WATER AND MOUNTAINS, UPSTREAM AND DOWNSTREAM: ANALYZING UNEQUAL RELATIONS

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Abstract: This chapter analyzes unequal access to water with a special focus on the Central Asian situation. It emphasizes the crucial issue of property rights and examines what happens when these are distributed in ways that lead to major inefficiencies and conflict. The chapter first presents a game theoretical investigation of this type of conflict situation and then ways in which the conflict might be solved if parties continue having relative risk aversion. In the case of Central Asia this type of solution would lead to mutually beneficial outcomes if credibility problems were lifted by using international institutions to guarantee the observance of contracts that contain prescriptions to share benefits associated with a change in the property rights structure.

Keywords: water, unequal access, property rights, Central Asia, game theory risk preferences

1. INTRODUCTION

Access to water at both the domestic and international levels is often characterized by inequality. Sometimes inequalities stem from different capabilities in terms of wealth and technology. Frequently, however, they are combined with geographical characteristics that give countries and regions differential access to water sources. This is particularly the case with upland-lowland situations, which are often combined with upstream–downstream relationships. The question raised by unequal situations is—as is often the case with natural resources—one of property rights. The issue

E. Wiegandt (ed.), Mountains: Sources of Water, Sources of Knowledge, 283–303.

is ultimately whether “ownership” can be clearly specified or whether users must share the water.

At the domestic level, the answer to such a question is relatively straightforward because in most cases some sort of property rights (or absence thereof) is specified. The problem is more complicated at the international level because there is no unambiguous jurisdiction with power of enforcement that can constrain the behavior of states. Thus power relations and power bargaining will often determine the outcome over a disputed access to natural resources, including water. Nevertheless, even at the international level, states often have established either contractual or customary arrangements over time. New problems in state relations often come about because such relations are questioned under the pressure of new economic or technological developments.

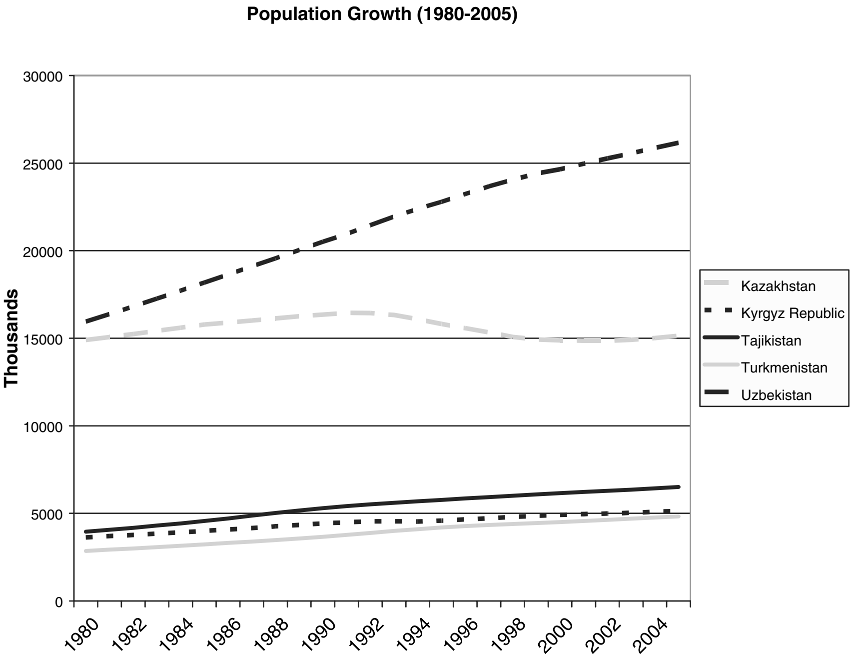
2. THE CENTRAL ASIAN SITUATION

Central Asia provides an emblematic context for addressing these questions because of both the level of tension water rights issues have generated and their underlying causal factors. What characterizes the Central Asian case is the evolution of political structures in which internal relations in the region, historically managed by a strong central authority, have become—since the demise of the Soviet Union—international relations between upstream and downstream countries where other asymmetries also play an important role. Reports from Central Asia regularly alert the international community to worsening ecological conditions, the dire social and economic status of its population, and the ensuing potential for serious civil and interstate conflict. The situation is particularly complex and delicate because familiar problems of overextensive irrigation agriculture and population increase have become mixed with interstate politics as a result of the collapse of the Soviet Union. As a consequence, “a very complex water management problem became a very complex *transboundary* water management problem” (Veiga da Cunha 1994, p. 6).

River water resources, especially from the Amu Darya and Syr Darya Rivers, play essential roles in the economies and societies of the Central Asian states of Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan, and Kazakhstan, some of which have become dependent in varying degrees on irrigated crops for survival. For example, cotton—the most important irrigation crop—is the major source of income and employment in Turkmenistan and Uzbekistan. Its production was encouraged under the

Soviet system as a source of hard currency. Overuse of water resources for irrigation is responsible for the drying of the Aral Sea, whose surface and volume have declined by 35 percent and 58 percent respectively since the mid-1980s. Water is wasted for cotton production in areas otherwise not suited for this culture in Uzbekistan and Kazakhstan. It is provided for free most often so there is no incentive to preserve it. The entire irrigation system relies on 32,000 km of canals, which are poorly maintained and full of leaks—including, for instance, the Karakoum canal, which constitutes a 1,340 kilometer open-air water way in the Turkmenistan Desert. Needless to say, losses to evaporation under such conditions are tremendous. The water that is used in agriculture can not be exploited by the upstream countries of Kyrgyzstan and Tajikistan, who rely on hydropower for 50 percent of their electricity production.

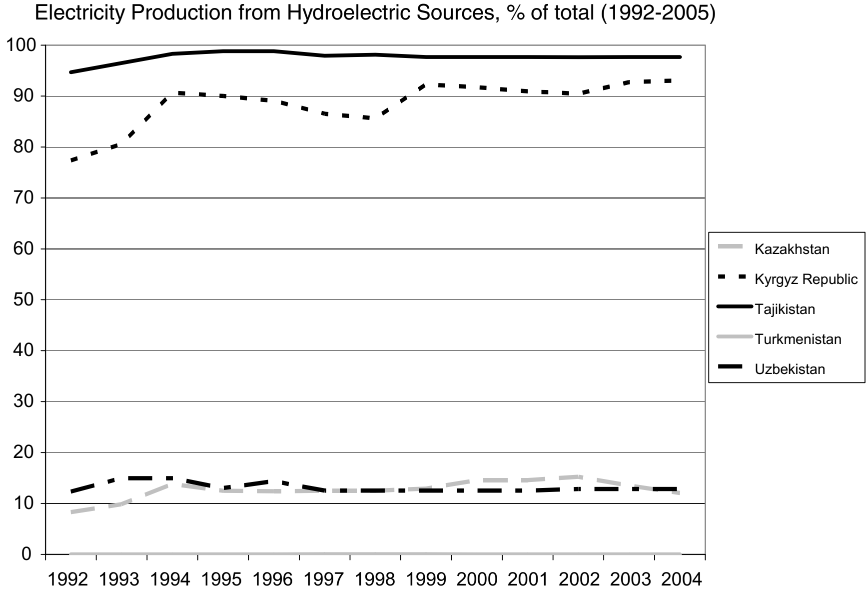
These competing water uses are aggravated by demographic pressures. Population grew by 140 percent between 1959 and 1989 (Horsman 2001, p. 71) and is projected to increase between 35 and 50 percent in most of the states between now and 2050 (Population Reference Bureau 2002).



Graph 1: Population Growth (World Bank Social and Economic Indicators).

Although tensions over water allocation are not new, they have taken on new significance since the collapse of the Soviet Union. Managed until 1992 from Moscow by a centralized administration, water systems have suddenly come under the control of separate sovereign states that have no history of agreements or coordination structures. This poses important allocation problems because of the nature of water resources and the weakness of new state institutions in the Central Asian republics.

Because upstream states Kyrgyzstan and Tajikistan need water for hydroelectric production as well as irrigation—Kazakhstan and Uzbekistan use water mostly for irrigation—they have held up release of water or threatened to charge for delivery downstream in order to pressure downstream users to compensate for energy production lost when water is released for downstream irrigation. It is important to note that despite their control over the source of water, upstream states are implicated in allocation schemes that oblige them to provide water downstream.



Graph 2: Electricity Production (World Bank Social and Economic Indicators).

It is common wisdom that resources whose allocation proves problematic because of the difficulty of assigning clear, unambiguous property rights are generally managed through common or centralized property institutions. This was the case under Soviet rule when the whole region was controlled from Moscow and agriculture, industrial, and energy production were part of national policy. The central state was able to enforce exchanges of water and energy between upstream and downstream users.

At present, the previous patterns are maintained, after being reaffirmed in the Almaty Agreement of 1992, but they are not perceived to be equitable. The arrangements reflect the favored status that downstream countries had achieved during the Soviet era. Kyrgyzstan and Tajikistan would like to expand irrigation agriculture and, especially, electricity production. However, even their dominant upstream position does not permit them to achieve their goals because of their political weakness in front of the downstream users' control over coal and gas and the energy produced by these fuels (Horsman 2001, pp. 74–75). Indeed, after independence, Uzbekistan and Kazakhstan introduced market prices for gas and coal. Kyrgyzstan could not pay these higher prices and their response was to increase electricity production in order to augment revenues. This meant that the amount of water available for downstream irrigation in Uzbekistan and Kazakhstan was reduced. As a consequence, agreements were not respected. In breaching their commitments, upstream states thus became vulnerable to reprisals from downstream states that have refused to provide energy in the form of natural gas and coal in return for water.

The case of Central Asia illustrates two important aspects of water resource allocation. The first is the nature of the asymmetries associated with its allocation. Upstream republics can control quantities of water sent downstream, but they are subject to reprisals because they do not control other critical resources like gas and coal. The second aspect is the shift from the status of regions in a single state to that of independent republics, which highlights the weakness of international regimes to regulate transboundary waters. No authority is empowered to impose a distribution system.

However inequitable an upstream–downstream relation may be, it will be stable unless the downstream user has other resources or power with which to pressure those upstream that control access to water. The asymmetric distribution of resources in the Central Asian republics is an example of an unstable relationship between users of a same natural resource with unclear property rights and crosscutting powers or access. In this case, there is no obvious solution that is both equitable and efficient. Management schemes must therefore be negotiated.

In Central Asia the asymmetry in access to waters could be compensated by industrial and agricultural developments that could, in the end, benefit all countries concerned. There might also be favorable spillover effects, where two countries or regions could share in the advantages created by the development of water resources in one region by specializing in complementary activities. This might consist of developing industry in the area less suitable for agricultural development and taking advantage of the cheaper electric power made available by dam construction in an upstream country. This dam development need not be limited to river run off low pressure constructions. High altitude countries can develop the kind of high pressure dams common in Alpine areas that are much less harmful for the downstream regions. These also have the advantage of providing large amounts of electric power under peak load conditions. They can then serve the industrial needs of firms located relatively far away from their particular location and thus be useful beyond the boundaries of a given country. Central Asia could be an example of such cooperation in power generation. The high altitude but relatively poor countries of Kyrgyzstan and Tajikistan could benefit from such schemes. In these cases, existing international organizations such as the World Bank would be appropriate institutions to devise policies that favor such positive spillovers and thus help to resolve otherwise intractable asymmetric water conflicts.

However, such a cooperative outcome is far from obvious. It requires a proper strategic analysis of asymmetric situations such as the ones we have been evoking above. We have to find out what the dilemmas are and which decisions and attitudes can get the parties out of the current dispute.

3. THEORETICAL CONSIDERATIONS

Access rights to water, even when inequalities are present, often take the form of shared property arrangements. It used to be difficult, at least in the past, to stop river flows so that waters from a basin were shared between different owners or different states. There are clear advantages to common property, notably risk sharing. The example of pools of water under properties defined at the surface is relevant. For each individual owner of the surface properties, digging a well might not be worth it because of the risks associated with the prospect of not finding any water under a particular property. Yet, as shown by Dasgupta and Heal (1979, p. 383), risk sharing in a common property arrangement tremendously increases the possibility of deriving benefits from digging wells in a coordinated fashion. In fact, the greater the number of participants in the risk sharing operation, the lower the costs associated with the enterprise and thus the higher the benefits for each individual owner. Similar reasoning can be made with respect to irrigation: it represents a kind of insurance scheme for agricultural producers who can then make use of it in case of drought. Thus, even risk-averse individual owners have an incentive to enter such an insurance scheme, which renders the costs of risk bearing negative (Dasgupta and Heal 1979, p. 386).

Within common property structures for water, the combination of the resource's inherent characteristics, technological features, and the institutional configurations related to its management underlie arrangements to prevent some groups or individuals from over-using water resources at the expense of others. Frequently the solution is to have a collective or central management structure. This form of management has its own special problems, the major one being the familiar "free rider" problem. Collective users have incentives to maximize the benefits of the common resource without paying their fair share of the costs. However, there are significant differences between water availability in the form of an underground or surface pool—like a lake—and in the form of a river basin with sequential access by different riparian users. Pool type access can be illustrated by the graph below, which shows that without socially imposed limits, the end result is overexploitation and dissipation of the resource.

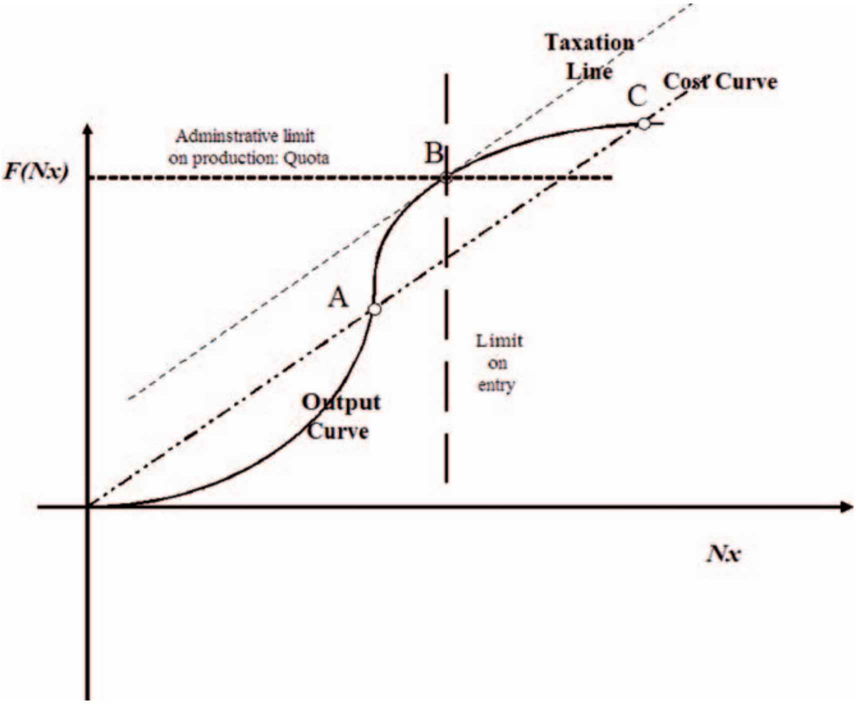


Figure 1: Optimal and Unsustainable Resource Use.

As this graph illustrates, production of a given natural resource type good like fresh water (the y axis) depends on the number of producers willing to share in its supply (the x axis). In order to ensure benefits in production, there must exist a relatively large number of producers, leading initially to increasing returns to scale. As more and more producers join, however, diminishing returns set in. This is illustrated by the S shaped aspect of the production curve. If each producer incurs a unit fixed cost, then the total cost of production can be represented by a (here the mixed dashed and dotted) straight line. This straight line crosses the production curve at two points: at A, where the number of producers is sufficient to initiate profitability; and at C, where too many producers have completely dissipated profits or surpluses. This also corresponds to the dissipation of the scarcity rent associated with the natural resource. Quite clearly the optimum lies at B, which maximizes surplus production over costs. This optimal situation can be maintained by limiting the number of producers entering the process, either by exclusion or by taxes, which increases the fixed costs of each entrant. A solution to the problem involving taxes is presented by the other (dashed) straight line, running parallel to the cost line and tangent to the production curve in B. A correct taxation of each entrant limits their number and assures maintenance of the scarcity rent.

Sequential access to water—like in distribution systems, or in rivers and irrigation systems drawing on them—often create “network “externalities.” For example, water networks are often dependent on individuals or small groups who occupy crucial positions within them or own land through which the water flows. Such situations have been called “weakest link” systems by Hirshleifer (1983) because each individual’s contribution is essential to prevent the collapse of the overall system and they therefore require a high degree of cooperation. In these cases, free-riding must be kept to a minimum because it threatens the society as a whole. While some of these features can make the supply of the collective good easier to achieve—because they provide opportunities for private benefits, even under conditions of public ownership—they can also, under some circumstances, enhance inequalities and create conflict situations.

As emphasized in Figure 1 above, in the general case of a common resource situation, the inefficiency due to overexploitation can always be corrected by an appropriate taxation policy called a Pigouvian tax (after the British economist Alfred Pigou). Establishing such a tax is relatively easy in the general case because profit seeking leads to a single maximum. A tax can then be used to reach such a maximum relatively easily. The tax keeps too many firms from entering production. Dasgupta and Heal (1979) show that such an outcome does not obtain when asymmetries, such as upstream–downstream relations with differentially defined property rights, are present. Imagine for instance the following: A downstream firm has to base its production on water that is also used by an upstream firm. Two parameters are important here. On the one hand, the degree of pollution generated by the first firm may significantly cut the possible profits available to the second firm; on the other hand, each firm has some kind of property rights as well as legal rights and obligations with respect to each other in terms of clean water. If the first firm has an unlimited right to pollute and the second firm no rights to clean water, the second firm will eventually be driven out of business in the absence of some Coasian (Coase 1960) type negotiated arrangement between the two. Conversely, if the first firm is constrained to produce without any pollution, it might have to cease its activities. However, things change when some property rights are assigned to one side or the other. If a maximum pollution level ê is allowed, the production possibilities of either firm are no longer convex and neither taxation nor buying or selling of rights will bring uniquely defined equilibrium solutions (Figure 2).

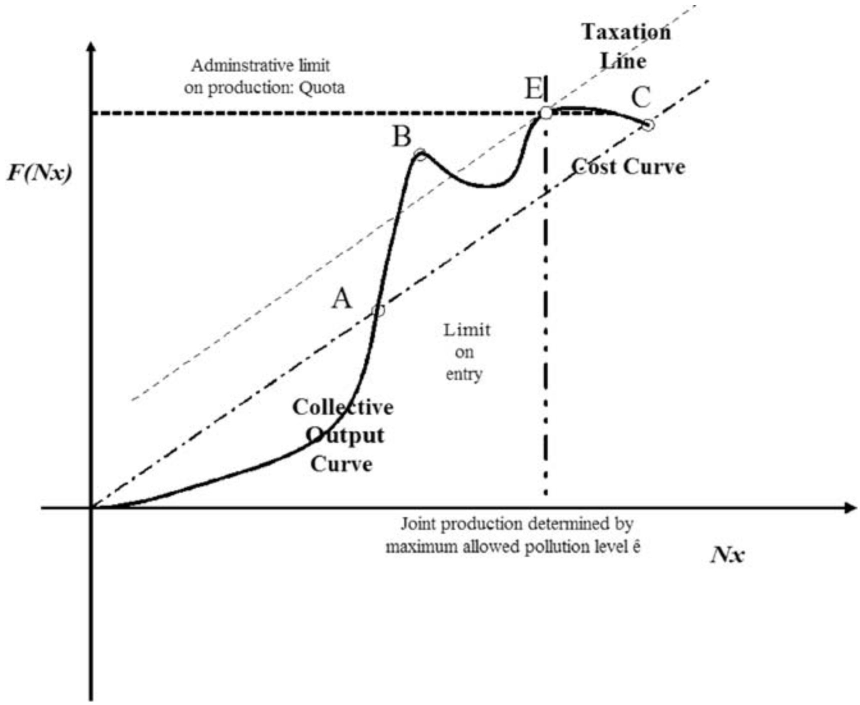


Figure 2: Water Use Disequilibria.

In Figure 2, point B would represent a better level of profit maximization than point E. But joint production will be stuck at the relatively suboptimal level E because property rights are determined in such a way that one firm uses the resource up to its maximal allowed level of depletion and thus keeps the other one from using the same resource more efficiently by restricting usage more for the first firm. Conversely, it is possible to imagine a situation where established property rights severely limit the access to resources of the firm that is the most efficient, thus reducing overall efficiency of resource use. This can be illustrated by the following graph (Figure 3):

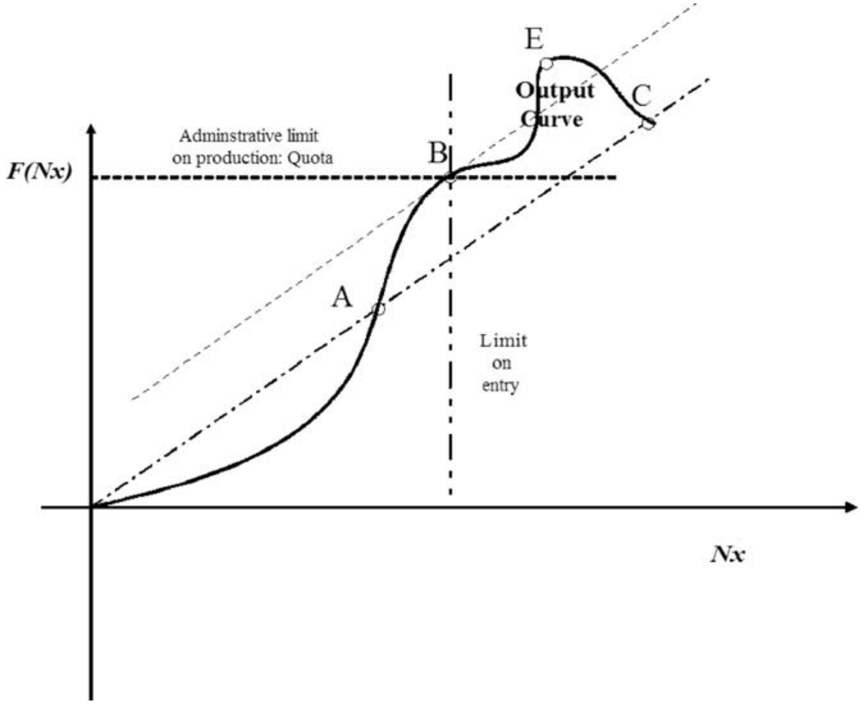


Figure 3: Water Use Inefficiencies.

One could ask why the two firms could not come to a Coasian type agreement where one of them could relinquish some of its property rights in exchange for a share in the higher profits generated by the one with the best productivity. The problem with such an arrangement is often one of credibility. Indeed, once property rights have been relinquished, or claims abandoned, there is no guarantee that the firm benefiting from this operation will then share the benefits if some superior authority does not insure the execution of the contract. This credibility issue is particularly acute if countries are involved instead of firms. Generally, in the international system no supreme authority exists to enforce contracts except in cases where states recognize an overarching authority such as an international court. This process can be described with the help of a sequential decision-making process with imperfect information between two decision makers, like the one presented in Figure 4. Here, two decision-makers, 1 and 2, decide sequentially about strategies to follow. Quite clearly, if information is complete and mutual responses fully anticipated on the basis of end payoffs, the equilibrium outcomes are generated by the sequences R L' or L R'(bold lines in Figure 4). However, only the sequence R L' is what is called subgame perfect, i.e., it can only be undermined by an incredible threat strategy, here a possible commitment by decision-maker 2 to play R' no matter what 1 does. This attitude is, however, incredible because once 1 has played R, 2 can only respond by playing L' to maximize his end gains (1 instead of 0). It is worth noticing however that the sequence L L' might bring in the end the best results for both decision-makers. Indeed, if somehow 1 and 2 can agree to share later on in the payoff of respectively 5 and 1, they could achieve a much better final outcome for both of them (assuming that 1 is able to redistribute from his own share of 5 a value to 2 that is higher than the 2 she would get if she reaches her best possible outcome). How can such a result obtain in a rational way, i.e., as deriving from the interactions between self interested

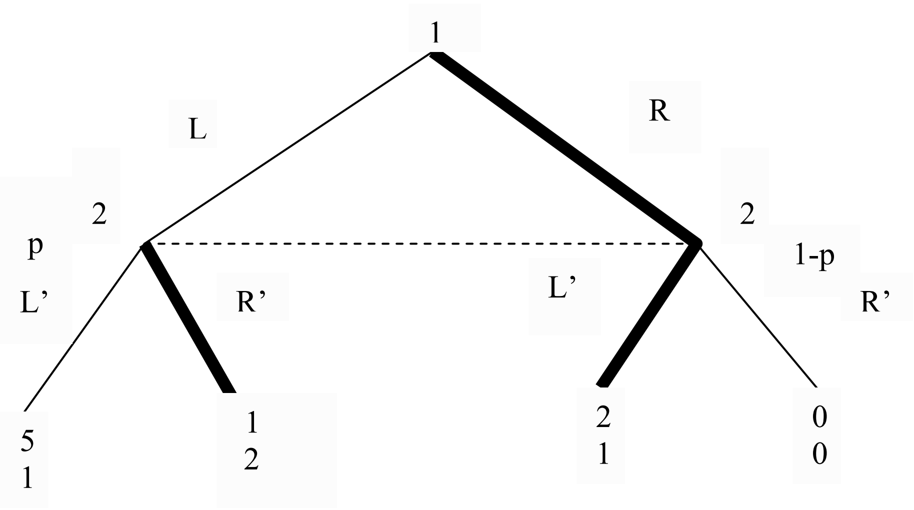


Figure 4: Game Tree with Imperfect Information.

parties? As we will try to show, the sequential decision-making process changes completely when the perspective of imperfect information is introduced. Assume that 2 does not know what 1 has chosen and attributes an equal probability of occurrence to the choice of both L and R by 1, i.e., $p=1-p$, which is consistent with a risk dominance analysis (Harsanyi and Selten 1988). Then 2 should determine her decision-making preferences on the basis of expected utility analysis.

However, here this decision-making procedure does not lead to any particular course of action since both L' and R' have the same expected utility (namely 1) for decision-maker 2 and therefore no simple risk dominance can be established. Even though both L' and R' are equivalent, it can be argued that 2 will act differently, depending on her attitude toward risk. If 2 is risk averse she will always chose L' because she will get 1 for sure; if she is risk preferring she will chose R', which gives her a chance of a higher reward. Decision-maker 1 will therefore get 5 if he anticipates that decision-maker 2 is risk averse; 1 if she is risk preferring.[1] If we assume that attitudes toward risk may change depending on the circumstances, the strategic problem for decision-maker 1 is to make sure that decision-maker 2 is risk averse. One is facing some kind of dilemma here because if 1 pushes to hard to extract concessions, 2 may feel threatened and become risk preferring. Decision-maker 1 has to try to anticipate 2's risk attitude and this may imply promising concessions rather than insisting on concessions by the other side. Once 2 has settled on a risk averse attitude, she will cooperate and make concessions of her own and a cooperative outcome between 1 and 2 will obtain if the assumption is made that 1 and 2 are utility maximizers and have changing attitudes toward risk. These changes should be occurring as a function of gains and losses: These decision-makers are risk averse with respect to gains and risk preferring with respect to losses. If all these are satisfied, one can formally prove that a cooperative outcome will obtain (see the proof in the Appendix).

What are the implications of this finding? And which strategies concretely should the decision-makers apply in a case like the one in Central Asia? Decision-maker 1 should offer a contract to decision-maker 2, guaranteeing a share of his gains to her. The credibility problem could be

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[1] This analysis only holds if one uses the risk dominance logic that implies a full compatibility with backward induction. Other approaches based on the notion of perfect Bayesian equilibrium (for an illustration, see Gibbons 1992, pp. 175–183) would insist that for decision-maker 2, p can only be 1 because it corresponds to an equilibrium belief. The equilibrium is the same if we assume that 2 is risk preferring; but this is not necessarily a correct assumption.

lifted, on the one hand, if decision-maker 1 does not act too aggressively, thus making 2 risk preferring and, on the other, if the contract is guaranteed by a third party like an international institution. In our case, as already mentioned, this would enable upstream republics, in particular Kyrgyzstan, to develop their hydroelectric potential with a promise to share the benefits with the downstream republics. Calculations presented elsewhere (Luterbacher, Kuzmichenok, Shalpykova, and Wiegandt, forthcoming) show that the hydroelectric potential of the region is largely superior to the current consumption of the countries of the whole region. Sharing profits from hydroelectricity would thus be a win-win situation, especially if one includes in addition the environmental benefits from such an operation.

4. CONCLUSIONS

We have tried to show in this chapter that asymmetric water conflicts do not have to escalate to open hostilities and that often they can be resolved through the use of special cooperative strategies at the state level. A game theoretical approach can be used to show that such strategies can be implemented in a way that makes sense analytically and that leads to a win-win situation: namely, the development of a hydroelectric potential whose benefits would be shared among all Central Asian states and whose redistribution scheme would be guaranteed by an international institution such as the World Bank. The remaining problem is that such win-win outcomes, despite their attractiveness, are not always achieved because they get opposed by powerful domestic interests. The political analysis of international trade has shown that commercial openness will be countered domestically by groups who are bound to loose from it. These are often powerful enough, despite being a minority, to derail any successful interstate negotiation. It is quite clear that agricultural interests in the downstream republics might incur losses from a hydroelectric buildup in upstream countries because they might have to face higher irrigation costs. There are however two ways in which such tendencies can be countered. First, the same international guarantors can put pressure on countries to resist such moves and threaten to cut international credit if these win-win projects are not implemented. Second, domestic interests that export industrial and fossil fuel could be mobilized to support new projects. In both cases, international institutions can play a crucial role in eliminating these sources of international conflict. Such tasks should however be in close conformity to their ultimate objective: to help organize more harmonious relations among states.

APPENDIX: UTILITY FUNCTION

Are parties to a bargaining process risk averse or risk preferring? This is basically an empirical question. However, a theoretical model that is constructed in order to be applied to concrete situations has to be able to account for both attitudes. So far analysts have dismissed the appearance of risk preference attitudes as relatively rare, even though it provides the one who displays it with increased bargaining power. Risk preference attitudes by themselves are probably infrequent. They may however appear quite often within "mixed" attitude representations. Experimental psychologists and even observers of animal behavior have noticed that risk preference often appears after risk aversion when a decision-maker is faced with the prospect of losses (Stephens 1990). Risk aversion and risk preferring behavior are regularly seen together, and various attempts have been made to explain their joint appearance. The principal analyses of hybrid risk attitudes are Battalio et al. (1990), Battalio et al. (1985), Camerer (1989), Fishburn and Kochenberger (1979), Friedman and Savage (1948),[2] and especially Kahneman and Tversky (1979) and Tversky and Kahneman (1992). In particular, Fishburn and Kochenberger (1979) show that the majority of individuals have an everywhere increasing utility function $U(x)$, where x is a measure of gains and losses in terms of the valued item alluded to above. *Most individuals are thus risk averse over gains and risk preferring over losses.* This notion can serve as a theoretical justification for the contention elaborated by Hirshleifer (1991)—that the poor have a comparative advantage in appropriation, which is obviously a more risky way to acquire wealth than capital accumulation through savings. Further, like Kahneman and Tversky (1979, 1992), Fishburn and Kochenberger show that the utility of no change is 0 (i.e., $U(0) = 0$), and that U is more steeply sloped over losses than over gains (i.e., $U'(-x) > U'(x)$ *for all* $x > 0$). A systematic discussion of these findings is given in Neilson (1993).

A natural extension of these considerations is to represent an average decision-maker's utility function by an everywhere increasing S curve in x, which adequately expresses the mix of risk aversion under gains and risk preference over losses.[3] Without loss of generality, we can then present the following risk averse/risk preferring (S shaped) utility curve (Graph 3):

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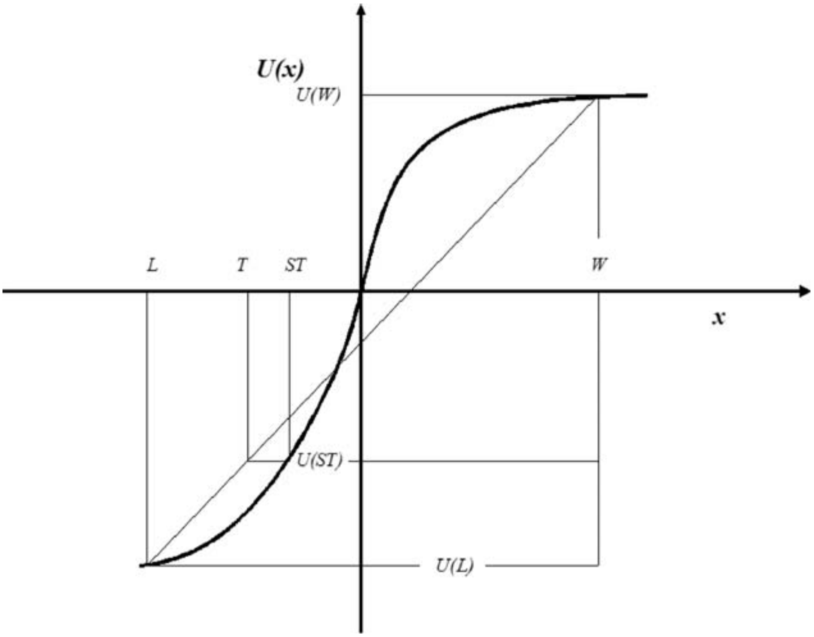
[2] Friedman and Savage use a perspective on the utility function in their article that differs markedly from ours.

[3] The S curve analysis and its application to conflict has been initiated by Dacey (1996a, 1996b, 1996c, 1998) and Dacey and Gallant (1997). The formulation used here below for the critical risk ratio is based on losses, whereas the formulation used in Dacey is based on gains. These formulations are logically equivalent. The formulation employed here is the one used in Harsanyi (1977).



Graph 3: Risk Averse/Risk Preferring Utility Function.

We present graphically here a risk averse/risk preferring curve that spans an interval on the *x* axis from *W* (winning) to *L* (losing). A sure thing value *ST* of *x* is also presented on this axis. One should note that this sure thing value is susceptible to change as a result of bargaining with another agent. In other words, *ST* may represent an “offer” by the other side. These values of *x* are projected via the S curve onto the *y* axis where they give respectively *U(W)*, *U(ST)*, and *U(L)*. *T* is the projection of *U(ST)* via the cord *U(L)—U(W)* onto the *x* axis. *T* defines the interval *ST−T* or *T−ST*—namely, the gain an individual seeks by taking risks or is willing to forgo by not taking them. We clearly have under risk aversion *T>ST*, and under risk preference *T<ST*. The switch from risk preference to risk aversion can then be described in terms of these inequalities.

What are the advantages of this model? It can give straightforward answers as we will show, as of when conflict initiation is preferred over staying at the bargaining table, when an agreement will be struck and why sometimes bargainers might get stuck in conflict.

Traditional bargaining theory[4] has been presented within two apparently different, but ultimately common frameworks. The first and older conception is due to John Nash (1950, 1953). Nash showed that a unique solution to a two person bargaining problem obtains under conditions of (1) joint efficiency; (2) symmetry of gains to the two actors if the game situation they were involved in was symmetric; (3) linear invariance of the solution; and (4) independence of the solution from irrelevant alternatives.[5] The unique solution to the joint bargaining problem is the result of the following maximization procedure: Choose actions (in our case) for *i* and *j* so as to:

$$Max\ [U_i - U_i(L_i)][U_j - U_j(L_i)]$$

where U_i and U_j are the respective utility functions of players *i* and *j* and $U_i(L_i)$ and $U_j(L_j)$ are disagreement outcomes. Harsanyi (1977) then showed that Nash's theory is mathematically equivalent to an earlier theory of bargaining developed by Frederick Zeuthen (1930). Harsanyi demonstrates that the Zeuthen theory expresses the bargaining process as a sequence of moves that eventually converge to the Nash bargaining solution. This demonstration is based on the notion of a critical risk ratio. As noted above, the critical risk ratio measures the probability of defecting or choosing the conflict outcome. It is:

$$r_{ij} = \frac{U_i(x_{ij}) - U_i(x_{ji})}{U_i(x_{ij}) - U_i(c)}$$

Here x_{ij} represents what agent *i* expects from agent *j* in the bargaining process, whereas x_{ji} is what he gets as an offer from *j* and *c* means the value of no agreement or conflict between the two agents. Obviously from the above fraction, r_{ij} is *0* if the offer from the other agent corresponds exactly to what he wants. On the other hand, r_{ij} is *1* if the offer from the other side does not differ from the value of the no agreement or conflict situation. Thus r_{ij} varies between *0* and *1*. A symmetric consideration holds for agent *j*. Harsanyi further postulates that, within a bargaining process,

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[4] Because the Nash solution sometimes involves the use of cooperative strategies, it is often considered to be only a part of cooperative game theory. However, the Nash theory is *not* confined to cooperative games. Harsanyi, for instance, has a lengthy discussion about its pertinence for noncooperative games (Harsanyi 1977, pp. 273–290). This point is also emphasized by Hargreaves Heap and Varoufakis (1995, p. 113).

[5] A thorough presentation of the Nash postulates is presented in Harsanyi (1977, pp. 144–146) and also in Binmore (1998, pp. 94–98).

the player with the lower critical risk ratio concedes to the player with the higher critical risk ratio. When the critical risk ratios of both players are equal, both make a concession. We will call these the Harsanyi-Zeuthen rules. Harsanyi shows that if both agents behave in this way the bargaining process will inevitably converge to the Nash solution. More recently, the bargaining approach advanced by Rubinstein (1982, 1985) has been considered more convincing than the Harsanyi-Zeuthen-Nash approach.

On the surface, these two approaches look very different. While the Harsanyi-Zeuthen-Nash theory can be interpreted as a sequence of bargaining moves, the particular sequential nature of the bargaining process is not taken into account. The Rubinstein conception is explicitly built on a process of alternating offers and counter-offers at different moments in time, according to the following script: Agent C makes an offer at time 1 to agent R for a division of a certain good. The amount of the good is assumed to be fixed so that if the offer made by C is x, then $(1-x)$ would be left to R. The bargaining process is characterized by time discounting: as time goes on, the value of the good shrinks at a different rate for each agent. This discounting and the sequential nature of the bargaining process favors the agent who makes the first offer because rejecting an offer is costly for the other agent. Rubinstein (1982) shows that if the first agent anticipates in his first offer the discounting of the other agent with respect to successive offers and counter-offers, then his initial offer will be accepted. In fact, the Rubinstein conception can be reduced to a special case of the Harsanyi-Zeuthen bargaining process with the introduction of discount rates. What the Rubinstein approach[6] shows with respect to bargaining is that if agents have different discount rates, they also have different attitudes toward risk and the curvature of their respective utility functions will be affected. Thus the Rubinstein conception pleads even more in favor of analyzing various attitudes toward risk in bargaining.

How does our conception, based upon the S shaped utility curve, fit with the perspective of the bargaining literature? We can observe the following, which holds independently of the geometry of the S curve: If a conflict is considered a gamble and this gamble is chosen over a sure thing or a (narrowly defined) status quo situation we have:

$EU(gamble) = p\,U(L) + (1-p)U(W) > U(ST) = EU(sure\text{-}thing\ act)$, which is equivalent to:

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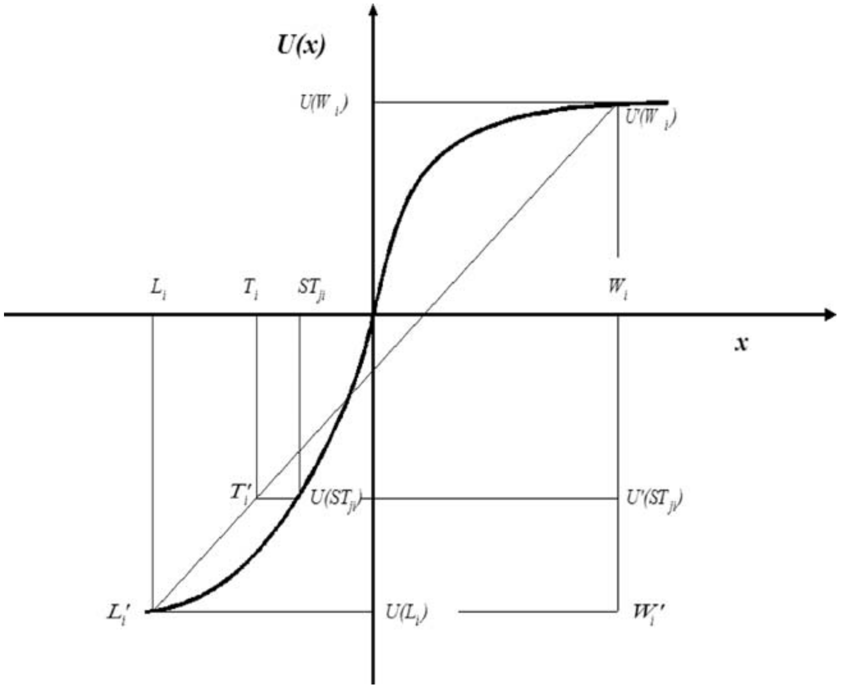
[6] The Rubinstein perspective is well described in Osborne and Rubinstein (1990).



Graph 4: The S Shaped Utility Curve and Bargaining.

$$\frac{U(W)-U(ST)}{U(W)-U(L)} > p$$

This, of course, is the Harsanyi critical risk ratio. We can now give this ratio an interpretation in terms of the geometry of the S curve. If the S curve is defined in terms of a bargaining situation between *i* and *j*, we get: We can now establish the following:

Basic Lemmas:

Lemma 1: The equality $\frac{U(W_i)-U(ST_{ji})}{U(W_i)-U(L_i)} = \frac{W_i - T_i}{W_i - L_i}$ holds everywhere in the domain spanned by the S shaped utility curve and the cord $U(W_i)$—$U(L_i)$. Proof: Consider the geometry of the S shaped utility curve and the interval spanned by the cord $[U(W_i), W_i]$—$[U(L_i), L_i]$, as for instance in Graph 4. Within the triangle $U'(W_i)$—W'_i—L'_i, there is another similar triangle $U'(W_i)$—$U'(ST_{ji})$—T'_i. Obviously, the interval $U'(W_i) - W'_i$ is equal to the interval $U(W_i) - U(L_i)$, the interval $U_i'(W_i) - (U'(ST_{ji})$ is equal to the interval, the interval $U(W_i) - U(ST_{ji})$, $U'(ST_{ji}) - T'_i$ is equal to the interval $W_i - T_i$, and the interval $W_i' - L_i'$ is equal to $W_i - L_i$. Thus we can establish that by similar triangles $\frac{U(W_i)-U(ST_{ji})}{W_i - T_i} = \frac{U(W_i)-U(L_i)}{W_i - L_i}$ then can be rearranged as $\frac{U(W_i)-U(ST_{ji})}{U(W_i)-U(L_i)} = \frac{W_i - T_i}{W_i - L_i}$ which completes the proof.

Lemma 2: The observable critical risk ratio $\frac{W_i - ST_{ji}}{W_i - L_i}$ is always higher than the "subjective" critical risk ratio $\frac{U(W_i)-U(ST_{ji})}{U(W_i)-U(L_i)}$ under risk aversion and always lower than the subjective critical risk ratio under risk preference. Proof: Given the equality $\frac{U(W_i)-U(ST_{ji})}{U(W_i)-U(L_i)} = \frac{W_i - T_i}{W_i - L_i}$ established by Lemma 1 and that under risk aversion $T_i > ST_{ji}$, the difference $W_i - ST_{ji} > W_i - T_i$ means that $\frac{W_i - ST_{ji}}{W_i - L_i} > \frac{U(W_i)-U(ST_{ji})}{U(W_i)-U(L_i)}$. Similarly, under risk preference we have $ST_{ji} > T$ and thus $W_i - ST_{ji} > W_i - T_i$ and then $\frac{W_i - ST_{ji}}{W_i - L_i} < \frac{U(W_i)-U(ST_{ji})}{U(W_i)-U(L_i)}$.

Existence of cooperative equilibria in the form of Nash bargaining solutions and of conflict equilibria:

Let us assume with Harsanyi the following: (1) Two bargainers will follow the Harsanyi Zeuthen principles. (2) They will not make concessions beyond the Nash bargaining solution. (3) No concession will be smaller than a minimum size $\varepsilon > 0$. We will add our own (reasonable) assumption that in a bargaining game, two bargainers estimate each other's subjective critical risk ratio (or probability) $\frac{U(W_i)-U(ST_{ji})}{U(W_i)-U(L_i)} = r_{ij}$ through the more objective estimator $\frac{W_i - ST_{ji}}{W_i - L_i} = \hat{r}_{i,j}$

Then:

Theorem 1: If both bargainers are risk averse, they will through mutual concessions always reach the Nash bargaining solution. Proof: All we have to show is that the estimation of the subjective risk ratio through the objective risk ratio is consistent with the Harsanyi Zeuthen principles. Then we can apply the Theorem demonstrated by Harsanyi (Harsanyi 1977:152–153) saying that: Under assumptions 1, 2, and 3 above, two bargainers will eventually reach the Nash bargaining solution. We proceed as following: The bargainers will estimate their mutual r_{ij}*'s* through $\hat{r}_{ij}$. Under risk aversion we always have $\hat{r}_{ij} > r_{ij}$ and also, of course, $\hat{r}_{ji} > r_{ji}$. Thus, whenever, $r_{ij} > r_{ji}$, $\hat{r}_{ij} > \hat{r}_{ji}$. This means that bargainer *j* will then make a concession to bargainer *i*. If these inequalities are reversed *i* will make a concession to *j*. Both of these conclusions are thus consistent with the Harsanyi Zeuthen rules. The case $r_{ij} = r_{ji}$ remains to be examined: Under risk aversion, $\hat{r}_{ji} > r_{ji}$, thus we can conclude $\hat{r}_{ji} > r_{ij}$, and hence *i* will make a concession to *j*. However, for the same reason $\hat{r}_{ij} > r_{ji}$ and hence *j* will make a concession to *i*. This is consistent with the Harsanyi Zeuthen rule that whenever $r_{ij} = r_{ji}$, both bargainers make concessions. Thus our construction is completely consistent with the Harsanyi Zeuthen rules and we can apply the Harsanyi theorem.

Theorem 2: If two bargainers are risk preferring, they will end up in an equilibrium in conflict. Proof: We need to show that the Harsanyi Zeuthen rules do not lead to any concessions under risk preference for the two bargainers. The critical risk ratio $\frac{U(W_i)-U(ST_{ji})}{U(W_i)-U(L_i)} = r_{ij}$ is again estimated via $\frac{W_i - ST_{ji}}{W_i - L_i} = \hat{r}_{ij}$ with the difference that $\hat{r}_{ij} < r_{ij}$. Thus $r_{ij} > r_{ji}$ does not mean that *j* will make a concession to *i* since $\hat{r}_{ij}$ eventually $\leq r_{ji}$. We can establish initially that whenever $r_{ij} = r_{ji}$ since $\hat{r}_{ij} < r_{ij} = r_{ji}$ no bargainer will offer a concession. This will also occur whenever $\hat{r}_{ij} < r_{ji} < r_{ij}$. We thus have to deal only with the case $r_{ij} > \hat{r}_{ij} > r_{ji}$. Suppose this condition holds. Then, we would have under risk preference, a space where j would offer ST_{ji} to i because this offer would appear superior to the conflict outcome. For such a space or interval to exist we would have always an interval $[a,b]$ such that for all $x \in [a,b]$, $u_A(x) \geq W_A - L_A$ and $u_B(x) \geq W_B - L_B$. However, under one-sided risk preference, $u_A(x') \leq x'$ and thus eventually $u_A(x') \leq W_A - L_A$, which is a contradiction and so the interval does not exist for A and if one reasons similarly neither does it for B. So no such space exists ever. A similar reasoning can be made for i. Hence the estimator $\hat{r}_{ij}$ is $\leq r_{ji}$ and thus no concessions are made on either side, which lead to bigger demands by the two bargainers and thus to a convergence $ST_{ji} \rightarrow L_i$ and $S_{ij} \rightarrow L_j$.

Theorem 3 (Asymmetry): If one bargainer is risk averse while the other one is risk preferring, two equilibria can occur: (1) The risk preferring bargainer presents a take it or leave it request to the risk averse bargainer, who accepts it (equilibrium in surrender). Proof: As already established above, the risk preferring bargainer never makes a concession. Therefore, only one offer is made. The risk averse bargainer overestimates the critical risk ratio of the risk preferring bargainer and is prepared to make the concession provided that his being worse of through it does not push him below the chord in terms of the geometry of the S curve, i.e., if he is sufficiently risk averse. (2) The risk preferring bargainer presents a take it or leave it request to the risk-averse bargainer. The other bargainer refuses it and fights. Proof: This offer puts the risk-averse bargainer in a position where he becomes risk preferring. No bargainer makes any concession as established above and either noncooperation prevails or fighting starts.