hezbollah militia is still active in Southern Lebanon despite indictments pronounced by the UN-back tribunal in the Hague in 2011. In 2006, Israel launched a military offensive after the Hezbollah militia seized two Israeli soldiers.

The most recent development in Sudan is of course the partition of the countryin July 2011 after South Sudan voted for independence. This put to an end of the opposition between the Arab Muslim North and the Christian and Animist South. However, a lot of issues remain unresolved regarding the establishment of the border and the distribution of oil revenues. Besides, the Darfur conflict remains unresolved with pro-government militia such as the Janjaweed accused by the United Nations of conducting an ethnic cleansing campaign against the non-Arab population.

Case Studies Datasets

Given that the above datasets contain annual data only, the research focus has shifted to compiling monthly data on potential case studies to be able to better analyze the *dynamics* of conflict behavior. Such an endeavor is particularly challenging due to the political sensitivity of publishing fatalities statistics on contemporary conflicts. At the same time, the study of recent cases allows to tap knowledge from international agencies and NGOs, which are based in the field, thus obtaining first-hand information. Generally, the numbers reported have hardly fluctuated significantly from one source to another, which speaks of their reliability.

Israel-Palestine offers a good starting point as it is a conflict that has been going on for a long time, the parties to the conflict are easily identifiable, and official data obtainable from both national and international institutions. For example, figures on fatalities have been acquired from three difference sources: one Israeli (B'tselem, the Israeli Information Center for Human Rights in the Occupied Territories), one Palestinian (the Palestinian Monitoring Group of PLO's Negotiations Affairs Department) and one international (the UN Office for Coordination of Humanitarian Affairs). Though the time periods vary, comparison among the three datasets

confirms the data reliability, thus making the merging of results or the use of low/high/best estimates possible. In addition, information has been compiled on injuries, attacks on religious sites, arrests, home demolitions, and assassinations. Most importantly, the data is disaggregated by party to the conflict (i.e. Palestinians killed by Israeli forces, Israeli forces killed by Palestinians, etc.), which is important for the purposes of the project.

Afghanistan has been a difficult case to collect data on as, apart from being politically sensitive, no organization seems to record conflict-related statistics on all the warring parties and international participants. To illustrate, the United Nations Assistance Mission in Afghanistan (UNAMA) gathers data on civilian fatalities but does not account for coalition casualties. Similarly, U.S. sources provide information on killed soldiers but not on civilians, and Taliban deaths largely remain a mystery. Coalition deaths can be traced back to the beginning of the war in 2003, while the UN and NGOs have only developed methodologies and embarked on recording fatalities as of 2007 onwards. Regardless of these difficulties, the project team has managed to collect monthly data on the coalition, the Afghan army and police, and civilian deaths. Some data on internally displaced persons (IDPs) has also been obtained from the Internal Displacement Monitoring Center (IDMC) in Geneva. Annual statistics on refugees and IDPs have further been acquired from TLO, an Afghan- based NGO. Additional conflict metrics (e.g. number of insurgent attacks, suicide bombings, local perceptions of security) have been extracted from the Worldwide Incidents Tracking System of the U.S. Counter-Terrorism Center, the Afghanistan Conflict Monitor of the Human Security Report Project, the Center for Strategic and International Studies (CSIS), and the Brookings Institution. Whereas issues related to the project's database structure remain to be resolved (e.g. time period, unit of analysis, etc.) it is believed that the SNIS-funded project can attract significant interest in its outputs if a comprehensive dataset on Afghanistan is compiled.

Data on fatalities in Darfur (2008-2010) has been obtained from the United Nations Development Programme (UNDP) and the Genocide Intervention Network in Washington, DC. Similar information has been acquired on South Sudan from the UN Office for the Coordination of Humanitarian Affairs (OCHA) but for a shorter time period. The information generally comes from media, UN reports, local authorities and OCHA assessment teams. According to experts, attacks are only sporadically reported which is generally a hurdle for the data collection. There are also no monthly monitoring reports with updated IDP figures.

Global Datasets

To be able to feed the computational model with empirical data, the following datasets have been obtained from other research institutes and their applicability for the purposes of this project assessed: two datasets on battle deaths from the Uppsala Conflict Data Program (UCDP) and the Peace Research Institute in Oslo (PRIO) for 1989-2008 and 1946-2002, respectively; statistics on fatalities from Armed Conflict Database of the International Institute for Strategic Studies (IISS); several datasets from the Correlates of War (COW) project, including battle deaths from interstate wars (1816 – 1991), extra-state wars (1816 – 1997), intra-state wars (1816 – 1997), and militarized interstate disputes.
Whereas all these large-N datasets are particularly useful for the computational modeling part of the project, their incorporation into a single dataset poses some

challenges in terms of differing definitions of conflict, divergent time periods, lack of data on recent conflicts, varying fatality thresholds (from 1,000 annual fatalities in the case of COW to 25 annual fatalities for UCDP), and diverse statistical units (some account for fatalities in terms of high/low/best estimate; others provide a scaled number or a magnitude score). While the project team should take a decision on all these aspects, the initial assessment of the datasets' applicability indicates that utilizing both high and low thresholds of fatalities may be beneficial for the project given its focus on dynamics (i.e. may allow for observing the process of moving from low-scale to high-scale violence). The time period should be specified based on the availability of data on other variables. For example, the World Bank socio-economic and demographic data goes back to the 1960s which may become determinant in this regard. Different approaches to the unit of analysis are also possible: if structured by country and year, the project team would be able to study phenomena related to the onset and occurrence of conflict; if organized by conflict, the dataset would speak about the duration of conflict, while a dyad-year structure would facilitate studying the different parties to a conflict. The initial effort has been on identifying and obtaining any relevant existing datasets, compare their structure and coding techniques, and assess their usefulness and applicability to the current project.

Three additional datasets have been discovered, which may be partially incorporated in the generic model's database: the State Failure Problem Set (1955-2009) developed by the Political Instability Task Force, George Mason University; the Major Episodes of Systemic Violence (1946-2008) which provides magnitude scores of international warfare and civil/ethnic violence, as calculated by the Center for International Development and Conflict Management, University of Maryland; and the Coup d'Etat Events dataset (1946-2009) compiled by the Center for Systemic Peace in Vienna. Their value is still being assessed due to the methodological issues that magnitude scores and scaled numbers present. The coup d'état data will possibly be bracketed as too episodic (and hence incomplete) as well as referring to intra-state conflicts only.

Ethnicity

The first sources used for the basic description and composition of ethnic groups in the case studies are the sources cited by Fearon (Fearon 2003, 12): the CIA fact book and the Encyclopedia Britannica. The CIA factbook pages have all been updated this year so these figures are probably the most reliable. The estimates are quite similar to those of the Encyclopedia Britannica. The following table, which takes figures of the CIA Factbook gives a snapshot of ethnic groups for the four case studies:

LOCATION	Ethnic Groups	Representation
Afghanistan	Pashtun	42%
	Tajik	27%
	Uzbek	9%
	Aimak	4%
	Turkmen	3%
	Baloch	2%
	other	4%

Gaza Strip	Palestinian Arab	100%
Israel (2004)	Jewish, Israel-born Jewish, Europe/America-born Jewish, Africa-born Jewish, Asia-born non-Jewish, mostly Arab	67,10% 22,60% 5,90% 4,20% 23,60%
Lebanon	Muslim (Shia, Sunni, Druze, Isma'ilite, Alawite or Nusayri) Christian (Maronite Catholic, Greek Orthodox, Melkite Catholic, Armenian Orthodox, Syrian Catholic, Armenian Catholic, Syrian Orthodox, Roman Catholic, Chaldean, Assyrian, Coptic, Protestant) Other	59,70% 39% 1,30%
Sudan	Sudanese Arab Fur, Beja, Nuba, Fallata	70% 30%
West Bank	Palestinian Arab and other Jewish	83% 17%

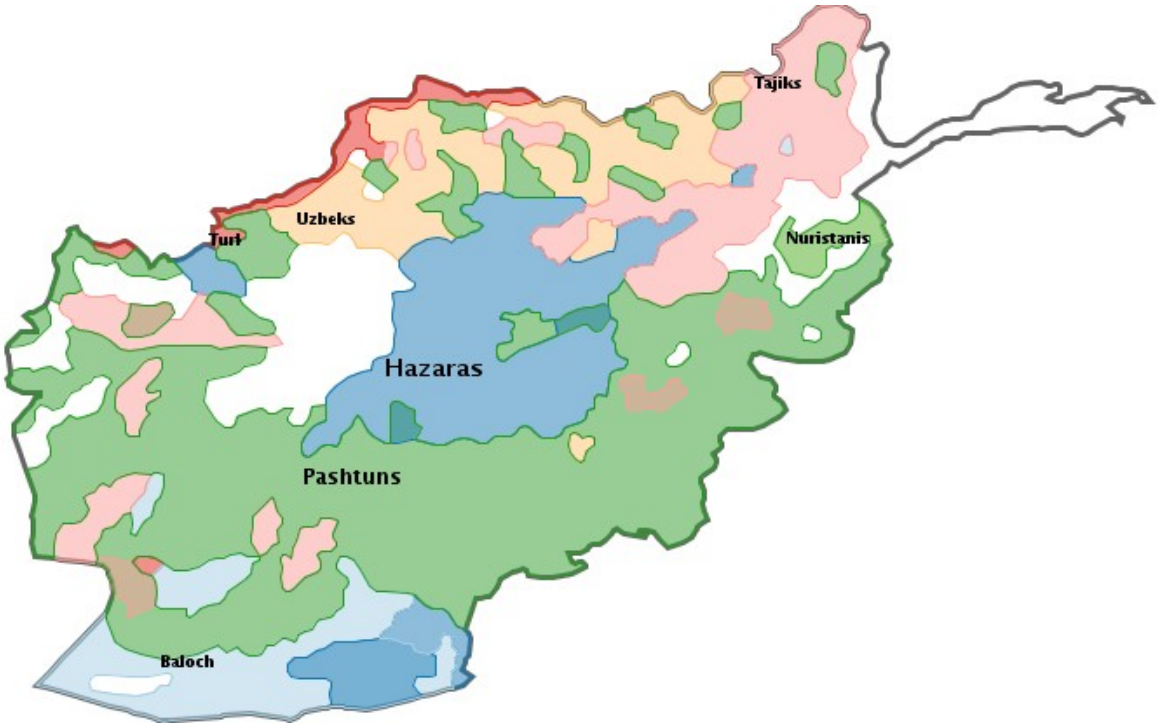
For Lebanon, it is added that 17 religious sects are recognized. We took here the religious composition more telling than the ethnic representation showing the following Arab 95%, Armenian 4%, other 1% and with the precision that "many Christian Lebanese do not identify themselves as Arab but rather as descendants of the ancient Canaanites and prefer to be called Phoenicians".
Lim, Metzler and Bar-Yam paper on "Global Pattern Formation and Ethnic/Cultural violence" elaborate a predicting model of conflict on the basis of settlement patterns of ethnic groups. As a consequence, the objective of the data collection was to come up with some GIS datasets.

The "Geo-referencing Ethnic Power Relations" (GREG) is a project based at the International Conflict Research Group at ETH Zurich. The portal "presents data on ethnic group power relations, ethnic settlement patterns, and civil war". It provides various datasets regarding the power and size of these ethnic groups, their settlement patterns, their access to power, their implication in intrastate conflicts. Weidmann, Rod and Cederman explain in their paper "Representing ethnic groups in space: a new dataset" that "the 'Geo-referencing of ethnic groups' (GREG) dataset employs geographic information systems (GIS) to represent group territories as polygons". Visual representations are provided below in the form of maps. The relevant data has been collected. One of the applications envisioned for the GREG dataset is precisely to explore the relationships between ethnic settlement and conflict as detailed by the authors; "The information in GREG can also be used in conjunction with geographic datasets on conflict to examine the relationship between the ethnic distribution and the occurrence of violence. For example, in their study on the diffusion of civil war, Buhaug and Gleditsch (2008) use GREG to determine whether a country has ethnic ties to groups within the conflict zone of a neighboring state" (page 11).

The GROW^{UP} project is based on three types of datasets:
-EPR-ETH Version 2.0 which identifies all politically relevant ethnic groups and their level of access to state power for all countries of the world from 1946-2009.

-GeoEPR-ETH Version 2.0 which codes the settlement patterns of politically relevant ethnic groups in independent states.
-ACD2EPR Docking Version 1.2 which links ACD v.4-2010 conflicts to groups identified by the EPR dataset.
The following snapshots obtained through GeoEPR-ETH Version 2.0 provide maps for the case studies establishing the settlement patterns of ethnic groups.

AFGHANISTAN (GeoEPR-ETH Version 2.0)



ISRAEL (GeoEPR-ETH Version 2.0)

<u>LEBANON (</u>GeoEPR-ETH Version 2.0)

<u>SUDAN (</u>GeoEPR-ETH Version 2.0)

The most detailed maps in terms of ethnicity, religion, languages and other indicators are to be found on the website of the Gulf 2000 Project of Columbia University. The maps are very detailed in terms of the distribution of ethnic groups. Religion and "strictly" ethnic variables are often overlapping so maps of the two types have been collected. In some cases, notably Lebanon, religion is probably more relevant than ethnicity in terms of divisions. For Sudan, it is interesting to note that maps are available not only for former united Sudan but also for the North and the South, showing subdivisions. Israel-Palestine and Lebanon ethnic maps are not available for the individual country but are visible on a larger Middle East map.

Demographic data

Density maps have been mostly taken from the Gridded Population of the World (GPW) project of the Center for International Earth Science Information Network (CIESIN) of Columbia University or the United Nations. The Center for International Earth Science Information Network (CIESIN) manages the Gridded Population of the World (GPW v3) project which provides information on the spatial distribution of human populations across the globe. It converts the distribution of population from national or subnational spatial units to a series of geo-referenced quadrilateral grids. Estimates are provided for 1995 and for 2000. Data has been collected for the two periods. The GPW dataset is also referenced and used in Weidmann, Rod and Cederman.

Economic development.

National aggregates are available for all countries through reports and factsheets usually elaborated by the World Bank such as the World Development Indicators. The Millenium Development Goals reports constitute another useful resource to establish the level of development for each case study. In addition to

economic indicators, natural resources and their spatial distribution constituted another useful indicator regarding conflict.

For Afghanistan, the availability of provincial briefs established by the World Bank helps in giving a more detailed picture in terms of regional development. They provide "a summary of selected social and economic measures of individual and household wellbeing". The country is highly dependent on foreign aid.
Though the UNEP's Desk Study on the Environment in the Occupied Palestinian Territories does not provide for direct economic indicators, it gives useful information on water for example or the location of industrial sites. The Socio-Economic and Food Security Atlas by the World Food Programme represents a comprehensive resource on the occupied Palestinian territory (oPt) as does the Lebanon Atlas by the French Institute for the Middle East.

On the website of the Gulf 2000 Project, it is noted that: "There is a very strong correlation between distribution of the Shias in the Middle East and the Caucasus and those of oil and natural gas resources. This is true from the Republic of Azerbaijan and the Caspian Sea to the Persian Gulf." This observation suggests, in line with the objectives of the project, to focus on one or several natural resources and explore correlations with the spatial distribution of ethnic groups in case studies.

The most important resource in Afghanistan when it comes to conflict is the cultivation of opium poppy. The MDGs report and data from the UN Office on Drugs and Crime provide data on the extent, the spatial distribution and the challenges related to the cultivation of poppy. The Afghanistan Economic Update October 2011 by the World Bank notes that 78 percent of cultivation is concentrated in the southern provinces. Other significant resources are oil and gold: they have been attracting increasing investments.

Two resources stand out for Sudan: land and oil. The African Union Panel Report on Darfur notes that "On the range of overlapping conflicts over resources, livelihoods and demands for recognition of ethnic identities that have propelled the conflict in Darfur, land is of particular significance" (p. xiv). The map by US Aid giving indicators relative to oil is particularly informative as it indicates for example, areas controlled by specific actors. Other resources, besides cultivable land and oil are gold and cotton.

The situation is less obvious for Lebanon and Israel in terms of dominant resources. Water may constitute the most relevant resource for both areas, especially for Israel and the Occupied Palestinian Territories. A partial explanation also resides in the nature of the Lebanese and Israeli economies. Where Afghanistan and Sudan primarily constitute agrarian economies, Israel constitutes an advanced market economy and the Lebanese economy a service-oriented economy.

Step 4: Scenario Simulations

Rough calibrations have been carried out in order to account for the basic demographic and macroeconomic variables of Sudan to just take one practical example. However, at this stage no analogy should be drawn to a real situation. The scenarios are just there to show what drives the model.

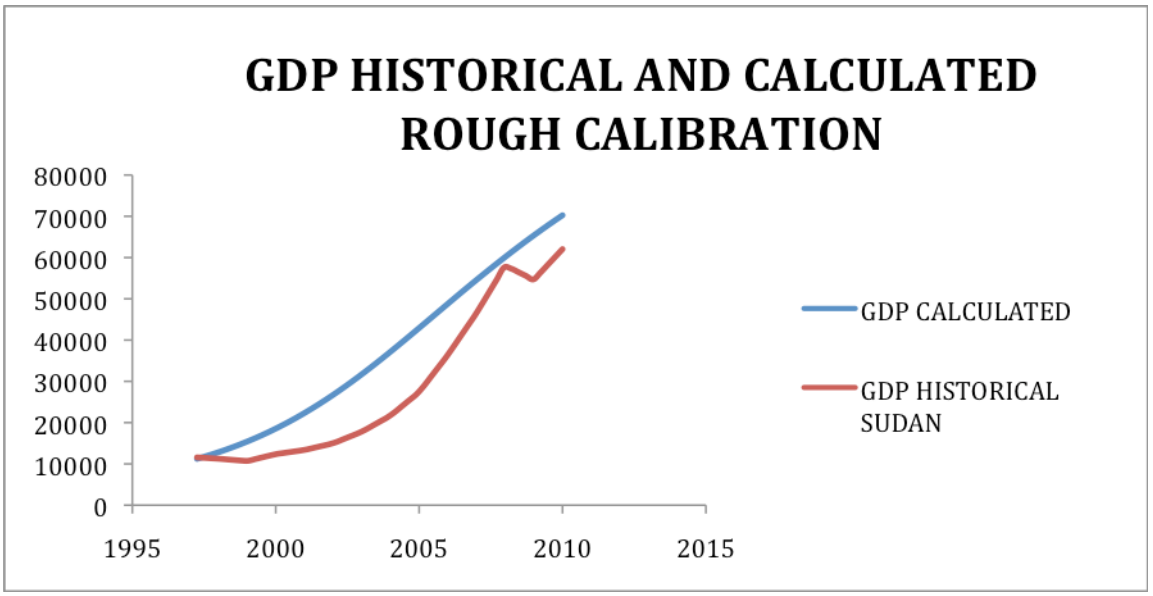


Fig. 2

What we see here in the above figure (Fig.2) is an increasing level of GDP for a country whose macroeconomic and demographic characteristics are like those of Sudan. Because of that (according to the model) things turn out well. Enough resources are shared (cf. the neuro-science finding on p. 21) in such a way that the N coalition (in our conception the insurgent group) after rising initially declines (Fig. 3).

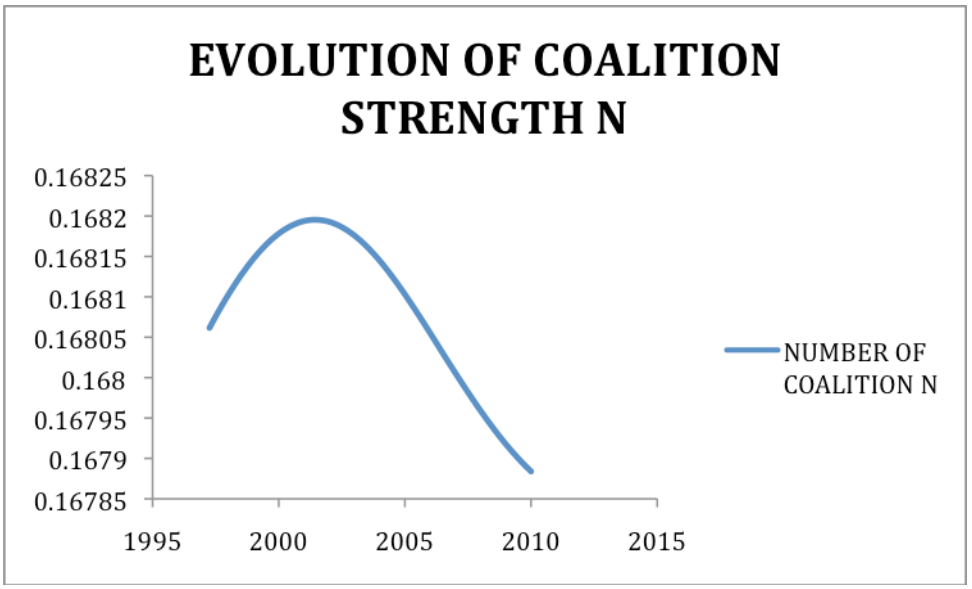


Fig. 3

But so does the dominant group coalition which loses strength as seen in Figure 4:

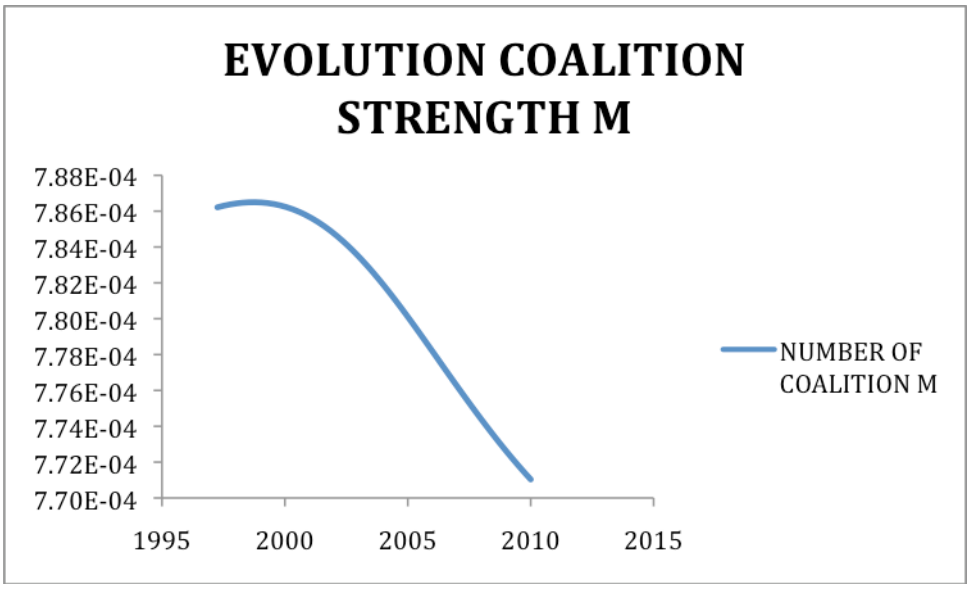


Fig. 4

This diminishes the propensity to fight as shown in Figure 5.

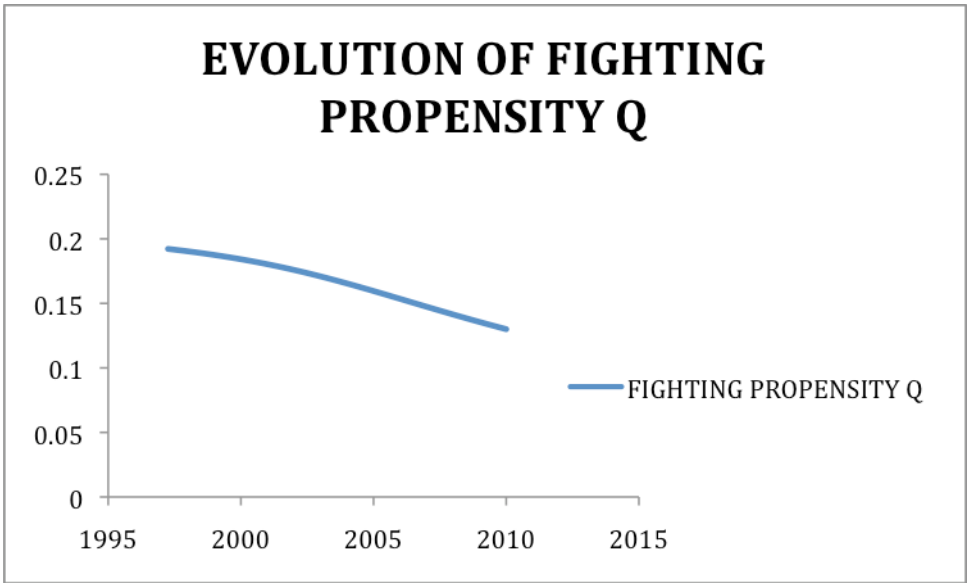


Fig. 5

Finally the number of combattants for N rises quite slowly but then stops growing as q diminishes enough to be below the combat threshold q^* as shown in Figure 6:

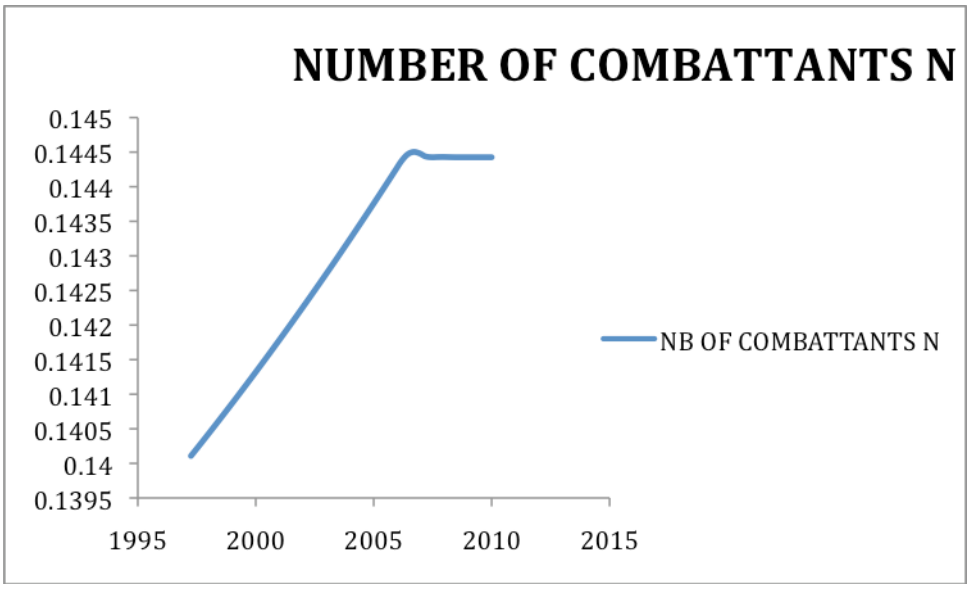


Fig. 6

We can now contrast this with an **Economic Collapse Scenario** that is represented in Figure 7:

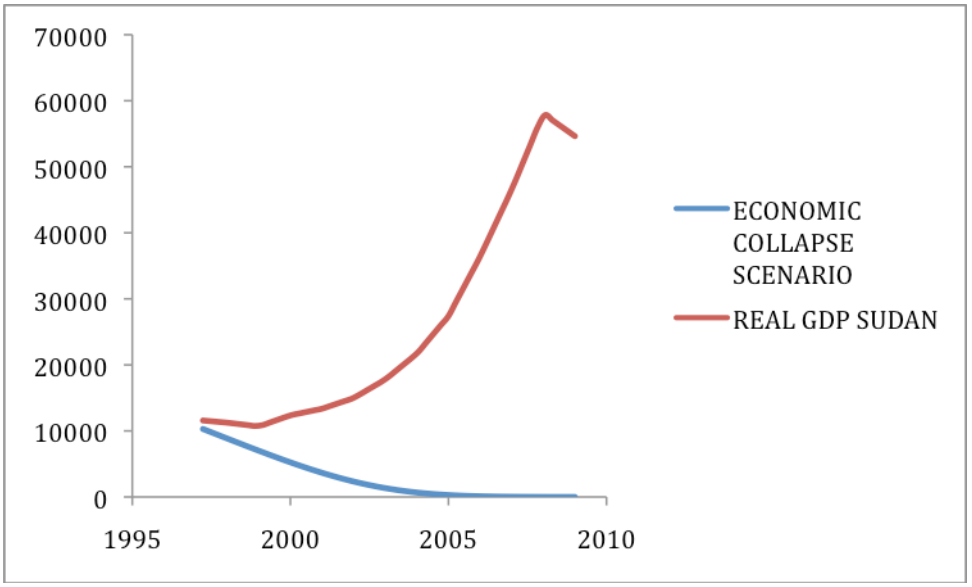


Fig. 7

In the economic collapse scenario capital growth slows down significantly which rsults in a significant lowering of GDP. The propensity to fight increases until leveling of at a high level plateau as shown in Figure 8:

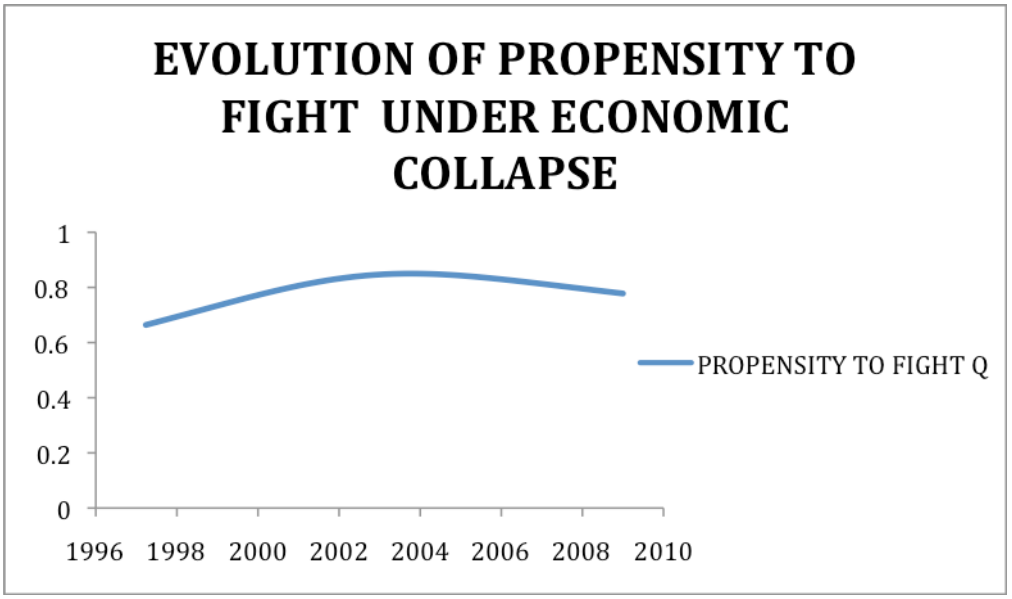


Fig. 8

The coalitions of both N and M increase in numbers as shown in Figures 9 and 10 adding to the conflict escalation:

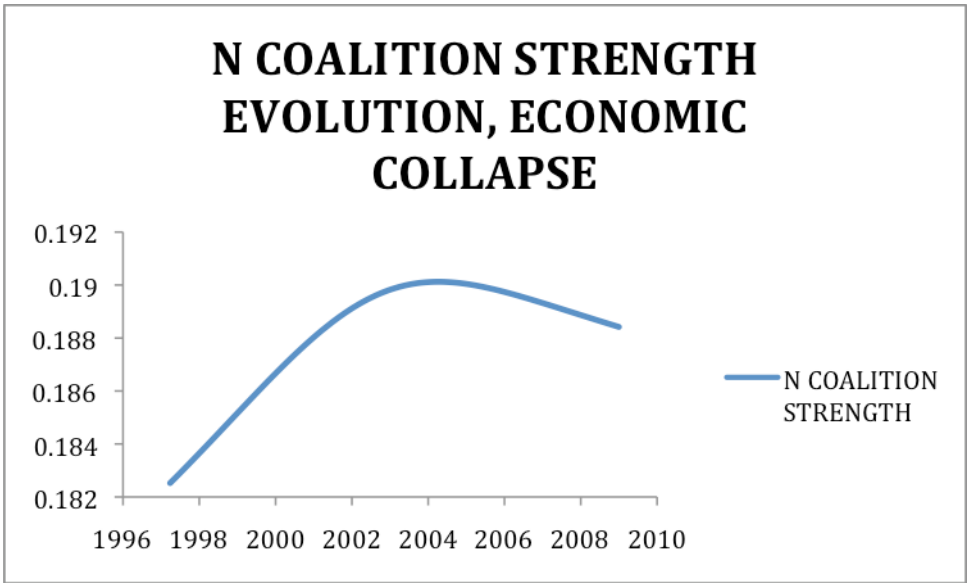


Fig. 9

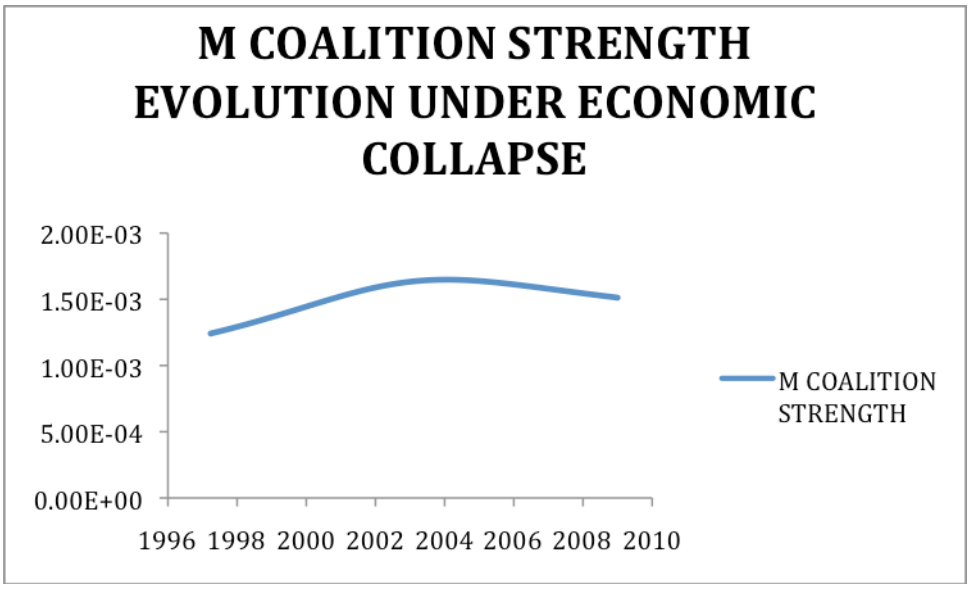


Fig. 10

As a result, the number of fighters for N increases with associated combat damages on the armed forces of M (Figure 11).

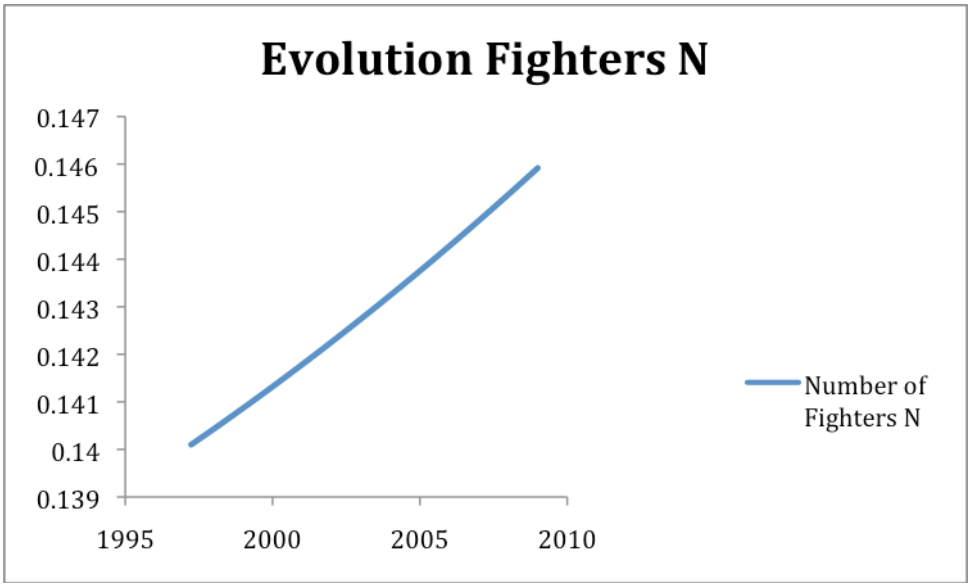


Fig. 11

Step 5: Conclusions

Quite clearly, if one follows these scenarios, economic conditions drive the model since in one case sustained growth produces stability and end of combats whereas deteriorating capital growth and GDP collapse lead to increased hostile coalition participation and more fighting. However, things are not that simple since the mere trigger of economic conditions is insufficient to explain conflict escalation, which results from increased participation in mutually hostile coalitions and greater fighting propensity where emotions such as fear and resentment play their role. Without the postulated risk attitudes which translate these emotional aspects into mathematical and simulation language formulae the scenarios described above would not be conceivable. In some sense what our scenario analyses show so far is

that external rewards (here the additional wealth derived from substantive growth rates) evoked by our neuro-science partner on p. 21 play their role in attenuating conflict over time. It is remarkable to point out here to make an analogy to the Sudan situation, that the conflict between North and South essentially broke out initially as poor growth conditions prevailed but as these improved remarkably over the last decade, the situation essentially got better in terms of the hostilities and the compromise of separating the North from the South was made possible. This being said, the analysis provided here constitutes just a first step toward the understanding of emotional factors in conflict. The mechanisms have still to be better understood. A conference organized by Graciela Chichilnisky at Stanford-SRI this summer a Workshop on Catastrophic Risks went a long way in providing better answers to some of the puzzles raised by emotions and preference distortions due to extreme events. Urs Luterbacher and Jean-Louis Arcand gave a paper on issues conflict escalation and risk there (conference schedule in the Appendix).

Appendix

Partner Collaboration

A one-day Project Coordination Meeting took place on May 23, 2011, with representatives of the institutions partnering on this project (IHEID – Geneva, EPFL – Lausanne, ETH – Zurich). Prof. Chichilnisky from Columbia University could not attend the meeting but she had been in regular contact with the Project Coordinator and had provided input for the meeting on the modeling aspect of the project. The meeting included a series of presentations on research progress; a discussion of measuring and modeling emotions in a rationalist framework; a discussion of the advisory committee (suggested committee members, scope of work, frequency of meetings); necessary input for the current mid-term report; and delineation of next steps. Two potential project partners also participated: (1) Prof. Ravi Bbhavnani who has joined the IHEID faculty in autumn this year, has significant experience in computational modeling, and is collaborating with the project; and (2) Mrs. Valérie Fert, President of the GMAP Research Group, who is working on an artificial intelligence system designed to analyze and map huge information flows, a software application that can be utilized for the purposes of the research project.
Graciela Chichilnisky and Urs Luterbacher have published a paper showing that redistribution of assets is optimal for developed and developing regions of the world with respect to the climate change problem. This article has a more general applicability in the sense that it shows that hierarchies in income and wealth are not efficient and as the neuro-science literature shows they should be reduced to avoid conflicts (reference below).
Graciela Chichilnisky has organized a Workshop on Catastrophic Risks at SRI Stanford on June 1st and second with the following schedule:

June 1st

8:45 am Light Breakfast

9:15 am Welcome and Introduction by Workshop Organizers and representative of the US Air Force Office of Scientific Research

9:30 am Welcome to SRI meet and greet with Dr. Curt Carlson, Director

9:45 am Introduction of Participants

10:00 am: Purpose and Content of AFOSR Workshop on Catastrophic Risks Graciela Chichilnisky, Columbia University and Principal Investigator of AFOSR Project on "Optimal Statistical Decisions with Catastrophic Risks"

10:15 am "Decisions Under Uncertainty: The Standard Model" - Key Note speech by Professor Kenneth J Arrow and Q&A

11:15 am Tour SRI Global Thermostat Carbon Capture from Air - Pilot Plant - Dr. Gopala Krishnan, SRI

12:00 pm Lunch Break - Refreshments and "Catastrophic Risks and the Carbon Cycle" - Professor Peter Eisenberger Columbia University

2:00 pm to 5:00 pm: Session 1: Fundamental Methodological Contributions

"Optimal Statistic Decisions with Catastrophic Risks" by Graciela Chichilnisky

"Catastrophes, Rare Events, and Black Swans: Some Methodological Issues" by Peter J. Hammond

"Probability, Conditionals and Strategic Decisions" by Brian Skyrms

"Kernel embedding of probability measures as Banach space functions" by Jun Zhang

6:00 pm Dinner

June 2nd

8:45 am Coffee and an hour of discussion

9:00am – 11:30am: Session 2: Catastrophic Economic Risks or Events

"Economic Crises: Natural or Unnatural Catastrophes?" by Alan P. Kirman

"Catastrophic Risks and the Carbon Cycle" by Peter Eisenberger

"Insurance, Beliefs and Effects: Using psychophysic paradigm to explore insurance behaviors facing catastrophic risk" by Olivier Chanel and Jean-Christophe Vergnaud and Sebastien Massoni

"Global Warming and Economic Externalities: Some implications for discounting." by Armon Rezai

11:30 - 12:30 am Hour of discussion

12:30 am Light lunch at Cook's Sea Food

2:00pm – 5:00pm: Session 3 Presentations : Behavioural or Psychological Reasoning

"Subjective Rationality in Decision Making" by Louis E. Narens

"Risk Management for Heavy Tails, Black Swans and Other Catastrophies by Jose Garrido

"Fear, Risk, Conflict Escalation, and Conciliation" by Jean-Louis Arcand and Urs Luterbacher

"Preference Representations in the Face of Catastrophic Risks" by Richard E. Ericson Chair and Jamie B. Kruse

5:00- 6:00 pm Discussion and Next Steps

6:00 pm Dinner at SRI before end of conference

More Workshops are planned in the future.

Publications actual and projected ones:

The following paper has been published :
Timmer M., Cordero M.I., Sevelinges Y. and Sandi C. "Evidence for a role of oxytocin and vasopressin 1a receptors in the long-term establishment of dominance hierarchies."
The following paper which draws upon previous work done for SNIS and the current project has come out:
Luterbacher, Urs. 2011. "Conflict, Environment, and the Dynamics of Fear: The Examples of Rwanda and Nepal," *Governance, Development and Conflict: contributions to Conflict Management, Peace Economics and Development,* Vol. 8:341-373, Emerald Group Publishing Limited.
Graciela Chichilnisky and Urs Luterbacher "Climate Change, Security, and Redistribution: How Can Political Dilemmas Linked to the Global Environment Be Solved?" *Brown Journal of World Affairs* Spring/Summer 2012, 18, 11: 227-260.

The following are planned:
Graciela Chichilnisky. Optimal Statistic Decisions with Catastrophic Risks

Jean-Louis Arcand and Urs Luterbacher. Fear, Risk, Conflict Escalation, and Conciliation

Articles based upon this report.

Generic Simulation Model
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