# The Biodiversity Bargaining Problem

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**Abstract**

We employ cooperative bargaining theory and Nash's 'rational threats' idea to cast light on the *biodiversity bargaining problem*. The problem of global environmental negotiations is argued to be of the nature of a bargaining problem, in which bargainers must agree on the distribution of cooperative surplus in order to move to the bargaining frontier. We discuss the importance of both efficiency (bargaining frontier) and fairness (recognition of characteristics of bargainers) in the choice of the appropriate contract. We show that the incremental cost contract, used to resolve the biodiversity bargaining problem, is of the form of an extreme point contract that fails to recognise the contributions of the South to the production of cooperative surplus. A rational response to such a contract is the use of threats of biodiversity destruction. Contracts must evince both efficiency and fairness in order to represent lasting solutions.

**Keywords**: North-South bargaining, Nash cooperative bargaining, rational threats, International Environmental Agreements

**JEL Classification:** Q15, Q16, Q21, O13, O34.

# 1 Introduction

One of the more interesting phenomena that occurs within global negotiations concerns the need to develop contracts that are able to handle gross asymmetries between the states concerned. This makes it more difficult to construct the international agreements required to engender cooperation. It is one thing to attempt to develop institutions that treat similarly situated states similarly, and it is an entirely different exercise to attempt to deal with the problem of treating differently situated states differently. This is one of the basic problems facing negotiators over the basic global development treaties - the Biodiversity Convention and the Climate Change Convention - where different regions of the world stand in very different positions regarding the resource concerned.

One context in which this problem arises concerns the creation of global mechanisms to regulate biodiversity. The need for global cooperation in the conservation of biological diversity is generally agreed. [3] There is increasing recognition of the important role to be played by genetic resources in addressing problems in the life sciences (health, agriculture) even as the decline of biodiversity continues apace. [21] [1] The management of this global resource is particularly problematic on account of the fundamental asymmetries regarding it. Some parts of the world are highly endowed with biodiversity (here, the "South") while others have very little (the "North"). The asymmetries exist throughout the research and development (R&D) industries relying upon these resources. The North is relatively well-endowed with the human capital required for technological innovation, and most of the R&D sector is physically located there. [31] Finally the domestic institutions relating to these capital endowments are very different, with clear property rights institutions in most forms of capital but few in regard to biodiversity.[2]

These asymmetries across endowments, industries and institutions result in an unbalanced bargaining process in which each party is negotiating from a position of relative strength in some respects, and abject weakness in others. So, this is the core of the biodiversity bargaining problem (BBP). While both North and South must combine inputs to generate the cooperative surplus, some means of compensating the respective contributions must be agreed in order to sustain the cooperative solution. The solution to the BBP requires the agreement upon an international institution that generates the *efficient* solution while implementing a *fair* distribution. Without solving *both* aspects of the BBP, efficiency and fairness, a lasting solution cannot be achieved.

To demonstrate this we use cooperative bargaining theory to characterise the *biodiversity bargaining problem* (BBP) between North and South. This characterisation makes plain

[1] It is recognised that genetic resources will likely play a crucial role in supplying the solution concepts within the life sciences industries. [17] [11]. Biodiversity does this by supplying genetic resources to R&D sectors supplying the life sciences industries. [25]

[2] What complicates this mutual interdependence between North and South is the specialised and sequential nature of the R&D process within this industry. It is only the South that contains the genetic inputs required for the R&D process. It is only the North that contains the expertise to convert these into the protected intermediate goods (patented products) that contain these valuable genes. Although both North and South may then use the intermediate goods to advance production and welfare, it is the North that appropriates the value of the R&D process through its exclusive rights in the intermediate goods. This vertical structure to the R&D industry renders the industry susceptible to the "hold up problem" and makes it difficult to coordinate the activities of the parties concerned. [26] There is little doubt that cooperation is important, but there is little within the nature of the problem that suggests the specific nature of an agreeable solution.

that, while the pursuit of the joint gains from cooperation explains the existence of these international institutions, it does not explain the specific division of the cooperative surplus between North and South. We demonstrate here that there are many possible efficient and feasible solutions to the biodiversity bargaining problem, and that all of these lie on the bargaining frontier. We discuss how theory indicates that the actual outcome of this process should hinge on essential characteristics of the bargainers, such as: a) the potential pay-offs in a state of conflict; and b) the bargaining power of each party that is relevant to the production of the cooperative surplus.

Our discussion then turns to the role of contracting in the implementation of solutions to the BBP. We find that there is an equally wide range of efficient contract types that can implement feasible outcomes. Then we turn to the contractual forms in use in the context of the BBP - the *incremental cost contract*. We demonstrate that this is a solution of the form of an extreme point contract, representing an extreme choice regarding the division of cooperative surplus. It is difficult to rationalise the choice of this form of contract by reference to the asymmetries within this particular bargaining problem. In short, our analysis indicates that the solution concept employed to address the BBP is efficient but unfair - in terms of Nash bargaining theory.

This leads us to examine the sorts of responses available to the South, when an unfair division of surplus is imposed by contract. That is, how can the South exercise its bargaining power when the proposed outcome does not recognise it? We examine this in the context of Nash's model of variable threats, demonstrating how residual bargaining power is able to alter the terms of agreement. Our analysis leads us to predict that the rational response of the South to the incremental cost contract is to threaten the further destruction of biodiversity resources. We find that an efficient contract that fails to recognise the inherent contributions of individual agents is unstable, and predict that a lasting solution will be based upon the essential contributions of the parties.

In sum, the specific contributions of this paper are threefold. One is to apply cooperative bargaining theory within the biodiversity context, demonstrating the bargaining frontier and the wide range of efficient contracts available for attaining it. The second is to use the insights of bargaining theory to characterize the observed incremental cost contract as an extreme point contract, and to demonstrate the division of surplus that this represents. Thirdly, by extending the bargaining situation to include the use of 'rational threats' [23], the paper shows that the existing contractual terms can be explained as an outcome of the BBP, but an unlikely long-term solution.

The paper proceeds as follows. In Section 2 we present a basic model of biotechnology, R&D and land use in a North-South world and describe the bargaining problem between a 'technology-rich' North and a 'gene-rich' South. Section 3 considers the BBP as a Nash Cooperative Bargaining Game between North and South, and indicates the factors determinative of the cooperative solution within this framework. Section 4 turns instead to a more positive approach to the BBP, by examining the contractual approaches actually in use to implement efficient solutions of the problem. In Section 5 we turn to the possible conflict between the solution concepts outlined in the previous two sections, and how this conflict might be resolved. We discuss the role of strategic threats in moving the solution concept in section 4 nearer to the solution concept described in section 3.. The conditions for the existence of rational threats are established and illustrated. Section 6 discusses the importance of efficiency and fairness in implementing long-term solutions to global problems.

Section 7 concludes.

# 2 The Biodiversity Bargaining Problem (BBP)

We commence our discussion by setting out a Nash cooperative bargaining model that incorporates the manner in which North and South must cooperate in order to generate joint surplus. We set this out as a world in which both agents have inputs that are essential to the production of the surplus, but where each is capable of a much-reduced level of production when operating on its own. The world of autarky (or conficlt) in this model is one in which the South uses its genetic resources to produce agricultural output, but without the technical know-how to translate them into high production agriculture. For the North, conflict represents the situation in which high-technology is available but the genetic resources for supplying it are not. When the North and South elect to cooperate, a high-production agricultural sector is possible in both parts of the world by reason of the combination of the specialised inputs from each. The sole hurdle to cooperation is the agreement on the division of surplus: How much should the South be compensated for the provision of biodiversity Reserves? How much should the North be compensated for the provision of the technology that makes use of these? Here we set this problem out in the form of a Nash bargaining game (NBG).

## 2.1 The Model: Biotechnology, R&D and Land Use

Here we develop a model to explore the nature of Nash bargaining between two very distinctive parts of the world, termed North and South. This is in line with previous models in this context (e.g. [8][19][14][24] ). We stylise these agents as being distinctive in several important respects: capital endowments, industrial structures and land use choices. The asymmetry in capital endowments refers to the relative richness of the North in human capital but poverty in natural (genetic) capital, while the South retains its relative richness in genetic capital but without a very rich human capital base. The differential industrial structure refers to the unique existence of an R&D sector in the North specialised in the production of intermediate goods containing embedded innovations, in contrast to the focus on primary production in the South. The distinct land use choices refer primarily to the South's unique capacity for supplying a biodiversity reserve sector, but also to the fact that the South's alternative land uses include both an intensive agricultural sector that is technology-dependent and a traditional sector which is not; whereas the North's land uses are relatively undifferentiated and involve mainly various forms of modern intensive agricultural production.[3] The biodiversity bargaining problem arises from the dependence of the North on the South for a supply of biodiversity reserves (to maintain an R&D sector), and the dependence of the South on the North for a supply of intermediate goods (to maintain

[3]Not only do we assume that these differences currently inhere, but we also assume that these stylised facts are inalterable, i.e. the South is the only possible source of biodiversity and the North is the only possible source of R&D. This implies that biodiversity losses are irreversible and that existing human capital endowments cannot be significantly altered within the timescale of this analysis

an intensive sector). We now set out the basic assumptions of our model, to make clear the asymmetries on which the following discussion is based.

**ASSUMPTION 1 (Asymmetries in Agents' Endowments):**

The parties engaged in bargaining are two, and are different in several important respects. **The North:** 1) The North has a capital endowment consisting primarily of human capital with a much lower level of natural capital; 2) The North's human capital is utilised within its R&D sector in combination with genetic resources from the South to produce intermediate goods within which innovations are embedded; and 3) The North has no land use choice regarding the retention of genetic resource reserves (as losses of genetic resources are irreversible) but only has choices over different productive uses of agricultural lands, one use employing the intermediate goods from the R&D sector and the other not. **The South:** 1) The South has a capital endowment consisting primarily of natural capital and a much smaller amount of human capital. 2) The South's natural capital consists of reserve lands endowed with diverse genetic resources which produce a flow of information which is useful when embedded within the intermediate goods of the R&D sector of the North. 3) The South's land use choice consists of both reserve retention and two methods of agricultural production, one of which uses the intermediate goods from the North and the other which does not.

We examine the interdependence between these two spheres as a stylised representation of the global agricultural biotechnology industry, in which genetic resources emanating from a 'reserve' sector in the South are the major input into a plant breeding sector situated exclusively in the North. The plant breeding sector relies upon the skilled human capital endowment in the North to undertake research and development activities based upon these genetic resources. This R&D sector produces innovations in the form of new seeds, within which the information from the genetic resources is embedded. These intermediate goods then can be used in intensive agricultural sectors in either the North or South. Of course, the expansion of intensive agriculture in the South is a means by which cooperative surplus might be shared, but it is also in conflict with the objective of retaining maximum amount of genetic resources for the R&D sector. The problem we examine is how the North and South might simultaneously determine land uses and distribute joint surplus within such an asymmetric bargaining environment.

We now describe the details of North-South interaction within this asymmetric environment, and both the centralised and decentralised bargaining solutions to the biodiversity bargaining problem.

### 2.1.1 The North

The North is endowed with basic natural capital (land) but a rich human capital base. The Northern land endowment ($L_N$) represents land that has been cleared of biological diversity and is allocated between two alternative land uses: a technologically inactive and relatively unskilled baseline sector and an intensive and technologically-active agricultural sector. We assume that all land is homogeneous for a given use, so marginal products will be constant. Baseline production in the North produces final output by the application of an unvarying technology to some part of the land endowment. It therefore represents a base-line production sector in the sense that its productivity is not associated with the outcome of the bargaining

process, or any choices made by the South. Production in this baseline sector is represented by the net output function:

$$y_N^b = bl \tag{1}$$

where $l$ is the land devoted to this sector and $b$ is a net productivity parameter[4]. We take final output as the numeraire.

The other productive sector in the North is technologically more active, and reliant upon decisions taken in the South. This "intensive" sector produces final output, $y_N^i$, using seeds, $n$, developed within the R&D sector.[5] The R&D sector operates by combining the North's human capital with the genetic resources from the South to generate productivity-enhancing innovations. The dependence on the South is captured in the assumption that innovations arrive with a probability which is positively affected by the South's choice of the size of the Reserve sector, $R$, in the South. [6] An innovation has the impact of effectively causing a land-augmenting productivity increase in the intensive sector, captured by the function, $\pi(R)$, which pre-multiplies the intensive sector production function. Thus, final output in the intensive sector captures the interdependent/joint nature of production as it is a function of HYVs from the North and Reserves in the South. Intensive production is represented by the net output function[7]:

$$y_N^i = \pi(R)n, \qquad (\pi(0) = b, \pi'(R) > 0, \pi'(0) = \infty, \pi''(R) \leq 0) \tag{2}$$

The land constraint is $L_N = n + l$ and total output is therefore represented by:

$$y_N = \pi(R)\, n + b\,(L_N - n) \tag{3}$$

The costs of R&D are assumed to rise with the quantity of the intermediate output, i.e. $c(x)$, where $c(0) = 0, c'(.) \geq 0, c''(.) > 0$. These increasing costs are attributable to the need to draw larger amounts of skilled labour into the sector at larger scales of production.[8] There is no significant amount of land used in the sector. The R&D sector can supply seed to the South (s) as well as the North so the total quantity of seed produced is equal to: $x = n + s$. We assume that the point of the R&D sector is to increase productivity over the baseline. From Equations (1) and (2) it is clear that when $R = 0$ both the baseline and the

[4] This represents the output net of costs valued in terms of output. This represents a constant returns to scale production technology. The coefficient $b$ can be thought of as a being equal to a value $(e - d)$, where $e$ represents the productivity of land devoted to this sector and $d$ represents the costs. Thus, setting $b = 0$ is the same as assuming a zero profit condition for the baselne sector. It may be instructive to think of this sector as being a capital intensive but low-technology sector, such as "organic food production"; however, the only function the baseline sector serves is to supply a threshhold level of production in the event of conflict with the South.

[5] We assume a fixed 1 to 1 relationship between seed and land, hence the amount of land used in intensive production is equal to n.

[6] The reserves are best thought of as representing traditional landraces in the context of HYVs. A similar interdependence could be discussed concerning tropical forests and the pharmaceutical industry although this would not easily capture the important land-use issues of interest here.

[7] Where $\pi'(.)$ is the first derivative of the function and $\pi''(.)$ is the second derivative with respect to its argument. This notation holds for the remainder of the paper and for other functions.

[8] The relationship between the scale of production and the scale of the required inputs into R&D is well-known in the biotechnology context. This is attributable to the observation that larger scales of use induce a more rapid evolutionary response, and thus hasten technological obsolescence. [11] [12]

intensive sectors are equally productive. However, when $R > 0$ the functional forms ensure that the intensive sector is preferred to the baseline sector over some range, and $l$ is the residual use of land. Lastly, the North can make a transfer payment, $T$ , to the South which may be dependent upon the levels $n$ and $s$ and other variables; so, for example, this transfer might be negative in quantity, and representative of the value transferred by the South for the intermediate good of the North, or positive and representative of the value transferred by the North for reserves in the South.

The utility function for the North represents all sectors and payments and is given by:

$$U_N(n, s, t) = (\pi(R) - b)\, n - c(n + s) - T + bL_N \tag{4}$$

### 2.1.2 The South

The South is endowed with a rich natural capital base and a basic labour endowment. The South is endowed with land, $L_S$. In contrast to the North, this land endowment includes substantial amounts of unconverted 'reserve' land that is rich in genetic diversity. Southern land can be maintained as Reserves with area $R$, or converted to either a traditional sector, $t$, or to an intensive agricultural sector using seed imported from the North, $s$.As above, land is homogenous regarding a particular use, and so marginal productivity is constant.

Production in the traditional sector occurs via a fixed proportions production function based on labour and land and is unaffected by technological innovation. Gross output in the traditional sector is $t$ and traditional production incurs a labour-related cost $k(t)$, (where $k(0) = 0, k'(\cdot) > 0, k''(\cdot) > 0$ as labour is drawn from other parts of the economy such that

the net output function is

$$y_S^t = t - k(t) \tag{5}$$

In the intensive sector, the South benefits from the presence of Reserves, $R$, in precisely the same way as the North in that productivity is augmented by the arrival of intermediate goods from the R&D sector. The joint nature of final output from the intensive sector is represented by an analogous production function:

$$y_S^i = \pi(R)\, s \tag{6}$$

Southern utility is then given by:

$$U_S(n, s, t) = \pi(R)s + t - k(t) + T, \tag{7}$$

which is maximised with respect to $t$, $s$ and the Southern land constraint: $L_S = R + t + s$, where $R$ is the residual land allocation and the transfer $T$ has the same interpretation as in the North.

This simple model provides each part of the world with a land use allocation problem that exists in isolation (i.e. in the absence of any recognised inter-linkages) and also a much more interesting problem which exists in the presence of this interdependence. This set-up is

intended solely for the purpose of establishing a baseline land use allocation that would exist in each part of the world when acting independently, and another when acting cooperatively.[9]

In the following section we characterise the conflict point of this negotiation and the extent of the cooperative gains.

## 2.2 North-South Conflict and Cooperation

### 2.2.1 The Conflict Point: $(s = 0, T = 0)$

The conflict point provides the benchmark against which all bargaining solutions are measured. Here the conflict point represents an 'Autarky' outcome in that it is characterised by: i) the absence of seed sales from North to South: $s = 0$; and ii) the absence of North-South transfers $(T)$. Consequently the South fails to internalise the value of reserves $(R)$ and there is an under-supply of this global good. Under these circumstances the problems of the North and South are as follows[10]:

**THE SOUTH:** The South maximises utility with respect to $t$.

$$\max_t U_S(s = 0, T = 0) = t - k(t) \tag{8}$$

$$s.t. : L_S = t + R \text{ and } 0 \leq t \leq L_S \tag{9}$$

If $k'(0) \leq 1 < k'(L_S)$, the South's optimal use of land under Autarky, $t^a$, will be an interior solution and satisfy the first order condition:

$$1 - k'(t^a) = 0 \tag{10}$$

Let $R^a = L_S - t^a$ be the South's Reserves under Autarky.

**THE NORTH:** The North takes the behaviour of the South as given and maximises utility over its choice of $n$ and $l$. The North's problem is as follows:

$$\max_n U_N(s = 0, T = 0) = (\pi(R) - b)\, n - c(n) + bL_N \tag{11}$$

$$s.t. : 0 \leq n \leq L_N \tag{12}$$

[9] Specifically, it is assumed without any real loss of generality that the only sectors with rising marginal costs are the intermediate goods sector in the North and the traditional agriculture sector in the South. These assumptions serve no purpose other than to provide a determinant solution to the baseline problem in each region, i.e. the optimal choice of each region if acting in isolation. In order to provide such a solution, rising marginal costs are assumed to inhere in the labour markets of that sector where production is most labour-intensive (R&D in the North, traditional agriculture in the South). This supplies the conflict point from which the analysis is initiated, but there are no other implications that flow from this assumption.

[10] We assume that the North and the South are single entities. This reflects the idea that the countries in the South are sufficiently large to influence the North in the bargaining solution.

If $c'(0) = 0$ and $c'(L_N) > \pi(L_S)$, the North's optimal land use, $n^a$, will be an interior solution satisfying the first order condition:

$$\pi(R^a) - b - c'(n^a) = 0 \tag{13}$$

This Autarky problem shows the interdependence of North and South, in that the North is dependent upon the South's selection of reserves to generate productivity in any intensive sector, while the South has no reason to supply reserves in the absence of a flow of intermediate goods from the North. For this reason, the South in Autarky maximises production in its traditional sector, which serves to lower the marginal productivity of the North's intensive sector $(n)$.

As either region always has the opportunity of production in isolation, the Autarky solutions will constitute the Conflict Point in any bargaining game over land use and distribution [11]. Furthermore, we characterise the the Autarky solution by the land allocations and payoffs $(t^a, R^a, l^a, n^a)$ and $(U_S^a, U_N^a)$ and describe it as an 'interior solution' whenever $R^a, t^a, l^a, n^a > 0$ .

### 2.2.2 First Best (Social Planner) Allocation

The social planner problem involves the maximisation of global surplus with respect to the land allocations $n, s$ and $t$. The problem can be stated as follows:

$$\max_{n,s,t} U(n,s,t) = U_S + U_N = \pi(R)(n+s) - bn + t - c(n+s) - k(t) + bL_N \tag{14}$$

$$s.t.\ R = L_S - s - t \text{ and } l = L_N - n$$

$$\text{and } s, n, t, l, R \geq 0$$

A complete characterisation of the optimal solution is unnecessary for our purposes, however Proposition 1 provides an analysis of the comparative statics of the optimal and Autarky solutions.

**PROPOSITION 1**: If the Autarky solution is interior, and the social planner wishes to hold positive levels of Reserves ($i.e. R^* > 0$) then:

a) intensive agricultural production will always be positive, i.e. $(n^* + s^*) > 0$;

b) optimal traditional production in the South will be less than under Autarky, (i.e. $t^* < t^a$);

c) whenever there is intensive production in the North, the optimal Reserve sector increases with global intensive agriculture

(i.e. $R^* > (<) R^a \Longleftrightarrow n^* + s^* > (<)\, n^a$); and

d) if profits are equal to zero in the baseline sector ($b = 0$), then $s^* > 0$ only when $n^* = L_N$.

[11] Welfare in the South under autarky, $U_S^a$, is defined as $U_S^a = t^a - k(t^a)$, and welfare in the North is defined by $U_N^a = (\pi(R^a) - b)\, n^a - c(n^a) + bL_N$.

**PROOF**: Whenever $L_S > R^* > 0, \frac{\delta R}{\delta S} = \frac{\delta R}{\delta T} = -1$ and the first order Kuhn-Tucker conditions yield:

$$s^* \geq 0 : \pi(R) - \pi'(R)(s^* + n) - c'(n + s^*) \leq 0 \tag{15}$$

$$n^* \geq 0 : \pi(R) - b - c'(n^* + s) \leq 0 \tag{16}$$

$$t^* \geq 0 : 1 - \pi'(R)(n + s) - k'(t^*) \leq 0 \tag{17}$$

with the inequalities in Eqns (15) and (16) strict equalities whenever $l^* = L_N - n^* \geq 0$.

Hence the proof follows in parts: a) From Equation (17) if $(n^* + s^*) = 0$ then $t^* = t^a$ and so $R^* = R^a$. Comparing Equations (13) and (16) when $R^* = R^a$, we have that $(n^* + s^*) = n^a > 0$, which is a contradiction; b) If $t^* = 0$ then $t^* < t^a$ by assumption. If $t^* > 0$ then $1 - k'(t^*) = \pi'(R^*)(n^* + s^*) > 0 = 1 - k'(t^a)$ , thus $t^* < t^a$ as $k''(.) > 0$; c) Comparing Equations (13) and (16), if $n^* > 0$, then $n^* + s^* > (<) n^a \Longleftrightarrow R^* > (<) R^a$; d) Given $b = 0$, comparing Equations (15) and (16); $n^* < L_N \Longrightarrow s^* = 0$ and therefore $R^* > R^a$.

Proposition 1(b) shows that the optimal size of the traditional sector in the South is smaller than under Autarky, however 1(c) shows that the overall level of Reserves will rise and fall with the size of the global intensive sector. How the socially optimal allocation compares with the Autarky state will depend upon the parameters of the model, particularly the relative productivity of the baseline sector in the North and the traditional sector in the South. A low value for $b$ increases the likelihood that the socially optimal level of Reserves is higher than under Autarky.

Proposition 1(d) shows that in the extreme case where the profits from the baseline sector are equal to zero ($b = 0$) the ambiguity is resolved and $R^* > R^a$ whenever the North's baseline sector remains active. In sum, the social planner is reluctant to have intensive agriculture in the South due to the loss of socially valuable Reserves this land use would entail, and where $b = 0$ the social planner would choose for each region to specialise in its own function for agriculture: intensive production in the North and Reserves in the South. Specialisation here is the result of the fact that only the South can provide Reserves while the value from intensive production may be pursued in either region. Although both are necessary for the production of joint surplus, under these conditions the emphasis is on the South providing that which only it can provide (i.e. Reserves).

This is indicative of the importance of cooperation in this context: when acting separately each pursues a similar mix of relatively unproductive activities, when acting cooperatively the two generate a vertical industry in which the South specialises in Reserves and the North specialises in final production. The incentive to cooperate is found in the enhanced productivity emanating from the industry. We turn now to defining the level of that cooperative surplus.

### 2.2.3 The Cooperative Surplus and the Bargaining Frontier

Defining optimal welfare under the social planner solution by $U^* = U_N^* + U_S^*$ allows us to define the extent of the social gains from cooperation, $U^C$, as the difference between the welfare under the social planner and that under Autarky:

$$U^C = U^* - (U_N^a + U_S^a) \tag{18}$$

Clearly, as the social planner is always able to select the Autarky outcome, $U^C \geq 0$. From Proposition 1, when the Autarky solution is interior then $t^* < t^a$ and it follows that the inequality is strict - so there exist strictly positive gains from cooperation.

Figure 1 shows the Autarky and optimal outcomes. $U^*$ is any point on the welfare frontier. $U^a$ is the conflict point. The set of efficient distributions is termed the bargaining frontier, since the parties are able to achieve any point along this frontier so long as they can agree on which point they wish to attain. Although the Social Planner is not concerned with the distribution of cooperative gains from biodiversity preservation, a system of lump sum transfers ordered by the Social Planner can facilitate any desired distribution.

[INSERT FIGURE 1 ABOUT HERE]

Now that the nature of the biodiversity bargaining problem has been established, the indeterminacy of the solution is obvious. Each one of the points along $U^*$ can be sustained as the Nash Equilibrium of a cooperative bargaining game. Choosing among these Nash equilibria depends upon the specifics of the bargaining process: the individual characteristics of the two agents and the institutions that determine their interaction. We turn now to the theoretical solutions to this problem and then to their relation to existing contracts/institutions.

# 3 Nash Cooperative Bargaining Solution to the BBP

Now that we have laid out the fundamental structure of the biodiversity bargaining problem, we can move towards a discussion of how the resolution of this problem might be selected. To this end we first illustrate the family of solutions to a conventional Nash Cooperative Bargaining Game. In Nash cooperative bargaining theory, there are primarily two determinative charactertics of the outcome to any bargaining game: a) the parties' respective conflict points; and b) the parties' respective bargaining powers.

In this section we describe the Nash Bargaining Solution, and discuss the way in which we would expect the parties' attributes to determine an outcome in the context of the BBP. In short, we would anticipate that the conflict points for the parties would each reflect the losses occasioned by the failure to make use of the other's asymmetric endowments. In terms of bargaining power, it is difficult to predict the outcome of the bargaining process although it is clear that every efficient outcome is feasible.

## 3.1 Nash Bargaining Solution

The solution concept developed by Nash is based in the axiomatic approach to bargaining, which consists of the application of several axioms of individual and joint rationality in order to separate out between the set of joint options that are consistent with those axioms, and those that are not. [13] These axioms include: a) IIA - the irrelevance of independent alternatives (irrelevance of options that are not preferred to the conflict point); b) pareto optimality or joint rationality - best outcomes from the set of jointly available options.

The axiomatic approach to bargaining does not indicate a specific solution, but simply separates between the set of feasible options consistent with the assumed axiomatic behaviour. Any point on the bargaining frontier can be the solution to an asymmetric fixed threat Nash Bargaining Game (NBG). This approach simply indicates the set of outcomes that may be eliminated from consideration if certain basic axioms of rationality are to be enforced. It focuses attention on the bargaining set - the set of options preferred to the conflict points - and utlimately on the bargaining frontier - the maximum attainable outcomes in the bargaining set.

Nash proposed a solution concept that would select a single outcome on the bargaining frontier. In order to do so, he hypothesised that specific characteristics of the bargaining agents would contribute to their capacity to capture a share of the surplus, assuming an outcome along the bargaining frontier. These relative "bargaining strengths" would then determine the share of cooperative surplus acquired by each agent in the game.

The general form of the Nash solution to a NBG is a point $(U_N, U_S)$ which maximises:

$$(U_N - U_N^a)^\alpha (U_S - U_S^a)^{(1-\alpha)} \text{ s.t. } U_N + U_S = U^* \tag{19}$$

where $\alpha \in [0, 1]$ denotes the relative bargaining strength of the North. The solution gives $U_N^* = (1-\alpha)U_N^a + \alpha(U^* - U_S^a)$ and $U_S^* = \alpha U_S^a + (1-\alpha)(U^* - U_N^a)$ [23].

## 3.2 Application: Nash Cooperative Bargaining Theory and the BBP

This section has demonstrated that the division of the cooperative surplus is not determinate within the structure of the bargaining game as set forth above. The entire range of efficient solutions remains possible, depending upon the structure of the bargaining process and depending upon the relative bargaining power of the parties within the process. Nash bargaining theory is indeterminate of an actual specific solution, but merely indicates the set of outcomes that are inconsistent with assumptions regarding rational behaviour.

Despite this inconclusiveness, according to Nash cooperative bargaining theory, the solution to a NBG will depend upon the relative bargaining power of the two regions and the parties' respective conflict points. Bargaining power may derive from many factors that are characteristic of the agents, including differences in physical endowments. These physical and institutional factors determine relative bargaining power and hence the respective shares achieved by the parties within an efficient bargaining process.

As we have described the parties to the BBP in Assumption 1, it is clear that each of the bargaining agents, North and South, has some important characteristics which it brings to the NBG. Although it is unclear what the precise outcome would be, it would be expected that rational bargaining behaviour would drive the outcome out towards the bargaining frontier and toward an allocation consistent with the respective contributions that the agents bring to the bargain. This sort of outcome would seem to be consistent not only with basic axioms of rationality in bargaining, but also with basic conceptions of fairness in the recognition of contributions to joint production. In the next sections we turn to look at why this might be the case.

# 4 Contractual Approaches to the BBP: Efficient and Incremental Cost Contracts

In this section we turn to a positive approach to the BBP, and examine how the actual implementation of a solution to a NBG might take shape. The outcome of a NBG will require the conclusion of some sort of a contract between N and S, and the agreement of its terms. This contract will then specify the precise point within the NBG that is agreed to be the implemented outcome. In this section we set out the class of contracts capable of determining a NBG.

We then look at what has in fact occurred within the context of biodiversity negotiations: What has been the outcome of the BBP? We wish to compare and contrast the observed outcome with the theoretical prediction from Nash bargaining theory. We will show that the outcome of the BBP appears to lie on the bargaining frontier, as predicted, but is representative of bargaining power distribution that appears unlikely to be the case. This disjunction between theory and reality is then something that we discuss later in this section.

## 4.1 Contractual Solutions to the BBP

Proposition 2 describes a general contract that could uphold any solution to an asymmetric NBG.[12] The following contracts contain lump-sum transfers to satisfy participation contraints and to uphold the contracted division of surplus:

**PROPOSITION 2 - GENERAL CASE**
**(Optimal Contracts for solution of the BBP)**:

General (N to S): If framed as an offer by N to the S, the optimal contract to uphold an asymmetric Nash bargaining solution would have North specify the contractual terms $s^*$ and $n^*$ and the transfer:

$$T_N(t) = \int_t^{t^a} [1 - k(z)]\, dz - \pi(L_S - s^* - t)s^* + (1-\alpha)\, U^C$$

**PROOF:** See Appendix 1.

Proposition 2 shows the general nature of the contract which specifies the asymmetric Nash solution to the bargaining game, depending on the prevailing distribution of bargaining power, $\alpha \in [0,1]$. This general form of contract which happens to be framed as an instance in which the N makes the offer to the S has three components. The first component compensates the South at the margin for choosing values of $t$ other than $t^a$, the second represents a transfer of surplus to the North (reflecting the idea that the residual rights lie with the party offering the contract, here the North). Together these terms ensure that the South is indifferent to any choice of $t$, including $t^*$, and push the South back to its autarky level of welfare.

[12] Within this framework, the party making the offer of the contract holds the residual rights to the cooperative surplus. In this example, that agent is assumed to be the N but the analysis is the same should the contract be structured as an offer from the S to the N.

The last term represents the sharing of cooperative surplus induced by the relative power distribution. Depending upon that power distribution, any point along the bargaining frontier is a possibility.

We turn now to define the special cases in which either one party or the other is able to capture the entirety of the cooperative surplus - this is the definition of the extreme point contract for the solution to the cooperation problem. The most extreme possibility is that there is no sharing of cooperative surplus within the bargaining game. Contracts supporting distributions that correspond to the limits of the bargaining frontier, in which one party is devoid of all bargaining power, are described as *extreme point contracts*. Such contracts must satisfy the participation constraint: the contracted payoff must be greater than or equal to the conflict payoff $(U_S^a, U_N^a)$. More generally, optimal contracts may be designed that will support any distribution of the surplus that meet or exceed the participation constraints of the parties.

**PROPOSITION 2 - SPECIAL CASE**
**(Extreme Point Contracts for solution of the BBP):**

a) Extreme Point (S to N): The optimal contract when the North has no bargaining power is for the South to specify the contractual terms $n^*$, $s^*$ and $t^*$ and the transfer:

$$-T = T_S(n,s) = [\pi(R^*) - b](-n) + c(n+s) + [U_N^a - bL_N]$$

where $R^* = L_S - s^* - t^*$.

b) Extreme Point (N to S): Inversely, the optimal contract when the South has no bargaining power is for the North to specify the contractual terms $n^*$ and $s^*$ and the transfer:

$$T = T_N(t) = \int_t^{t^a} [1 - k'(z)]\, dz - \pi(L_S - s^* - t)s^*$$

**PROOF**: See Appendix 1.

The outcomes identified here may be related once again to the basic BBP structure set forth in Figure 1. Proposition 2(a) states that the extreme point contract offered by the South will specify $\left(U_S^E, U_N^a\right)$ in terms of Figure 1. Proposition 2(b) states that the extreme point contract offered by the North will specify $\left(U_S^a, U_N^E\right)$. Each extreme point contract is optimal in the sense that it allows the agents to attain the bargaining frontier, but each merely compensates the party receiving the offer for the costs of its participation. These extreme point outcomes may result from the bargaining process where all the bargaining power resides in either the North or the South, respectively.[13] Alternatively, it is also possible that the extreme point outcome may result from a procedure independent of bargaining power. This may occur where the identity of the party making the offer of the extreme point contract is determined by some institutional or structural factor, that pre-determines the contractual outcome in advance of the bargaining process. This is the case, for example, if the identity of the party able to give the first offer - the first-mover advantage - is determined by structural reasons from outside of the bargaining process. This does not obviate the bargaining power

[13]. To see an example of this for the Nash Bargaining outcome see Example 1 and evaluate (19), below, and the welfare outcomes for $\alpha = 1$ and $\alpha = 0$.

of the second-mover, it merely makes it irrelevant to the outcome of this particular bargaining process.

## 4.2 Application: Incremental Cost Contracts as Extreme Point Contracts

This section has outlined the range of efficient contracts available to implement the solution to the BBP. The general case outlined in Proposition 2 indicates that any outcome may be implemented efficiently. The mechanism for paying for these inputs could be of the nature of a property rights solution. [27] Or it could be of the nature of some sort of global fund.[14] It might also be some agreed formula for contractual compensation - such as the concept of "incremental costs" used under the terms of the Convention on Biological Diversity (CBD) and its financial instrument the Global Environment Facility (GEF). In any event, any solution concept must address the fundamental bargaining problem outlined above.

What are the contractual terms that have emanated from the actual attempts to resolve this global bargain? In the case of biodiversity, these terms are found in the CBD and its supporting financial mechanism, the GEF. These international environmental agreements established the framework within which the North and South agreed that biodiversity should be provided as a global good, and further established the basis for determining how states providing biodiversity should share in the benefits of the global public good they provide. Implicit within the terms of the CBD is the idea that the South must provide much of the biodiversity resource, and the focus of the agreement is the means by which they will be compensated for doing so - the answer to which is found in the concept of *incremental costs [IC]:*

> '[the North] *shall provide new and additional financial resources to enable* [the South] *to meet the agreed full incremental costs to them of implementing measures which fulfil the obligations of this Convention*'. [Art. 20, CBD].

The meaning of the term "incremental costs" is further defined within the founding instrument of the GEF as:

> '[the costs of] *additional national action beyond what is required for national development [the baseline] that imposes additional [or incremental] costs on countries beyond the costs that are strictly necessary for achieving their own development goals, but nevertheless generates additional benefits that the world as a whole can share ...*"[15]

[14] Recently an additional international instrument: the International Treaty on Plant Genetic Resources for Food and Agriculture came into force. Its future impact is unclear since i) important countries (e.g United States, China and Brazil) have not signed or ratified and; ii).key mechanisms of the Treaty, (e.g. the financing mechanism) have not been defined. The TRIPS agreement is not silent on this issue either. Section 27(b) extends intellectual property rights to lifeforms and genetic material, and encourages sui generis property rights systems for traditional knowlege and indigenous flora and fauna.

[15] GEF/C.7/Inf.5: para.2 & GEF/C.2/6 para.2, see [18]

Thus, the terms of the agreements establishing the CBD and the GEF impose an obligation on those states hosting biodiversity to supply it for the global good, and dictate that the North shall share the benefits of such public goods with the South *by paying the amounts required to compensate it for the costs of its* participation.

It is clear that, in the language of the BBP, the IC contract requires the North to compensate the South for the additional costs it incurs by electing the cooperative development path (choosing $t^*$) rather than its baseline development strategy (choosing $t^a$). There is no allusion to or provision for enhanced sharing by the South in the cooperative surplus by reason of this election, but only provision for the compensation of its costs incurred to "..generate additional benefits that the world as a whole can share." The South will of course obtain its share of this cooperative surplus, but the contract does not provide for any enhanced share in exchange for its cooperation, nor does it condition payment on the level of the South's Reserves.[16] The IC contract does not bear any of the hallmarks of the contract that would be anticipated to arise out of the NBG. Instead, the IC contract is a straightforward offer of the extreme point contract, in which the North offers the South compensation for its costs incurred in participating in the cooperative outcome. The puzzle of this NBG is how such an unanticipated outcome could result from this sort of bargaining problem. We turn now to analyse the repercussions that are likely to arise from selecting this particular contractual outcome.

# 5 Nash Bargaining with Variable Threats: Strategic Destruction

The description of the BBP, and the asymmetries that it embodies, point to the unlikely nature of the observed contractual solution: the incremental cost contract. This, albeit efficient, solution can only derive from either a complete absence of bargaining power on the part of the South, which seems unlikely given the unique and irreversible options it brings to the bargain, or from complete control of the contracting procedure on the part of the North. The discord between underlying realities of the BBP and the incremental cost contract, begs the question: does the incremental cost contract represent a lasting solution?

To answer this question we examine the rational responses of the South to the North's imposition of an efficient but unfair contract. We examine how the South might employ threats to dislodge itself from such a contract and focus the bargain on alternative solutions. Even in this simple framework it is possible to show that if residual bargaining power in the South has been overlooked in the contracting process, then the incremental cost contract may not be a lasting solution to the BBP. In short, the analysis shows that imposed contracts are likely to be temporary solutions if they are inconsistent with the underlying realities of the situation.

[16] Elsewhere in the CBD there are provisions for benefit-sharing that provide for sovereignty over national genetic resources and prior informed consent for making access to and use of these resources. We deal in companion papers with the issues surrounding the use of property rights mechanisms to distribute the cooperative surplus. (Groom et. al. 2006; Sarr and Swanson 2006) Suffice it to say that we do not find that these provisions make any significant impact on the contractual outcome observed here.

## 5.1 Rational Threats in the BBP

We use the concept of rational threats, first analysed by Nash [23] to model how bargaining power might be exerted.[17] One feature of many solution concepts to bargaining games, including the NBG, is that the value received by one player (e.g. $U_i^*$) is not only increasing in the value of any outside option available to that player ($U_i^a$) but also increasing in the maximum value of cooperation to the *other* player $\left(U_j^* - U_j^a\right)$. The power this confers can be readily observed in the solution concept above. Any actions available to one player that increase the value of cooperation to the other player,[18] without reducing their own outside option, increase the payoffs to that player within the cooperative bargaining game. A viable strategy can then be issued as a "threat" which is the basis for more power within the cooperative game.

But how is bargaining power of this type distributed in the BBP? Our portrayal of a 'gene rich' South and a 'technology rich' North is one of specialised yet interdependent regions. At first glance it would appear that the asymmetric endowments would result in equivalent and reciprocal threat capacities: the North could threaten to reduce R&D while the South could threaten to limit the supply of Reserves[19], resulting in no real bargaining advantage. However, this ignores the question of credibility. In any application of the NBG parties must be able to commit to their threats, via irreversible actions[20]. One obvious means of making a credible commitment is for the party concerned to threaten destruction of the required assets, should the parties fail to reach agreement on the basis for cooperation. Here there is a clear asymmetry in bargaining capacities: the South can credibly threaten destruction of its environmental resources, but the North cannot credibly threaten to destroy human capital. Furthermore, the assumption of irreversibility means this threat contains a 'natural' commitment mechanism. In short, the asymmetry in capital endowments means only the South can satisfy the necessary conditions for a credible threat in the BBP.

While it has been noted in other contexts that destruction of resources can be used to secure bargaining power,[21], what can strategic destruction mean in the context of biodiversity? For concreteness, strategic destruction of Reserves can be understood as a literal threat to destroy resources, as witnessed in Latin America [33] and discussed in relation to fisheries [6], or as the static representation of a threat to allow ongoing and irreversible land conversion in the absence of cooperation. In the confines of the model we model this as a strategic threat to destroy Reserves, R. The next section examines the consequences of overlooking the South's residual bargaining power for the North-South bargain.

[17] More generally, rational threats imply that prior to negotiation of the bargaining solution, parties can *commit* to actions to be played in the event that bargaining fails and by manipulating the conflict point in this way affect the terms of the agreement in their favour. In short, commitments are not made because the agents are interested in the conflict payoffs themselves, but rather in the effect of these strategies on the final bargaining outcome. This realisation has important implications for our understanding of the BBP by alerting us to the prospect of strategic behaviour in the search for a solution.

[18] Or, equivalently, increase the costs of disagreement.

[19] Parallels can be easily drawn between this type of threat for the North and the trade restrictions and limitations on technology transfer that have been the focus of the strategic trade literature (e.g. [19], [20])

[20] Whereas the original stylised exposition by Nash [23] involved an imaginary 'umpire' to ensure the credibility of the threats, any application of this model requires that the threats are credible.

[21] The possibility of incentives for strategic destruction of environmental resources has also been highlighed by Copeland [6] in the context of international fisheries management. Furthermore, [2] and [33] also provide examples of destruction threats being issued by bargaining parties.

## 5.2 BBP as an NBG with Strategic Threats of Destruction

We model the BBP as an NBG with variable threats for the South. The variable threats take the form of threats of strategic destruction and are modelled as the permanent loss of land containing Reserves. This implies a reduction in the land available for production: the land endowment ($L_S$), and the level of Reserves ($R$). This makes $L_S$ a strategic variable[22]. Through this lens the BBP unfolds as follows: i) the initial non-cooperative outcome or conflict point is determined as Autarky ($U^a$); ii) the South issues its threat in the form of a land allocation in the event that cooperation fails. This involves a choice of strategic destruction ($D$) and defines a new conflict point $\left(U^D\right)$; iii) the bargaining game is solved by reference to this new conflict point yielding payoffs $U_i^T$, where the superscript refers to threats. Each of these points is illustrated in Figure 2. The credibility of strategic threats requires a commitment mechanism (irreversibility in Assumption 1), *viability* and *autarky independence*:

**DEFINITION 1 (Viability):** A strategic threat is viable if it could be carried out and yet leave the South with a payoff in any subsequent Nash solution no less than it could expect in the fixed threat Nash solution.

**DEFINITION 2: (Autarky Independence)**: A strategic threat satisfies Autarky Independence if it could be carried out and yet leave the Autarky payoff no less than in the fixed threat NBG.

Since Reserves are residual to the South in Autarky, reflecting the informational nature of the goods they supply and the market failure in the Reserves market, autarky independence is guaranteed in the BBP so long as no disproportionate amount of ancillary resources is expended in choosing to destroying Reserves.[23] Assuming cost-neutrality, strategic destruction will not reduce the South's conflict payoff.

The viability condition basically ensures that the South would not 'shoot itself in the foot' in any future bargaining game by committing to destroy reserves. Note that actual destruction would cause the bargaining frontier to move inwards. Given the interdependence of the North and South in the biotech industry it seems unlikely that the South could gain from this exercise, and likely that viability will be an extremely stringent condition. Let $L_S^*$ denote the maximum level of Reserves available to the South, and let $L_S = L_S^* - D$ be the amount of land the South wishes to maintain, where $D$ is the amount of land destroyed. Proposition 3 shows that viability is far from impossible:

**PROPOSITION 3 (Viable Strategic Destruction)**: If cooperative and autarky solutions are interior and autarky independence holds, strategic threats are *viable* in terms of definition 1 if:

$$\pi'(L_S^* - t^a)(n^a) > \pi'(L_S^* - s^* - t^*)(n^* + s^*). \tag{20}$$

**PROOF**: See Appendix 2.

Proposition 3 describes the circumstances under which the South's share of surplus would

[22] We assume that destruction renders land incapable of supporting either Reserves or traditional production.

[23] In this model the primary factor of concern in the South is the land endowment, and in regard to this destruction of reserves is costless. In regard to ancillary resources (such as labour), the activity of destruction is not obviously more labour intensive than other uses of the land (such as conservation), and so the cost-neutrality of destruction is a reasonable assumption.

increase with destruction more than the associated loss of global surplus. It states that strategic destruction is a viable strategy if the social marginal value of reserves increases rapidly as reserves become scarce. Specifically, the marginal value must be higher in autarky than on the bargaining frontier. This seems extremely plausible and can be supported by plausible functional form restrictions.[24]

Viability means that *actual* destruction would increase the benefits of cooperation for the North, therefore increasing the Nash payoff for the South in any subsequent Nash bargaining game. Although destruction is merely threatened in the NBG, viability can be understood by inspection of Figure 3. Here, destruction shifts the conflict point downwards as Reserves are destroyed. Condition (20) ensures that the Nash bargaining solution subsequent to destruction $\left(U_S^{*D}\right)$ lies down and to the right of the Nash solution with fixed threats $(U^*)$ such that: $U_S^{*D} > U_S^*$. Strategic threats would then yield the payoff $U_S^T > U_S^*$.

This section has described an important yet simple mechanism through which the South can bring its residual bargaining power to bear on the problem. The next section examines what this means for the contractual solutions.

## 5.3 Predictions: Contractual Solutions Consistent with Rational Threats

We now wish to examine the how the availability of viable and credible "rational threats" to one side of this bargaining problem, the South, affects the contractual solutions to the BBP. Of interest here are the following two questions: What is the form of the efficient contract? and; what resemblence does this contract bear to other contractual solutions? If the details of the contracts differ substantially under strategic threats compared to fixed threats, this will be an indication that contracts which ignore the South's residual bargaining power will not be long lasting.

Formally, the solution to the problem for each party under strategic threats is now: $U_N^T = (1-\alpha)U_N^D + \alpha(U^* - U_S^a)$ and $U_S^T = \alpha U_S^a + (1-\alpha)(U^* - U_N^D)$, which differs from the fixed threat solution only by the presence of $U_N^D$ : the conflict point for the North under strategic threats (See Figure 2). As above, this solution could be upheld in practice with a contract offered either by the North or the South which includes a lump-sum payment reflecting the bargaining solution agreed under threat from the South. We continue with the North making the offer, to be consistent with the form in which Proposition 3 was expressed. Proposition 4 makes the new contractual form concrete:

**PROPOSITION 4a (The North's contract with strategic threats from South):** Where the BBP is modelled as an NBG with viable and credible strategic threats, the solution

[24] **Example 1 (Strategic Destruction in the BBP)**: Assume the following functional forms: $\pi(R) = R^\delta$, where $\delta < 1$, $c(x) = x^\beta$, where $\beta > 1$ and $k(t) = t^\gamma$, where $\gamma > 1$, and assume that $b = 0$. Then for $L_N$ sufficiently large, destruction is worthwhile to the South if and only if:

$$L_S^* > \left(\frac{1}{\gamma}\right)^{\gamma-1} \text{ and } \beta > \frac{1}{1-\delta} \tag{21}$$

**PROOF**: See Appendix 2.

This shows how viability can depend upon the relative curvature of the seed cost and R&D functions, $c(.)$ and $\pi(R)$ respectively.

can be upheld by a contract in which and the North specifies $s^*, n^*$ and offers the following transfer to the South:

$$T_N\left(L_S, t\right) = \int_t^{t^a} \left[1 - k'\left(z\right)\right] dz - \pi(L_S - s^* - t)s^* + \left(1 - \alpha\right)\left(U^{CD}\right)$$

Where $U^{CD} = U^* - \left(U_N^D + U_S^a\right)$.

**PROOF:** See Appendix 3.

The only difference between this contract and the general contract described in Proposition 1 is in the right hand side term $\left(1 - \alpha\right) U^{CD}$ which contains the North's new conflict payoff, $U_N^D$ rather than $U_N^a$. The difference between the contracts is therefore equal to $\left(1 - \alpha\right)\left(U_N^a - U_N^D\right)$ which measures the increased North-South transfer which is mobilised by the presence of strategic threats. The unique capacity of the S to make a viable and credible threat alters the power distribution in the relationship. The new solution to the BBP (once the threat is taken into consideration) will lie along the same bargaining frontier, but with an increased distribution of the surplus to the S.[25]

The contract clearly differs from the fixed threat contract in its sharing of the cooperative surplus, which is an important finding in its own right. However, a closer look at the details of this contract reveals some more important differences. These are summarised in Proposition 4b:

**PROPOSITION 4b (Payments for the stock of reserves):** The efficient contractual solution with strategic threats must condition on, and compensate for, the stock of threatened Reserves to prevent strategic destruction.

**PROOF:** The term $\left(1 - \alpha\right)\left(U_N^a - U_N^D\right)$, representing the additional North-South transfer can be written as follows: [26]:

$$\left(1 - \alpha\right)\left(U_N^a - U_N^D\right) = \left(1 - \alpha\right)\int_{L_s^D}^{L_S^*} \left[\pi'\left(x - t_a\right) n^a\right] dx \tag{22}$$

This clearly shows that the contract which upholds the Nash bargaining solution with strategic threats is now dependent upon the existing stocks of Reserves through the specification of the interval $L_S^*$ to $L_S^D$. QED.

Specifically, the efficient constract contains a payment for a proportion (determined by $1 - \alpha$) of the spillover from Reserves that the North would receive in Autarky. In order to prevent actual strategic destruction the South simply must be compensated for the stocks of reserves. The details of the contract therefore deviate substantially from the fixed threat contract of Proposition 1 and clearly bear even less resemblence to the IC contract specified in Proposition 2. Because the currently observed incremental cost contract completely overlooks the residual bargaining power of the South in determining the solution, it seems reasonable

[25] This may be conceived of as a physical endowment that contributes to the bargaining power of the S. The addition of this factor occasions a shift in outcome along the original bargaining frontier, which may equally be conceived of as a shift in the power coefficient (from $\alpha$ to $\alpha'$) in favour of the S. Of course, if $\alpha = 0$ strategic threats disappear altogether. But this would represent an unlikely distribution of bargaining power.

[26] In equilibrium the compensation is the integral from $L_S^*$ to $L_S^D$. Once more $z$ is simply the argument of the integral.

to expect that it is unlikely to be a long-run equilibrium to this NBG.[27] Furthermore, one response to this imposed contract is to revert to strategic threats.

[27] The adoption of a particular contractual form that is inconsistent with the existing characteristics of the bargainers raises the question of how such contract-making is possible. We address some possibilities about that here, although the analysis of such bargaining strategies is not at the core of our enquiry.

The distribution of bargaining power between the parties renders the bargaining process within the BBP a place with clear leverage for the South but little obvious source of power for the North. Given that the North has the foresight to see the implications of these asymmetric endowments for the BBP, it may be inclined to circumvent the Nash bargaining agreement altogether by pre-committing to an alternative institution. Pre-bargaining commitments in the resolution of environmental conflicts have been analysed elsewhere in relation to international agreements ([30], [15]). In such cases, irreversible (sunk) capital investments are crucial in determining the eventual terms of the agreement. In the case of the BBP, the nature of pre-commitment is institutional. Specifically, we argue here that the North was able to select and commit to its preferred institutional form prior to bargaining, in order to target contractual terms that are both capable of attaining its preferred extreme point solution and of doing so in such a manner as to nullify the capacity for strategic destruction in the South.

The obvious solution for North is to maximise its payoff by pre-commitment to the extreme point contract of Proposition 2b. This contractual form has the same extreme point nature, as in 2, and so allocates the cooperative surplus to the North; however, unlike the more general contract solution, this contract has the additional advantage of rendering the South indifferent over destruction. So, through commitment, the North is able to attain its first-best outcome while negating the incentives for inefficient bargaining.

How was this accomplished in the case of the BBP? One possibility is that the North might have been able to achieve pre-commitment in this context through the vehicle of the pre-existing institutional commitment to the Montreal Protocol. This international environmental agreement was developed over the decade of the 1980s for the purpose of controlling emissions of those chemical substances with deleterious effects upon the ozone layer. That international agreement was based on entirely distinct initial conditions and endowments, and there was no obvious reason why its solution concept would have any application within the context of the BBP. In the first instance, there was far more symmetry in initial conditions, in that the global public good existed outside any party's territory so that each party had a symmetric interest in its use or destruction. In addition, given the atmospheric nature of the good, the capacities to harm the good were largely symmetric and reciprocal (at least in the medium run). Finally, it was even possible that damage to the atmospheric good was potentially reversible with a halt in ongoing impacts. In many ways the initial conditions and physical endowments regarding chemical industries and ozone depletion generate a bargaining game that could not be more different in its basic nature than the BBG.

Nevertheless, the North managed to pre-commit prior to the BBG to the contractual terms developed within negotiations concerning the Montreal Protocol, as indicated in the GEF audit report. "The application of incremental cost in the Montreal Protocol influenced the development of the subsequent global environmental conventions..." (GEF Evaluation Office, The Evaluation of GEF Incremental Cost Methodologies, December 27, 2005,http://www.gefweb.org/MonitoringandEvaluation/MEOngoingEvaluations/documents/Ongoing_Evals-GEF_Incremental_Cost_Method-Approach_Paper.pdf

The concept of IC was developed within the financial mechanism of the Montreal Protocol (where the text was first written in the mid-1980s and then made effective in 1989) and then extended to the BBP by its express incorporation within the terms of the CBD in 1992 [Art 20 above]. [18] There is no reason in logic for the straightforward extension of one bargaining outcome to a very different context; however, the assertion of the precedential value of this concept for the compensation of global public goods was able to establish the institution as a pre-commitment. Its extension to the BBP represents an institutional pre-emption of the bargaining game that would otherwise have resulted.

# 6 Discussion: Fairness and Efficiency, Threats and Contracts

In this paper we have attempted to narrow down the range of potential contractual outcomes to the biodiversity bargaining problem (BBP), by considering how the asymmetries between the parties (laid out in Assumption 1) might contribute to the determination of a solution concept to the problem. We have found that the range of outcomes on the bargaining frontier is (as always) complete. A NBG provides for the full range of possible outcomes. Nevertheless we have attempted to indicate the factors that determine the likely outcomes, and the characteristics that contribute to the probable outcomes. This has led us to conclude that the observed outcome to the BBP is an unlikely one.

Although both parties make important contributions to the creation of the cooperative surplus, the fact that the endowment (the reserves) of the South is inherently and irreversibly destructible provides the South with a significant bargaining advantage. Since irreversibility is a sufficient condition for a threat to be credible, the South has the unique capacity in this context to shift surplus towards itself.[28] The idea that the South has much of the bargaining power in the BBP is interesting in its own right.

Secondly, the asymmetry in physical endowments indicates the nature of the process by which it would be expected that the South could drive a bargaining process based upon them. It would appear that the South should be able to exercise its unique advantage to drive the bargaining outcome in its favour. In terms of the BBG, we would anticipate that the South would be able to command a substantial share of the cooperative surplus. In addition, as (22) shows, an efficient solution to the BBP would imply that the contractual terms explicitly base compensation upon the existing level of Reserves.

Why is it the case that the current (incremental cost) contract is unlikely to be able to be a lasting one? Consider the bargaining process. One possibility is that the parties engaged in bargaining, and that the North offered these terms of contract in the context of the NBG. The problem with this explanation is that the South has the option of destruction, once bargaining has commenced, and destruction is a possible outcome in the face of an offer that fails adequately to compensate the South for its bargaining position. The offering of contracts of the form shown in Proposition 2c with inadequate sharing with the South, can induce anticipatory strategic destruction by the South. The weakness of this form of contracting is that they are silent on the commitment to any level of reserves. Faced with a contract of this form, when strategic threats are viable (condition (20) holds), the South can commit to (undertake) strategic destruction [29]. Figure 3 illustrates this point. When destruction is viable, payoffs can be increased from $U_S^*$ with fixed threats to $U_S^D$ if anticipatory

[28] It is interesting to note that if the threat is viable (that is, condition (20) holds), then the strategic threats are viable irrespective of the initial bargaining power situation, represented by $\alpha$. That is, even if the bargaining solution without threats significantly favours the South ($\alpha \to 0$), the South will find it viable to employ strategic threats to improve the negotiated payoff. Additionally, where the North has all the initial bargaining power ($\alpha = 1$) the South is indifferent to threatening destruction even if condition (20) does not hold. Ultimately, whatever the initial bargaining power of the North, the South can bring considerable bargaining power, in the form of strategic threats, to the negotiating table.

[29] Given our informational assumptions a contract of this form would not specify $t^*$ and $s^*$ in the final stage of the game, but the optimising values of these land allocations given destruction has taken place. This is reflected by the solution being located on a bargaining frontier that has shifted inwards in Figure 3.

destruction is carried out, despite the inward movement of the bargaining frontier. In short, a naive approach to bargaining by the North within the BBP can induce destruction of Reserves[30].

In contrast, optimal contracts of the form described in Proposition 4 condition payments explicitly on $L_S^*$, the socially optimal level of the South's endowment, hence removing the incentive to destroy. This can be seen by inspection of condition (22). Indeed, when the South is offered such a contract it is indifferent between any choice of $L_S$ and can be easily coerced into choosing $L_S^*$. The interpretation of (22) is also interesting. This implies that in order to uphold the Nash solution with variable threats the North must transfer some fraction of the positive spillover it receives in Autarky. In effect this means that the South must be paid for the stocks of Reserves it would hold in Autarky. This general recommendation accords with findings elsewhere (see e.g. [32]). Figure 2 illustrates this point: Payoffs can be increased from $U_S^*$ with fixed threats to $U_S^T$ where destruction is threatened. In this case the solution is on the efficient frontier at $U^{*T}$, the movement from $U^*$ reflecting the South being remunerated for stocks of Reserves.

In sum, it is unlikely that this extreme point contract can be a lasting result from a bargaining process commencing from the power distribution described in Section 3. Even if the North has the capacity to make the initial offer of the IC contract, it is not a stable outcome of the bargaining game. The South retains bargaining leverage that would imply that outcomes will take a form that take into account its unique endowments. We would expect that the rational threats described in section 5 will in due course move the contractual solution to the BBP nearer to the outcomes described in Proposition 4.

But have we witnessed any such responses from Southern countries? The answer to this is, yes, we have. The most well documented examples concern the Governments of Cameroon and Ecuador. In Cameroon in 2005 the Minister of Forestry, Joseph Thatta, made a clear statement of what the government perceived to be fair share of the cooperative surplus, while effectively redefining the conflict point in the negotiations with international conservation organisations over the Ngoyla-Mintom forest. An annual fee of US$1.6m for 830,000 ha of biodiverse tropical forest was requested to prevent the concessions being sold to logging companies.[31] Rough calculations suggest that the global value in terms of carbon sequestration alone is double the value of the logging concessions, so conservation is on the bargaining frontier.[32] In the absence of any offers, in March 2009 the Government made good on its threat and process of determining forest concessions began. In terms of the bargaining framework, the process appears to be stuck at the conflict point.

Similar threats were issued by President Rafael Correa of Ecuador in relation to the Yasuni National Park at a meeting of the United Nations in September of 2007. Again, the conflict point and the share of the surplus was clearly defined, albeit under different circumstances to Cameroon. The conflict point was defined as the development of the oil fields beneath National Park. The share of the cooperative surplus, arising from leaving oil in the

[30] This is akin to the pre-contractual commitments in the form of sunk capital analysed by Stranlund [30]

[31] See "The price of conservation: the unkindest cut", in The Economist print edition, 14 February 2008.

[32] The 830 000 ha of forest in the Ngoyla-Mintom store over 200 million tonnes of carbon dioxide (assuming a conservative 250 tonnes of carbon dioxide/ha). Assuming conservation reverses the 1% trend in deforestations, and assuming emissions of 160 tonnes of carbon dioxide/ha from logging, at US$3 /tonne of CO2, payments for carbon through the REDD scheme would generate credits with an NPV of US$64 million (over 30 years at 5% discount). This exceeds the US$26 million in logging concession fees (The Economist print edition, February 2008).

ground, included compensation for lost oil revenues from the international community, which resembles the incremental cost component, and carbon credits amounting to the foregone carbon emissions, reflecting a payment for the stock of carbon[33]. This contractual solution bears more than a passing resemblence to the optimal contract under strategic threats. This approach has been more successful than in the case of Cameroon, and has received numerous pledges of finance. Nevertheless, to date the threat remains on the table until sufficient finance is attracted.

Both of these examples represent attempts to dislodge the status quo and certainly represent active use of threats, or at the very least, a laying bare of the structure of the bargaining game. Threats are not the only responses to the status quo that have been witnessed in the realm of biodiversity. The formation of the Group of Like Minded Mega-Diverse Countries (LMMC) represents an alternative means by which to garner bargaining power, dislodge current solutions and improve benefit sharing. In sum, these recent responses support the main finding here, that current solutions to the BBP are unlikely to be long lasting.

# 7 Conclusion

This paper has set out to make three basic points regarding institution-building for global environmental management. First, it is important to begin thinking about global environmental problems as questions of cooperation over the production of joint surplus. The basic problems of biodiversity and climate change have little to do with preventing externalities or with conserving amenities. These are problems dealing with the fundamental notion of the division of the surplus available from certain forms of production. Biodiversity concerns the product available from the life sciences industries. Climate change concerns the product available from fossil fuel based production. A basic problem of global cooperation concerns how the states will agree to divide up the product from these basic industries. These are the basics of bargaining problems. The NBG is the appropriate way to think about these problems.

Second, these problems are made fundamentally difficult by reason of the asymmetries between the states concerned. In the context of biodiversity, the South holds the genetic resource capital while the North holds the vast majority of the human capital. The South has very few property rights over its capital, while the North holds extensive rights over its inputs. The North sells the R&D outputs of the life sciences industries, while the South provides the inputs to it. These fundamental differences mean that institution-building must be directed toward dealing with them. International institution-building is about dealing with these differences in an efficient fashion. It is about finding ways to move toward the bargaining frontier in the presence of these fundamental asymmetries.

Third, the essence of the Nash cooperative bargaining approach is that important differences between the parties must be part of the ultimate solution concept for the bargaining problem. That is, the notion of a fair distribution - that is capable of resolving the bargaining game with finality - will emanate from these essential differences. Any contractual outcome can be efficient, but only in a short term sense. Divisions of surplus that are not

[33] It is estimated that leaving the ITT oil undeveloped would result in permanently sequestering nearly 436 million tons of carbon dioxide in the ground.

based upon the essential characteristics between the parties will provoke a rational response for that characteristic to be recognised. Any lasting contractual outcome will consider the potential for such rational threats, and offer divisions of surplus that incorporate them. This means that efficient contracts offering lasting solution concepts to the NBG will be based upon the characteristics identified within the Nash framework.

In conclusion, the most interesting result obtained here is the observation that global contracts must be based on the real characteristics and real contributions of the bargaining parties. We have shown that, although any contracted outcome on the bargaining frontier is possible, those contracts that fail to anticipate the potential for rational responses will necessarily be short-lived solution concepts. Real bargaining power derives from real differences - those important to the production of cooperative surplus. Contracts chosen on the basis of perceived political power that fail to recognise inherent economic power must fail. What will turn out to be "efficient" (in the form of a long run cooperative equilibrium) will also turn out to be "fair" (in the sense of Nash theory).

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## APPENDICES

### Appendix 1: PROOF of PROPOSITION 1

a) If the South selects output level $t = \widetilde{t}$, the desired output levels $(n, s) = (\widetilde{n}, \widetilde{s})$ and the transfer

$$T_S(n, s : \widetilde{t}) = \left[\pi(L_S - s - \widetilde{t}) - b\right](-n) + c(n + s) + [U_N^a - bL_N]$$

then the North's utility is given by

$$\begin{aligned} U_N(n, s, t) &= (\pi(R) - b)\, n - c(n + s) + T_S(t : n, s) + bL_N \\ &= U_n^a \end{aligned}$$

which is independent of $(n, s)$ . Thus the North is willing to produce at any output levels, including $(n, s) = (\widetilde{n}, \widetilde{s})$ . Of course a small deviation penalty could be included to ensure compliance.

Given that the North will select $(n, s) = (\widetilde{n}, \widetilde{s})$ , the South's problem is to select the values of $(\widetilde{n}, \widetilde{s}, \widetilde{t})$ to maximise

$$\begin{aligned} U_S(n, s, t) &= \pi(L_S - s - t)s + t - k(t) - [\pi(L_S - s - t) - b](-n) - c(n + s) - [U_N^a - bL_N] \\ &= \pi(L_S - s - t)(n + s) - bn - c(n + s) + t - k(t) - [U_N^a - bL_N] \\ &= U(n, s, t) - U_N^a \end{aligned}$$

which, as $U_N^a$ is a constant, is equivalent to the social planner's problem and has solution $(n^*, s^*, t^*)$ as required.

b) If the North selects output levels $(n, s) = (\widetilde{n}, \widetilde{s})$, a desired output level $\widetilde{t}$ and the transfer

$$\begin{aligned} T_N(t \quad : \quad \widetilde{n}, \widetilde{s}) &= \int_t^{t^a} [1 - k'(z)]\, dz - \pi(L_S - \widetilde{s} - t)\widetilde{s} \\ &= [t^a - t] - [k(t^a) - k(t)] - \pi(L_S - \widetilde{s} - t)\widetilde{s} \end{aligned}$$

then the South's utility is given by

$$\begin{aligned} U_S(t &: \widetilde{n}, \widetilde{s}) = \pi(L_S - \widetilde{s} - t)\widetilde{s} + t - k(t) + T_N(t) \\ &= t^a - k(t^a) = U_S^a \end{aligned}$$

which is independent of $t$. Thus the South is willing to produce at any level of $t$, including $t = \widetilde{t}$.

Given that the South selects $t = \widetilde{t}$, the North's problem is to select the values of $(\widetilde{n}, \widetilde{s}, \widetilde{t})$ to maximise

$$\begin{aligned} U_N(n, s, t) &= (\pi(R) - b)\, n - c(n + s) - T_N(t : n, s) + bL_N \\ &= \pi(R)(n + s) - bn - c(n + s) + t - k(t) - [t^a - k(t^a)] + bL_N \\ &= U(n, s, t) - [t^a - k(t^a)] \end{aligned}$$

which, as $[t^a - k(t^a)]$ is a constant, is equivalent to the social planner's problem and has solution $(n^*, s^*, t^*)$ as required.

c) The only difference between the contract in (b) and (c) is the inclusion of a constant term $(1 - \alpha)U^C$ in the transfer payment. A constant transfer payment has no impact on the optimising decisions of the agents, thus the solution remains unchanged from (b).

QED

**Appendix 2. PROOF OF PROPOSITION 2: Strategic Destruction by the South**

Let $U^*(L_S)$ and $(U_N^a(L_S), U_S^a(L_S))$ represent the optimal social planner and autarky payoffs for particular values of $L_S$, with the payoffs to the Nash bargaining solution given by

$$\begin{aligned} U_N^*(L_S) &= (1 - \alpha)\, U_N^a(L_S) + \alpha\, (U^*(L_S) - U_S^a(L_S)) \\ U_S^*(L_S) &= \alpha U_S^a(L_S) + (1 - \alpha)\, (U^*(L_S) - U_N^a(L_S)) \end{aligned}$$

We are interested in finding conditions for $\frac{dU_S^*(L_S)}{dL_S} < 0$ at $L_S = L_S^*$, so that a reduction in $L_S$ improves the South's payoff after the bargaining game.

From the above equations, we have

$$\frac{dU_S^*(L_S)}{dL_S} = \alpha \frac{dU_S^a(L_S)}{dL_S} + (1 - \alpha) \left( \frac{dU^*(L_S)}{dL_S} - \frac{dU_N^*(L_S)}{dL_S} \right)$$

As $\frac{dU_S^a(L_S)}{dL_S} = 0$ whenever $L_S > t_a$, we have that

$$\frac{dU_S^*(L_S)}{dL_S} < 0 \Longleftrightarrow \frac{dU^*(L_S)}{dL_S} - \frac{dU_N^*(L_S)}{dL_S} < 0$$

From Equations (11) and (14), and the Envelope Theorem, for any interior solution we have that

$$\frac{dU^*(L_S^*)}{dL_S} - \frac{dU_N^*(L_S^*)}{dL_S} = \pi'(L_S^* - s^* - t^*)(n^* + s^*) - \pi'(L_S^* - t^a)(n^a)$$

thus

$$\frac{dU_S^*(L_S^*)}{dL_S} < 0 \Longleftrightarrow \pi'(L_S^* - s^* - t^*)(n^* + s^*) < \pi'(L_S^* - t^a)(n^a).$$

QED

**PROOF OF EXAMPLE 1:** From Equation (15) & (16) we have $s^* = 0$ (as $b = 0$) and $n^* = \left(\frac{(L_S - t^*)^\delta}{\beta}\right)^{\frac{1}{\beta-1}} > 0$ when $L_N > n^*$.

Let $\Phi(L_S, t, n) = \pi'(L_S - t)(n) = \delta(L_S - t)^{\delta-1}\left(\frac{(L_S-t)^\delta}{\beta}\right)^{\frac{1}{\beta-1}} = \left(\frac{\delta}{\beta^{\frac{1}{\beta-1}}}\right)(L_S - t)^{\delta-1+\frac{\delta}{\beta-1}}$.

Destruction is beneficial to the South if $L_S^* > t^a = \left(\frac{1}{\gamma}\right)^{\gamma-1}$ and $\frac{d(U^* - U_N^a)}{dL_S} < 0$ at $L_S^*$ .

The last condition requires that $\Phi(L_S^*, t^a, n^a) > \Phi(L_S^*, t^*, n^*)$

$$\Longleftrightarrow \left(\frac{\delta}{\beta^{\frac{1}{\beta-1}}}\right)(L_S^* - t^a)^{\delta-1+\frac{\delta}{\beta-1}} > \left(\frac{\delta}{\beta^{\frac{1}{\beta-1}}}\right)(L_S^* - t^*)^{\delta-1+\frac{\delta}{\beta-1}}$$

given that $t^a > t^*$, this inequality hold iff $\left(\delta - 1 + \frac{\delta}{\beta-1}\right) < 0 \Leftrightarrow \beta > \frac{1}{1-\delta}$

**Appendix 3. PROOF of PROPOSITION 3:** The proof follows that of Appendix 1 only replacing $U_N^a$ with $U_N^D$. Equation (22) holds because $U_N^a = \pi\left(L_S^* - t^a\right)n^a - c\left(n^a\right)$ and $U_N^D = \pi\left(L_S^D - t^a\right)n^a - c\left(n^a\right)$.

**Figures** .

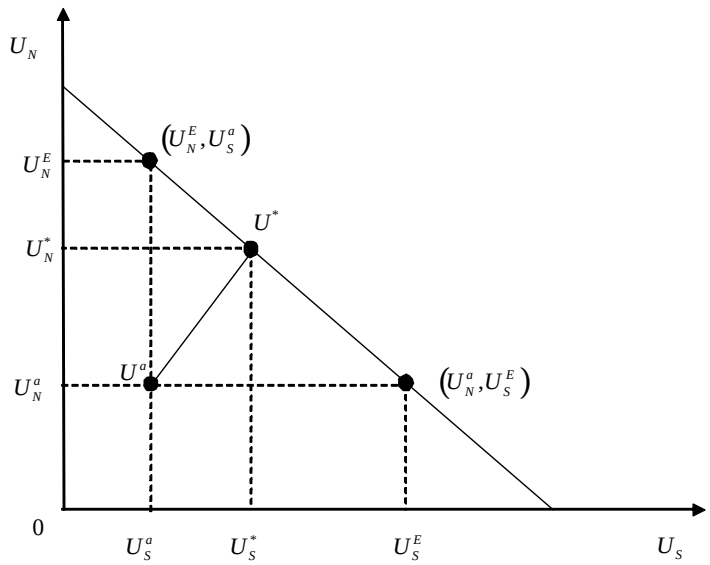


Figure 1: The Fixed Threat Nash BBP.

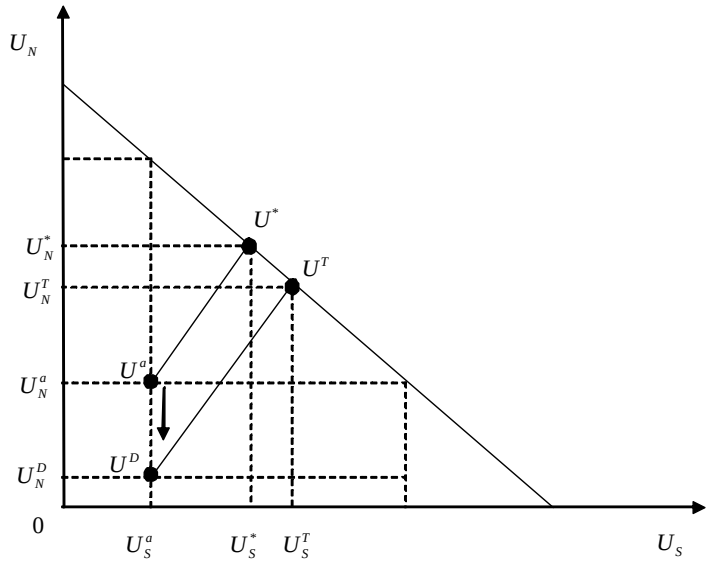


Figure 2: The Variable Threat Nash BBP.

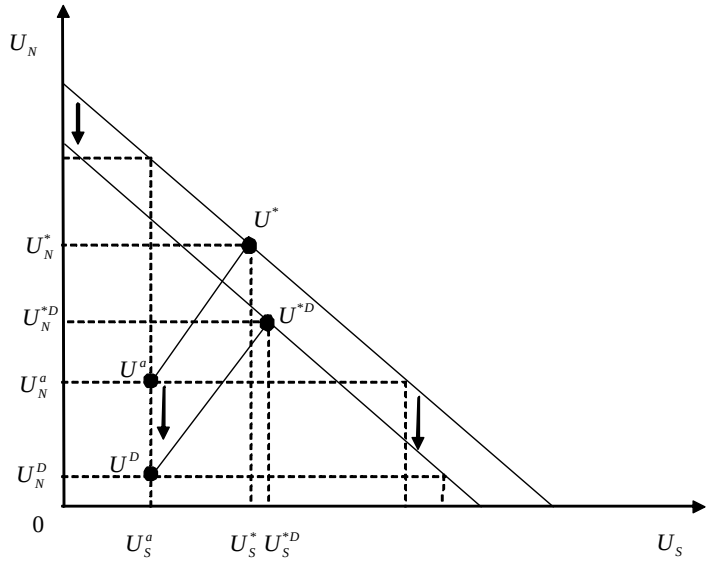


Figure 3: Pre-Contractual Strategic Destruction.