The Syr Darya River Conflict: An Experimental Case Study

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October 2005

Abstract

With the disintegration of the USSR a conflict arose between Kyrgyzstan, Uzbekistan and Kazakhstan over the Syr Darya river. Upstream Kyrgyzstan operates the Toktogul reservoir which generates hydropower demanded mainly in winter for heating. Downstream Uzbekistan and Kazakhstan need irrigation water in summer, primarily to grow cotton. Regional agreements obliging Kyrgyzstan to high summer discharges in exchange for fossil fuel transfers in winter have generally been unsuccessful, notably due to lack of trust between the parties. Striving for self-sufficiency in irrigation water, Uzbekistan initiated new reservoir construction. This paper examines their economic impact. We report a laboratory experiment modelling the Syr Darya river scenario as a multi-round three-player trust game with non-binding contracts. Payoff schemes are estimated using real-life data. While basinwide efficiency maximisation requires regional cooperation, our results demonstrate that cooperation in the laboratory is hard to achieve. Uzbek reservoirs improve the likelihood of cooperation only weakly and their positive economic impact is limited to low-water years.

Keywords

Central Asia, common-pool resources, conflict, dams, hydropower, irrigation, experimental economics, regional public goods, transboundary rivers, Syr Darya, trust games, water.

JEL Classification Codes

C72, C92, O53, Q25

Acknowledgements

We wish to thank the following individuals in Almaty and Bishkek for their kind help: Kydykbek Beishekeev (Kyrgyz Ministry of Water and Agriculture), Simon Kenny and Natalia Charkova (World Bank), Leonid Dmitriev and Igor Steinberger (Kazgiprovodhoz), Peter Graham (DFID), Tim Hannan and Zharas Thakanov (UNDP), Dyushen Mamatkanov (Kyrgyz Academy of Sciences), Cholpen Mambetova and Shaminder Puri (Asian Development Bank), Bakyt Makhmutov (Swiss Development Cooperation), Ken McNamara (USAID), Aliya Satubaldina (European Commission), Akylbek Tumanbaev (Kyrgyz State Energy Agency) and Alexi Zyranov (JSC Kyrgzenergo). We thank Jacinto Braga, Richard Cornes, Simon Kenny, Dyushen Mamatkanov, Oliver Morrissey and seminar participants in Amsterdam and Montreal for helpful comments and suggestions. Thanks also to Ping Zhang and Karen Kong for assistance in conducting the experiments and to Nazgul Esengulova for help in translation. All errors remain our own. Financial support from the following institutions is gratefully acknowledged: The British Academy, the Spanish *Ministerio de Educación y Ciencia* (BEC 2003-00412), and the University of Nottingham (Asia Fund, Centre for Research in Economic Development and International Trade (CREDIT), Faculty of Law and Social Science Water Initiative Fund, School of Geography and School of Economics). Part of this research has been carried out while Abbink was a visitor at the Institut d'Anàlisi Econòmica (CSIC), Barcelona. He gratefully acknowledges that institution's hospitality and support. The findings, interpretations, and conclusions expressed in this paper are entirely those of the authors. They do not necessarily represent the view of the World Bank, its Executive Directors, or the countries they represent.

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1. Introduction

The collapse of the Soviet Union in 1991 left the newly independent Central Asian Republics (CARs) with a difficult transition task and inter-state relations that have not always been easy. Almost immediately a conflict arose over the use and allocation of the waters of the Syr Darya river with major economic and political ramifications for the region. Upstream Kyrgyzstan operates the huge Toktogul Reservoir to facilitate hydropower production while the downstream riparians, Uzbekistan and Kazakhstan, abstract water from the river to irrigate land dominated by cotton cultivation. The conflict stems from the diametrically opposed seasonal requirements for water in the different countries. Kyrgyzstan has the highest demand for electricity in the winter months thus generating an incentive to store summer inflows into Toktogul for release during the winter. In contrast the downstream countries want water to be released during the summer months so that they can irrigate their agricultural lands.

The different water requirements of the upstream and downstream republics has long been problematic. During the Soviet period the decision on when and how much water was to be released from the upstream reservoir was made by the central planners in Moscow. For years Kyrgyzstan was ordered to discharge water during the summer so that the cotton fields of Uzbekistan and Kazakhstan could be irrigated.[1] In return the downstream countries sent electric power, coal and gas to Kyrgyzstan during the winter months. With Moscow no longer intervening in such matters the riparian states were forced to seek voluntary cooperative agreements over water and energy. However, barter agreements that obliged Kyrgyzstan to operate the reservoir in an irrigation mode, in exchange for coal and gas supplies during the winter months, were invariably breached by all three parties. A fundamental lack of trust has been central to the failure of interstate agreements and although a co-operative agreement could be beneficial for all three countries, it has proven prohibitively hard to implement one in an environment of mistrust.

Frustrated by the history of failed agreements the downstream countries are increasingly leaning towards a policy of self-sufficiency, making themselves less dependent on Kyrgyzstan. To this end, Uzbekistan has pursued plans to construct new reservoirs on its territory. The reservoirs will store upstream winter releases for irrigation use in summer. But to what extent do these new reservoirs represent the long-awaited solution to the conflict? Several issues need to be addressed to answer this question. First, the fact that the cooperation record has been poor so far does not imply that this will be the case in the future. The March 2005 revolution in Kyrgyzstan and the forthcoming retirement of senior government officials in all the riparian states bring new players to the negotiation table.[2] It is possible that new players will act differently, making expensive reservoir construction obsolete. So the question arises whether the previous failure of cooperation is systematic or idiosyncratic. In other words, has cooperation failed because this is inherent to the problem, or because the decision makers in charge have been incapable of working together? Secondly, the capacity of the new reservoirs is limited. While they mitigate the costs of uncoordinated behaviour, they do not

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[1] When Stalin delimited the borders of the CARs in the 1920s and 1930s he deliberately created water-rich and water-poor republics. This ensured that there was always competition between the upstream and downstream republics. Such competition worked to Moscow's advantage in two ways. First, disputes over water reinforced the national distinctiveness of the Republics, thus limiting the potential for regional cooperation which would threaten Soviet control. Secondly, as competition for water increased the Republics were forced to ask Moscow to intervene; a role it was more than willing to undertake (see for instance O'Hara, 1998).

[2] Many of the most senior officials in the water sector are near or have passed the offical age of reirement.

eliminate the need for cooperation to maximise basinwide efficiency. If incentives to cooperate get even worse, not much may be gained.

The aim of this paper is to address these questions. We designed a model that estimates the economic impact of the new reservoirs on the riparian economies. In doing so we had to tackle two difficulties. First, the model needs to trace the real economic situation as accurately as possible, despite notoriously limited data availability. We collated data from a variety of sources and from a series of interviews with experts on location—government officials and representatives of donor agencies—to make estimates as informed as possible. Secondly, costs and benefits from the new reservoirs crucially depend on the ability of decision makers to cooperate, which is a behavioural issue. To examine this, we introduce a novel approach to the analysis of transboundary river conflicts. We used a model estimated from real data and designed a game that resembles the strategic environment in the Syr Darya river conflict. Controlled laboratory experiments were then conducted to study the likelihood of future cooperation. Building on a long tradition of experimental research the laboratory appears to be an ideal testbed to study scenarios of cooperation and conflict in shared river basins. We re-create an analogous, although stylised, set of conditions where we can analyse the strategic environment of the Syr Darya conflict in different future scenarios. In two separate treatments, we simulate the economic scenario with and without the new Uzbek reservoirs under three representative hydrological regimes.

We find that Uzbek reservoirs do not represent the solution to the river conflict. Maximisation of basinwide efficiency continues to require riparian cooperation. Though they alleviate Uzbekistan's problems in low-water years the reservoirs are not sufficiently large to achieve Uzbek self-sufficiency in irrigation water. Moreover, the experimental results reveal that cooperation is indeed very hard to establish in the present strategic environment, especially in low-water years. Thus failure to cooperate should not solely be attributed to the unwillingness or incapability of current decision makers. Finally, we find that reservoirs improve the likelihood of cooperation only marginally.

The remainder of this paper is organised as follows: Section 2 provides background information on the river conflict and reviews relevant literature. Section 3 develops the model and its estimation. Section 4 describes the experimental design. Section 5 presents the experimental results. Section 6 summarises and concludes.

2. Background[3]

Water resources are of critical importance to the Central Asian economies.[4] Mountainous Kyrgyzstan has a substantial hydropower potential currently covering up to 80 percent of its domestic energy needs. Hydropower exports - through barter trade to other CARs and to Russia in cash – account for approximately ten percent of total exports with an estimated monetary value of US$ 46.8 million in 2001. In Uzbekistan, irrigated cotton production is the most important economic activity in an agriculturally dominated economy. The country is the World's second largest cotton exporter with a market share of almost 10 percent. Cotton exports totalled US$ 669 million in 2002, equivalent to 26.7 percent of total exports and

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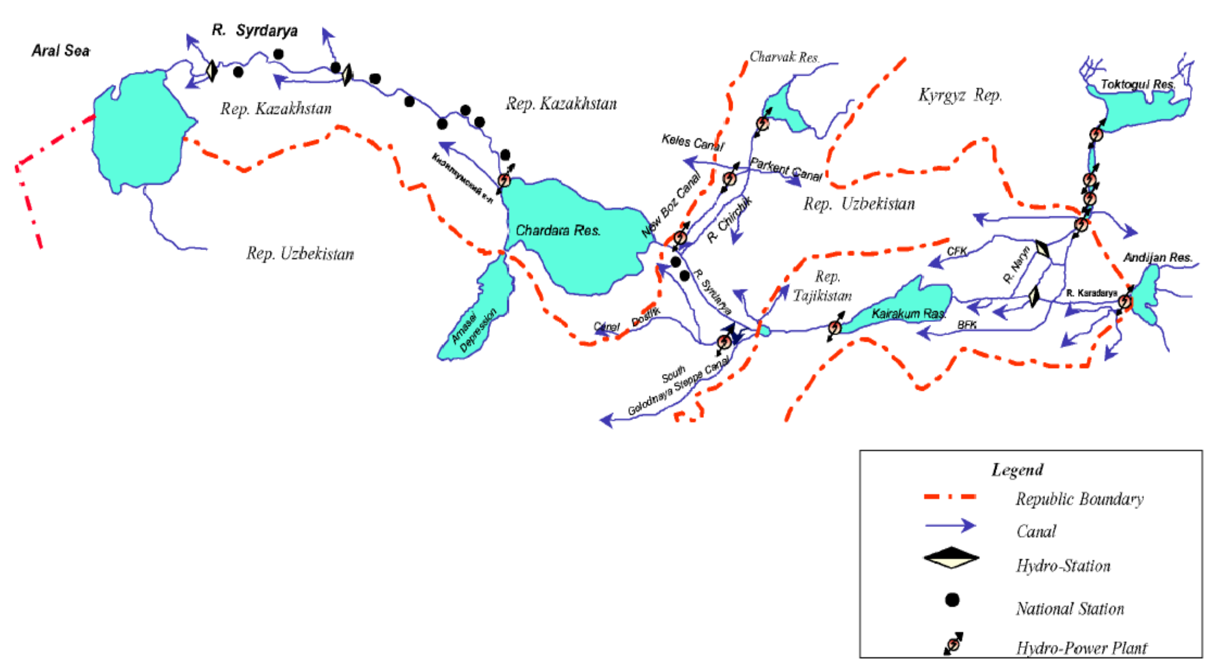
[3] For further information see EIU (2004), IMF (2003), Moller et al (2005), O'Hara (2000a, 2000b), SPECA (2004), USDA (2004), and World Bank (2004a, 2004b, 2004c, 2004d, 2004e).

[4] With a GDP of US$ 1.6bn and a population of 5m, Kyrgyzstan is one of the poorest countries in the region. Uzbekistan is larger and slightly less poor. It has a GDP of US$ 9.7bn and a population of 25.3m. Kazakhstan is the most prosperous country in a poor region. Its GDP is US$ 24.2bn in a population of 14.8m.

around 60 percent of hard-currency export earnings.[5] Finally, although the Syr Darya is of relatively low economic significance to the oil-dominated Kazakh economy, it is nevertheless of substantial regional importance. Cotton exports from South-Kazakhstan (one of the two provinces that the Syr Darya flows through) equalled US$ 104.6 million in 2002, or one percent of total Kazakh exports.

The Syr Darya, one of Central Asia's most important transboundary rivers, rises in the mountains of Kyrgyzstan. It has two main tributaries, the Naryn and the Kara Darya which merge in eastern Uzbekistan to form the Syr Darya proper. From there the river flows into Tajikistan[6] before re-entering Uzbekistan and finally flowing into Kazakhstan where it discharges into the remnants of the Small Aral Sea (see figure 1).[7] Its annual discharge varies from 21 to 54 billion cubic metres (BCM) with a mean of 37 BCM. The flows of the Syr Darya and its tributaries are regulated by a series of reservoirs built during the Soviet period. The most important of these being the huge, multi-purpose Toktogul Reservoir built in the 1970s on the Naryn River in Kyrgyzstan. The reservoir, which has an active storage capacity of 14.5 BCM, was primary used to even out inter-annual variations in river flows thereby maximising its irrigation potential. Toktogul is also used to produce hydropower.

Figure 1. Map of the Syr Darya river



Note: Map not drawn to scale. Source: World Bank (2004a).

Under Soviet administration Toktogul was operated under an irrigation regime whereby 75 percent of the annual discharge was released from the reservoir in the summer months (April-

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[5] In addition to taking water from the Syr Darya Uzbekistan also uses significant volumes of irrigation water from the Amu Darya and the Zerefshen Rivers. The figures given in this section are for the country as a whole and not just production in the Syr Darya Basin.

[6] Tajikistan plays only a minor, regulatory role on the Syr Darya due to its relatively low reservoir storage capacity and insignificant irrigation withdrawal rates. For this reason Tajikistan is not treated explicitly in this analysis.

[7] The tragedy of the shrinking Aral Sea is a disastrous side effect of intensive irrigation. This issue is outside the scope of our study.

September). Releases during the winter months (October-March) accounted for the remaining 25 percent. Surplus hydropower generated in the summer was fed into the Central Asian Power System for use by the Uzbek and southern Kazakh regions. Since the Kyrgyz region lacked any significant fossil fuel resources, they were transferred from the Uzbek and Kazakh republics to enable the Kyrgyz region to meet its winter demand for electricity and heat.

After independence, the Soviet arrangement came under great strain. Fossil fuel prices rose quickly to world price levels and payments were increasingly demanded in hard currency. Households switched from expensive fossil fuel fired heating to electric heating, thus increasing winter electricity demand. Kyrgyzstan could not afford to import fossil fuels to generate electricity and started to increase winter discharges of water from Toktogul to meet its winter power demand and reduce summer releases to store water for the following winter. As a result, farmers in Uzbekistan and Kazakhstan faced irrigation water shortages in summer. Furthermore, the frozen waterways and canals were unable to handle the larger volume of water in winter, occasionally causing flooding on downstream territories.

In the absence of a central planner to solve this conflict, the newly independent CARs were forced to seek voluntary cooperative agreements. In February 1992 they signed the Almaty Agreement whereby the CARs agreed to the joint ownership and management of the region's water resources, while retaining sovereign control over crops, industrial goods and electric power obtained from them. The agreement further reiterated the need for cooperation. But this, as well as annual agreements for the release of water and exchange of electricity and fossil fuels, proved ineffective and could not arrest the increasing orientation towards power production of the Toktogul operation. Eventually in March 1998, Kazakhstan, Kyrgyzstan and Uzbekistan entered into a Long Term Framework Agreement which explicitly recognised that annual and multi-year irrigation water storage has a cost and that it needs to be compensated, either through a barter exchange of electricity and fossil fuels or in cash. But, the supply of fossil fuels generally fell short of agreed quantities and quality, forcing Kyrgyzstan to increase winter discharges. In wet years downstream states did not need the agreed volumes of summer discharges and this affected the export of electricity and the compensating quantities of fossil fuel transfers to Kyrgyzstan. The latter was thus exposed to a serious risk in meeting its winter demand for heating and power. To reduce this risk, Kyrgyzstan, on average, reduced summer releases to 45 percent of the annual discharges (and winter releases increased to 55 percent) during the 1990s.

Regional cooperation efforts were dealt a further blow when the republics failed to conclude annual agreements in 2003 and 2004. To some extent, this can be attributed to above-average precipitation in those years, but more fundamentally, the collapse of the barter agreement system was due to a change in the Uzbek position towards a decisive unilateral stance. The most explicit expression hereof has been the decision to construct a series of re-regulating reservoirs. Uzbekistan is currently proceeding with the design of new water storage capacity of the Karamansay reservoir (0.69 BCM), as well as constructing the Razaksay (0.65-0.75 BCM) and Kangkulsay (0.3 BCM) reservoirs. These facilities together with the natural reservoir in the Arnasai depression (0.8 BCM) will provide additional storage of about 2.5 BCM.[8]

The impact of the Uzbek decision has been substantial for Kyrgyzstan and Kazakhstan. The Kyrgyz challenge is that even when operated in the noncooperative 'power mode', production

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[8] Recognising the strategic importance of these reservoirs, the Uzbek government gave little away about its intentions and actions to co-riparians and donors. To illustrate, the World Bank only found out about them when representatives from a visiting, albeit unrelated, mission were taken to one of the construction sites. (Personal communication with Simon Kenny, World Bank, Almaty, 13 December 2004).

is insufficient to cover domestic winter electricity demand. In the absence of a regional agreement, the Kyrgyz government must aim to cover this deficit through a combination of domestic reforms and construction of new power-generating facilities - both of which represent daunting challenges. Kazakhstan, which had otherwise pursued a cooperative strategy towards Kyrgyzstan, has had to come to terms with the fact that this strategy ultimately depended on Uzbek willingness to cooperate. Since the latter was not forthcoming, Kazakhstan has shown renewed interest in the construction of re-regulating reservoirs on its own territory. Plans exist for constructing a 3 BCM reservoir (Koksarai) near Shymkent at a cost of US$ 200 million, although no final political decision has been made to initiate construction.[9]

The central problem for the interstate agreements has been one of trust. Short of military action there are no means to enforce a contract between sovereign republics who are generally suspicious of each other. If Kyrgyzstan discharges additional water in summer, it must trust the downstream riparians to deliver fossil fuels in winter, otherwise it will face a severe problem of not being able to meet its energy demand in the subsequent winter. Hence, it incurs a temporary loss and relies on compensation from the downstream neighbours – without being able to enforce the reward. Uzbekistan and Kazakhstan, on the other hand, are less inclined to pass fossil fuels to Kyrgyzstan if they fear that the latter will deviate from the agreement by releasing large volumes of water in winter. The Syr Darya conflict therefore has the nature of a *trust game*, reminiscent of those that have been extensively studied in the experimental economics literature (e.g. Fehr, Kirchsteiger, and Riedl (1993), Berg, Dickhaut, and McCabe (1995), Dufwenberg and Gneezy (2000), Abbink, Irlenbusch, and Renner (2000), Fershtman and Gneezy (2001), Gächter and Falk (2002)).[10] In trust (or reciprocity) games a first mover can send money to a second mover, who in turn can voluntarily reward the trustor by sending money back. The games are constructed such that by doing so, both players can be better off with respect to final payoffs, but in equilibrium no trust and no rewarding would be exhibited. Contrary to the theoretical prediction, the common finding of these studies is that first movers often show trust by passing money, and second movers often reward them by sending money back, even if the game is played only once and under completely anonymous conditions. In light of these findings the poor record of cooperation in the Central Asian river conflict looks surprising. However, the games in the literature use artificial payoff structures which differ from those underlying the Syr Darya river game, and involve only two players.

The economic literature on transboundary river sharing includes *inter alia* contributions by Barrett (1994), Dinar and Wolf (1994), Moller (2004), Rogers (1997), Kilgour and Dinar (2001) and Ambec and Sprumont (2002). These, mainly theoretical, contributions are preoccupied with how and under what circumstances riparians can attain cooperative outcomes in conflicts over water quantity sharing, but they do not address inter-temporal conflicts arising over upstream hydropower and downstream irrigation use. Most of the economic literature that does address this type of conflict typically deals with inter-state rivers, especially in the United States, rather than rivers crossing international borders. Particularly pertinent are the studies of the Snake-Columbia river by McCarl and Ross (1985), Houston and Whittlesey (1986), McCarl and Parandvash (1988), and Hamilton et al (1989). The Colorado river has been analysed by Gisser et al (1979) and the irrigation districts in Central California by Chatterjee et al (1998). The study by Owen-Thomsen et al (1982) of Egypt's High Aswan Dam represents an exception to the focus on US-based rivers. These

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[9] Personal communication with Leonid Dmitriev, Kazgiprovodhoz, Almaty (15 December 2004).

[10] Irlenbusch (2005a, 2005b) reports results from a slightly more complex game, but with the non-binding contracts that characterise the real game.

studies use mathematical programming to analyse the impacts on the agricultural sector of a water transfer to hydropower production because the latter often has the highest marginal productivity. Authors such as Hamilton et al (1989) consider the possible role of market mechanisms to improve the resource allocation. Others, such as Chatterjee et al (1998), have emphasised the establishment of clearer property rights. Both of these policy remedies, however, are less suitable in an international context. International trade in water is rare, partly because the conflicting principles of international law complicate the property rights issue.

There are just three economic studies of an international hydropower-irrigation conflict. Aytemiz (2001) examines the conflict between Turkey and Syria on the Euphrates. Moller (2005) develops a theoretical model of the Syr Darya conflict. He takes a noncooperative approach by examining the conflict-reducing impact of a range of infrastructure projects. Construction of downstream reservoirs is found to reduce conflict through a Pareto-improvement, but it does not lead attainment of basinwide efficiency (Pareto-optimality). World Bank (2004a) takes a cooperative approach to the Syr Darya conflict by examining how side payments can be used to attain efficient outcomes. It demonstrates that net Syr Darya basin benefits are substantially higher when the Toktogul reservoir is operated in an 'irrigation mode' than under the 'power mode'. Developed before the collapse of the barter agreements, the report recommends a number of ways in which the existing regional cooperation mechanisms could be improved. These include *inter alia* proposals to use multi-year rather than annual agreements, a 'letter of credit scheme' and the introduction of a monitoring and guarantee mechanism to ensure compliance with agreed obligations. Reception of these proposals by riparian governments, however, was largely negative (see World Bank 2004b for details).

Building on the work contained in World Bank (2004a) our paper also explores the scope for cooperation in the Syr Darya conflict. Using similar assumptions about key economic variables we develop a more general economic model which is then used for laboratory experiments.[11] The major difference between our model and that in World Bank (2004a) is threefold: The first relates to different assumptions about water availability. We assume an average annual water outflow of around 13 BCM compared to 9 BCM used in the World Bank report. The latter figure has been discredited (and World Bank (2004b) concedes) because it is based on a non-homogenous data set for the 1911-2000 period compiled by BVO Syr Darya (a basinwide agency located in Tashkent) which under-records inflow since 1975. Secondly, the Bank report compares two different water allocations (irrigation and power mode) while we generalise the analysis by considering a continuum of allocations within the historically relevant range. Thirdly, and as a consequence, we have introduced a range of capacity constraints to provide a realistic treatment of extreme scenarios. The subsequent section develops the model and estimates its parameters.

3. The Model

Before formulating the economic model we had to make some choices. First, since Uzbek reservoirs are at an advanced stage of construction we decided mainly to focus on these in the experiment, and not to include the Kazakh reservoirs because the government has not yet approved their construction. Further, we neglect the impact of winter flooding, though this is

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[11] Experiments on games informed by real-world data are surprisingly rare. Some have been carried out in the course of consulting projects for spectrum auctions, but their results are often not published due to confidentiality concerns of the clients (an exception is Abbink et al. (2002)). In a different context, Güth, Kröger, and Maug (2003) parameterise a bargaining game with data from a case study on the film industry.

a much-discussed concern of the Uzbek and Kazakh governments. Reliable estimates of the damages of flooding proved impossible to obtain, but there are some indications that the economic costs of flooding are relatively small. The most substantial damage seems to be political, since flooding is a very visible event likely to stir public anger.

3.1. Payoff Functions

3.1.1. Kyrgyzstan

Electricity output in the summer season, Y^s MWh, is given by the hydropower production function:

$$Y^s=\alpha q^s_{ky} \qquad (1)$$

where $\alpha>0$ is a productivity parameter and q^s_{ky} BCM is the Kyrgyz water release from the Toktogul Reservoir in the summer season. Kyrgyzstan must cover a domestic energy demand of E^s MWh in summer. Due to technical losses, the necessary gross power generation necessary is given by E^s/ν^s MWh, where $\nu^s\in[0;1]$ is an efficiency parameter. The Kyrgyz domestic energy deficit in the summer season, D^s MWh, is defined as follows:

$$D^s=E^s/\nu^s-\alpha q^s_{ky} \qquad (2)$$

To cover this deficit Kyrgyzstan operates its thermal power plant, Bishkek I, fuelled by imported natural gas and coal. Bishkek I has a short-run marginal cost of C_I US$/kwh and an operating capacity of K MWh. If the domestic energy deficit is larger than the capacity of Bishkek I, a second thermal power plant, Bishkek II, is operated. It has a short-run marginal cost of $C_{II}>C_I$ and an assumed unlimited capacity within the relevant range of the model. Conversely, in the case of a domestic energy surplus, Kyrgyz electricity is exported to Uzbekistan and Kazakhstan. Electricity payments are not modelled explicitly, but may implicitly constitute a part of the side payments between countries. The Kyrgyz gross payoff during summer (excluding side payments), measured in million US$, is given as follows:

$$\pi^s_{ky}=-\mathrm{MIN}\{C_I D^s, 0\} \qquad \text{for } D^s\leq K \qquad (3.a)$$

$$\pi^s_{ky}=-C_I K-C_{II}(D^s-K) \qquad \text{for } D^s>K \qquad (3.b)$$

In winter, hydropower is produced using the same constant-returns-to-scale technology as expressed in (1). Denoting all seasonal variables by superscript *w*, the Kyrgyz domestic energy deficit in winter is given by:

$$D^w=E^w/\nu^w-\alpha q^w_{ky} \qquad (4)$$

A domestic energy deficit is covered by the Bishkek I and II thermal power plants in the same manner as in the summer period. In case of a domestic energy surplus, Kyrgyzstan is assumed to have no export markets in the winter period. The Kyrgyz gross payoff in winter is written:

$$\pi^w_{ky}=-\mathrm{MIN}\{C_I D^w,0\} \qquad \text{for } D^w\leq K \qquad (5.a)$$

$$\pi^w_{ky}=-C_I K-C_{II}(D^w-K) \qquad \text{for } D^w>K \qquad (5.b)$$

Denoting the side payment received by Kyrgyzstan from Uzbekistan for its water and electricity services by S_{ky} the Kyrgyz total payoff (in million US$) is:[12]

$$\pi_{ky}=I_{ky}+\pi^s_{ky}+\pi^w_{ky}+S_{ky} \qquad (6)$$

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[12] In the model, Kazakhstan does not issue a side payment directly to Kyrgyzstan (as it does in reality), but rather to Uzbekistan. This is done to ensure that Uzbekistan has an incentive to release water to Kazakhstan. In reality, the Uzbek incentive to release water to Kazakhstan is mainly political, i.e. Uzbekistan does not want to upset international relations with its downstream neighbour.

The intercept of the payoff function, I_{ky}, is not specified and can be chosen arbitrarily, since our economic analysis only aims at comparing payoffs in different scenarios. If it is omitted, then a zero Kyrgyz payoff corresponds to a situation in which the domestic energy deficit is non-negative in both seasons.

3.1.2. Uzbekistan

Uzbek payoff relates only to the summer period and can be divided into two components: irrigation and electricity. Uzbek irrigation supply for cotton production is available from two main sources: summer water released by Kyrgyzstan, q_{ky}^{s}, and water available in the new Uzbek reservoirs, R, which are filled in the winter period where $R<q_{ky}^{w}$. Uzbekistan releases some of this water to Kazakhstan, $q_{uz} \leq q_{ky}^{s}+R$, and withdraws the residual, $q_{ky}^{s}+R-q_{uz}$, for cotton production. Of its total water withdrawals, only a share $0 \leq \beta_{uz} \leq 1$ is used for cotton irrigation with the residual $(1-\beta_{uz})$ used for other crops, the production of which is assumed non-profitable. The economic value of irrigation water for cotton production is P US$/KCM. While we have not explicitly modelled an agricultural production function, it would be unrealistic to expect that marginal benefits are always positive, especially for high levels of water input. It is therefore assumed that if irrigation input reaches an optimum point, O_{uz}, then the marginal value of irrigation water is zero.[13] Uzbek gross irrigation benefits (in million US$) are thus written:

$$P\beta_{uz}MIN\{(q_{ky}^{s}+R)-q_{uz},O_{uz}\} \qquad (7)$$

We now turn to the Uzbek electricity benefits. Suppose that Kyrgyzstan runs a domestic energy surplus in summer and that a share of this surplus is exported to Uzbekistan. In this case Uzbekistan can import electricity at a lower cost than were it to produce this electricity domestically. The gross benefit of electricity imports is valued at the opportunity cost of operating a coal fired power plant in Uzbekistan, the short-run marginal cost of which is C_{uz} US$/kwh. After accounting for the technical loss of transmitting electricity through the Uzbek power grid, electricity available for import equals $-\rho D^{s}$, where $0 \leq \rho \leq 1$ is an efficiency parameter. Due to technical constraints in the transmission grid, electricity exports cannot exceed X MWh. The exported electricity is shared between Uzbekistan and Kazakhstan. Denoting Uzbekistan's share by $0 \leq \gamma \leq 1$, its electricity benefits are:

$$MAX\{C_{uz}\gamma\rho MIN\{-D^{s},X\},0\} \qquad (8)$$

Denoting the side payment from Kazakhstan to Uzbekistan, S_{uz} we can write the Uzbek payoff as follows:

$$\pi_{uz}=I_{uz}+P\beta_{uz}MIN\{(q_{ky}^{s}+R)-q_{uz},O_{uz}\}+MAX\{C_{uz}\gamma\rho MIN\{-D^{s},X\},0\}+S_{uz}-S_{ky} \qquad (9)$$

As with the Kyrgyz payoff function the intercept does not have any meaningful interpretation. If intercept and side payments are omitted and R=0 then a zero payoff would correspond to a situation in which Kyrgyzstan releases no water at all in summer.

3.1.3. Kazakhstan

Like Uzbekistan, Kazakhstan also benefits from irrigation and electricity in the summer period. The Kazakh payoff-function is similar to that of Uzbekistan and is given by the following expression (where Kazakh variables are denoted with subscript *ka*):

$$\pi_{ka}=I_{ka}+P\beta_{ka}MIN\{q_{uz},O_{ka}\}+MAX\{C_{ka}(1-\gamma)\rho MIN\{-D^{s},X\},0\}-S_{uz} \qquad (10)$$

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[13] Clearly this represents a substantial simplification of a more realistic cotton production function with diminishing returns to scale (and possibly a negative marginal product). The practical significance of this for the experimental results, however, seems neglible.

where I_{ka} is the unspecified intercept of the Kazakh payoff function.

3.2. Estimating the model

Having defined the payoff functions of the three riparians the next step is to use real data to estimate the model. Analytically, this procedure is straightforward since it simply involves the use of numerical values for all exogenous variables and parameters. In practical terms, however, the compilation and selection of relevant data constituted a significant challenge.

Water availability is a key determinant of riparian payoff. We use primary data collected by JSC Kyrgyzenergo for the 1988-2003 period (see Appendix A, Table A1). Water inflow is a stochastic variable determined by nature while water outflow is a reflection of political decisions made by Kyrgyzstan. The presence of what is, in effect, two stochastic variables (summer and winter inflows) adds complications to the experimental design. We thus make the simplifying assumption that Kyrgyz winter release is residually determined, $q^w_{ky}=Q-q^s_{ky}$ where Q denotes annual inflow.[14] This is equivalent to assuming that annual inflow equals annual outflow. While this is true in the medium to long term it is a restrictive assumption on an annual basis. Thus while in practice the Toktogul Reservoir is large enough to enable multi-annual regulation, our analysis focuses exclusively on the seasonal conflict.

Table A2 (Appendix A) summarises the assumed values of the remaining exogenous variables and parameters. A few assumptions deserve special mention: First, we have set the economic value of irrigation water at US\$ 20/KCM (1,000 cubic meters). According to the World Bank (2004a), the value of irrigation in Central Asia is estimated as being in the region of \$20-\$50 per KCM. To produce conservative benefit estimates we choose the lower range of this estimate. Secondly, optimal irrigation input has been calculated on the basis of total land under cotton in Uzbekistan and Kazakhstan, including additional land introduced in the medium term. Our results are consistent with those provided by Antipova et al (2002) who estimate a total downstream irrigation need of 6.5 BCM. Thirdly, to capture the effect of increased marginal cost of thermal power production beyond the capacity of Bishkek I, we used cost figures for Bishkek II. The Bishkek II plant, however, currently exists only at the design stage and although it could be completed by 2007 the Kyrgyz government is yet to approve its construction.[15]

3.3. Properties of the model

The payoff functions of the three riparians in equations (6), (9) and (10) can be expressed as cost and benefit functions if the intercepts and side payments are omitted. The costs of cooperating are borne entirely by Kyrgyzstan and are defined as:

$$C(q^s, Q) \equiv -\pi_{ky}(q^s, Q) \qquad (11)$$

The benefits of cooperation accrue jointly to Uzbekistan and Kazakhstan:

$$B(q^s) \equiv \pi_{uz}(q^s)+ \pi_{ka}(q^s) \qquad (12)$$

This reformulation of the model turns out to be quite useful in illustrating its properties. In the following we use Q=13 as a benchmark and assume, for illustrative purposes, that water is shared equally between the two downstream riparians, i.e. $q_{uz}= q_{ky}{}^s/2$.[16]

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[14] Ambec and Doucet (2003) and Moller (2005) make similar assumptions.

[15] The Kyrgyz government hesitates to do so because the plant relies on imported natural gas from Uzbekistan.

[16] The assumption about water sharing does not affect the properties of the model in any significant way. It merely affects the size of total benefits and the distribution of those benefits between Uzbekistan and

Figure 2 illustrates the marginal costs and benefits as a function of q^s. Marginal costs and benefits are constant, piecewise linear and each schedule has five steps. Consider first each of these steps on the marginal benefit curve starting from left: (1) For low values of q^s, downstream marginal benefits are limited to cotton irrigation. (2) Marginal benefits increase for higher values of q^s as the associated Kyrgyz energy surplus enables import of cheaper summer electricity by downstream countries. (3) Marginal benefits then fall slightly as Kazakh irrigation demands are saturated. (4) The capacity constraint of electricity exports becomes binding. (5) Marginal benefits eventually reach zero as Uzbekistan receives sufficient irrigation water.

Marginal costs are determined by summer as well as winter effects. Put simply, low values of q^s are associated with a domestic energy deficit in summer (and a surplus in winter) while the reverse is the case for high values of q^s. The five steps on the marginal cost curve are characterised as follows: (1) For low q^s-values, Kyrgyzstan operates both thermal power plants in summer (Bishkek I and II). Each additional water unit q^s released reduces the cost of operating these plants, thus marginal costs are negative (i.e. Kyrgyzstan incurs a marginal benefit). (2) As q^s increases Kyrgyzstan only requires Bishkek I and marginal costs increase, but remain negative. (3) Marginal costs equal zero when the primary energy balance is non-negative in both seasons. (4) For higher levels of q^s marginal costs (of operating Bishkek I) become positive since a high summer release causes a winter energy deficit. (5) Marginal costs peak when Bishkek II also needs to be operated in winter. Finally, we note that net benefits of cooperation are maximised at the intersection between the marginal cost and marginal benefit schedules.

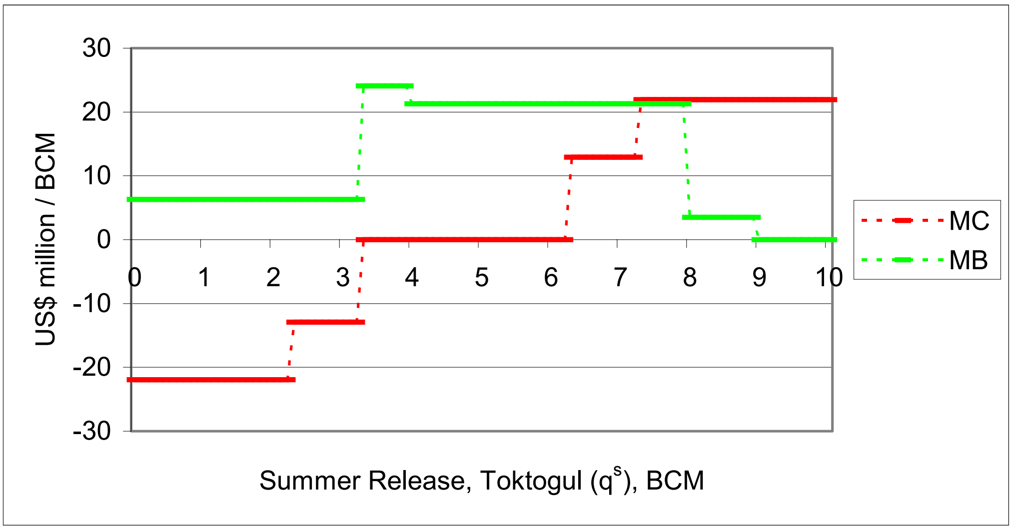

Figure 2. Marginal costs (MC) and marginal benefits (MB), Q=13.

The properties of the theoretical model depend critically on the two treatment variables: water inflow (Q) and Uzbek reservoirs (R). Consider first model sensitivity to changes in Q within the historically relevant interval: [10; 16]. A change in Q affects the cost function but not the benefit function, cf. equations (11) and (12). The noncooperative equilibrium is non-unique and thus defined as an interval of q^s_{ky}–values (table 1 refers). The start interval is always

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Kazakhstan. Equal water sharing produces conservative benefit estimates because the potential for downstream optimisation is not neccessarily exploited. Note that the variable q_{uz}, is endogenous in the experiment.

q^s=3.3 because this value is sufficient to eliminate the domestic energy deficit in summer. The end interval - which is increasing in Q - is determined by the point where Kyrgyzstan incurs a domestic energy deficit in winter. The cooperative optimum is typically unique and increasing in Q because higher overall water availability reduces the Kyrgyz marginal costs in winter and shifts the right-hand part of the marginal cost schedule downwards. Cooperation typically involves a higher Kyrgyz summer discharge, q^s_{ky}, than noncooperation, except in high-water years where the two may be identical. This implies that the downstream riparians have a higher marginal productivity of water than Kyrgyzstan. Table 1 also illustrates the intuitive property that basinwide gains from cooperation are highest when water is scarce.[17]

Uzbek reservoirs are represented by the second treatment variable, R, which has so far taken the value zero. To consider the economic impact of reservoir construction we simply set this value to 2.5. The economic impact of the new reservoirs is as follows: First, Uzbek cotton benefits, and thus basinwide new benefits increase by up to 8.8 million US$ depending on Q. By and large, the basinwide gain from Uzbek reservoirs is decreasing in Q, i.e. reservoirs are most useful in low-water years. Secondly, Uzbek reservoirs may make cooperation slightly less attractive.

Table 1. Model results for alternative values of the two treatment variables

Q	10	11	12	13	14	15	16
Noncooperative equilibrium (q^s_{ky})	3.3	3.3-4.2	3.3-5.2	3.3-6.2	3.3-7.2	3.3-8.2	3.3-9.2
Cooperative optimum (q^s_{ky})	4.2	5.2	6.2	7.2	7.9	8.3	9.0*
Basinwide gains from Uzbek reservoirs (million US$):							
Noncooperative**	8.8	8.7	8.8	8.8	6.3	2.8	0.0
Cooperative	8.8	8.7	8.7	6.3	3.9	2.4	0.0
Basinwide gains of cooperation (million US$):**							
Without reservoirs	9.5	9.0	9.0	9.0	6.4	0.0	0.0
With reservoirs	9.5	9.0	8.9	6.5	4.0	0.0	0.0

* q^s_{ky}=9.0 without reservoirs but is given by the interval [7.9;9.2] with reservoirs. **refers to the highest noncooperative water release.

Maximisation of basinwide efficiency requires regional cooperation (with or without reservoirs), except when water is abundant. In this sense reservoirs do not establish Uzbek self-sufficiency in irrigation water, i.e. Uzbekistan could increase its benefits by cooperating with the other riparians. For a normal water year we compute a cooperative surplus equal to US$ 9.0 million per year.

4. Design and Procedures

4.1. The stage game

Having formulated the payoff functions we now turn our attention to the strategic environment. The Syr Darya river conflict is characterised by negotiations between governments of the three countries and the problem of their subsequent implementation. Consequently, we design a game that consists of two parts. First, in a negotiation part the three players – each representing a country – are given the opportunity to make a contract on a

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[17] Note that the value of basinwide gains depend on the selection of the non-unique, noncooperative equilibrium. Table 1 produces conservative estimates because we assume that the equilibrium with the highest release is selected. This is also the least inefficient one. Equilibria with lower releases do not benefit Kyrgyzstan but harm the downstream countries.

combination of water releases and possible side payments. This contract, however, is non-binding, as there is no way in which a country can be forced to obey (leaving aside the unlikely possibility of military intervention). In a second part of the game the players decide on the water releases and side payments they actually implement.

In the real conflict negotiations take place annually in trilateral negotiations. In the experimental design we attempt to model such a scenario. However, to make it playable in the laboratory we need to impose a certain structure on the negotiations, which takes into account that laboratory time is limited. Therefore we simplified the bargaining process by randomly giving one of the players the opportunity to make a proposal and asking the other players to accept or reject. The proposal consists of the following four elements: 1) The amount of water that Kyrgyzstan releases from Toktogul in summer, q^s_{ky}. 2) The amount of water that Uzbekistan passes on to Kazakhstan, q^s_{uz}. 3) A compensation payment that Uzbekistan makes to Kyrgyzstan, S_{ky} and; 4) a compensation payment that Kazakhstan makes to Uzbekistan, S_{uz}.

The inflow is exogenously given and known.[18] Uzbekistan can release to Kazakhstan any quantity of water up to what it receives from Kyrgyzstan. The compensation payments are amounts of money. This rule represents a simplification of conduct of play in the real conflict, where Uzbekistan refuses to make any monetary payments in exchange for water or to attach a price on water (services) - a demand from the Kyrgyz side. In practice, however, Uzbekistan has implicitly agreed to pay compensations through an inflated price for the electricity it receives from Kyrgyzstan in summer. For the experiment simplicity is important, such that we decided not to model these additional behavioural complexities.

At the first stage of the game, one player makes a proposal to the other two players. We chose to draw the proposer at random in each round of the game (each with a probability of one third), in the absence of a natural candidate.[19] After the proposal is specified, its terms are communicated to the other two players. These players are then simultaneously asked to accept or reject it. Note that since the contract is not binding, the negotiation part of the game is merely 'cheap talk' in the game theoretic sense. It may be used to co-ordinate the players' behaviour, but it cannot be enforced and does not restrict the players in their subsequent actions.

After the proposal has been either accepted or rejected, the players make the decisions for real. As the first mover Kyrgyzstan decides on a release of water from Toktogul (q^s_{ky}). At the next stage Uzbekistan makes two decisions at once. It chooses which quantity of water to release to Kazakhstan (q^s_{uz}), and an amount of money to pay to Kyrgyzstan (S_{ky}). At the final stage of the game, Kazakhstan decides on a side payment to make to Uzbekistan (S_{uz}). At all stages all players are informed about all players' decisions at preceding stages.[20]

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[18] In practice there is an additional complexity since the inflow level is a stochastic variable (see section 3.2). Agreements are generally made before knowing the actual inflow level. However, since most of the inflow into Toktogul comes from glacier and snow melt in spring, the year's inflow is largely known when Kyrgyzstan makes a decision on releases. Hence, the governments could make agreements contingent of the inflow if they wished (though to date they have not). We therefore model the realised inflow in a given year as known.

[19] One may argue that the downstream country is the most natural candidate, since the downstream riparian wishes to change the status quo and alter the behaviour of the upstream player. However, always making Kazakhstan the proposer seems somewhat at odds with the reality of the conflict, in which the strongest conflict of interest is between Uzbekistan and Kyrgyzstan.

[20] There are some information problems due to neglect of metering stations and a generally secretive attitude of the Central Asian governments. At the aggregate level, however, the relevant information is largely available.

4.2. The conduct of the experiment

Since the payoff functions developed from the available real-world data are complex, they needed to be presented in the simplest possible way. We used tables that list the payoffs obtained by each combination of water releases from Kyrgyzstan to Uzbekistan and from Uzbekistan to Kazakhstan. Depending on the range of feasible releases these payoff tables could quickly become very large and incomprehensible. Therefore, the number of choices was restricted. Water passes had to be in integer numbers. We further cut the strategy space in a way that Kyrgyzstan could pass any integer number from 3 to 9. Releases outside this range are historically irrelevant and did not seem to be plausible choices. The resulting payoff tables consisted of 49 lines and four columns. The first three columns showed the payoffs for each of the three players, the last column the sum of the three payoffs (enabling participants to identify efficient outcomes). The payoff tables can be found in appendix B.

For the specification of the payoff values from the payoff functions we had to make some choices. First, we adopted the principle that 'a dollar is a dollar', thus we did not account for a different marginal utility of money in the three countries. Those could arise from their different population sizes or GDP levels. Such corrections, however, would have been somewhat arbitrary (for example, in Kazakhstan water benefits apply to the South Kazakhstan and Qyzlorda provinces only). Further, such considerations do not seem to play a significant role in the actual policy debate. Secondly, in the theoretical model payoffs are formulated in additional costs of water release for Kyrgyzstan and additional benefits for the downstream riparians. In the experiments absolute payoffs needed to be implemented, thus the unspecified intercepts of the payoff functions had to be defined. We decided to choose the intercepts in a way which was experimentally most suitable, rather than derive them from some real-world benchmark (such as GDP). This way we could make sure that equal payoffs for the three players – a natural focal point in experiments – could be implemented in cooperative scenarios (thus cooperation was not impeded by incompatibility with possible equality considerations). Further, we had to make sure that different strategy choices could lead to substantially different payoffs in order to properly incentivise the participants. As a benchmark we chose the least inefficient noncooperative equilibrium outcome without reservoirs in the normal water year ($Q=13$), where Kyrgyzstan discharges 6 units (BCM) and Uzbekistan releases 1 unit (see next section 4.3), since this is currently the most relevant scenario in reality. Payoffs were adjusted in a way that each player gets 370 talers (the experimental currency unit) in this scenario. From there we calculated all other payoffs using the cost and benefit functions derived earlier. Each taler difference between two numbers in the payoff tables corresponds to US$ 100,000 per year in the real game. Note that side payments would be added or subtracted from these figures, such that a wide range of payoff combinations was achievable.

The experiment was conducted at the *Centre for Decision Research and Experimental Economics* (CeDEx) of the University of Nottingham. The software for the experiment was developed using the *RatImage* programming package (Abbink and Sadrieh (1995)). Subjects were recruited by e-mail from a database of students, who had previously registered at CeDEx as potential participants in experiments. Each subject participated in only one session, and no subject had participated in experiments similar to the present one. The subjects were undergraduate students from a wide range of disciplines. The majority of participants were British. Among the substantial fraction of foreign students the largest group was Chinese. Virtually all subjects were aged between 19 and 25, with a balanced gender distribution.[21]

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[21] Ideally we would have wished to conduct the experiment with participants from a Central Asian cultural background. However, few students from that region are enrolled at the University of Nottingham, and in Central

In each session subjects interacted in fixed groups of three subjects. The role of a participant as representing Kyrgyzstan, Uzbekistan or Kazakhstan did not change throughout the experiment. This set-up reflects the repeated-game character of the real situation. Subjects were not told who of the other participants were in the same group, but they knew that the composition of the groups did not change. Each session began with an introductory talk. The experimenter read aloud the written instructions (see appendix C). The language used in the instructions was semi-natural. The situation was framed as that of a 'resource being passed' from one player to the other, but we did not label the players as the three countries they represented. Since we did not expect many students to be familiar with the Syr Darya river conflict, we were concerned that an entirely natural framing would cause confusion. On the other hand we did not expect a benefit from completely disguising the situation using abstract terms as this would have made the instructions more difficult to understand.

We conducted 24 rounds of the stage game.[22] These were divided into three phases of eight rounds, using the different inflow levels of 10, 13, and 16 to represent low, normal and high water levels, respectively. The order of the three phases was varied in a way that each water level was played in each of the phases in the same number of sessions. The different levels of inflow implied different payoff distributions, but otherwise the structure of the game remained the same in each phase.

Subjects were granted a capital balance of 1,000 talers at the outset of each session. The total earnings of a subject from participating in the experiment were equal to the capital balance plus the sum of all the payoffs he or she made during the experiment minus the sum of that subject's losses. A session lasted for about two hours (including time spent to read the instructions). At the end of the experiment, subjects were paid their total earnings anonymously in cash, at a conversion rate of one pound sterling for 400 talers. Subjects earned between £3.44 and £39.10 with an average of £21.95, which is considerably more than students' regular wage in Nottingham. At the time of the experiment, the exchange rate to other major currencies was approximately US$1.90 and €1.45 for £1.

We conducted three sessions with each treatment (with and without Uzbek reservoirs). The treatments differ in the payoff tables, but not in the structure of the game. Each session comprised of 12, 15, or 18 subjects, where the variation is due to show-up rates. Subjects interacted with each other within groups but not across groups so that each group of three countries can be considered a statistically independent observation. In total, we gathered 15 independent observations in the treatment without reservoirs and 16 in the treatment with Uzbek reservoirs.

4.3. Game-theoretic considerations

Using the payoff tables shown in appendix B, the subgame perfect equilibria (Selten (1965, 1975)) of the stage game can easily be identified with a backward induction argument. It is straightforward to see that in a noncooperative equilibrium no side payments are made. At the

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Asia we did not have access to a computerised laboratory. Experiments conducted with participants from different cultures sometimes show differences (Roth, Prasnikar, Okuno-Fujiwara, and Zamir (1991), Willinger, Lohmann, and Usunier (2000)), sometimes not (Brandts, Saijo and Schram (2000), Lensberg and Van der Heiden (2000)). Typically the differences are not large and would not lead to radically different conclusions.

[22] Subjects were informed about the number of rounds for reasons of transparency and practicality. This creates a deviation from the real situation which resembles an infinitely repeated game. Contrary to the real-life decision makers, subjects could theoretically solve the 24-round supergame by backward induction and be guided by this solution. However, since such behaviour is virtually never observed in any other experiment (and greatly at odds with the existing evidence from trust games), it seems unlikely to be the case in our setting.

last stage a side payment only reduces Kazakhstan's payoff. Since the other players' decisions are taken, Kazakhstan cannot gain anything from making a final payment. Analogously, Uzbekistan does not gain from making a side payment to Kyrgyzstan, since Kyrgyzstan's decision is already made.

The equilibrium choices with respect to water releases can be obtained from the payoff tables. Since Kyrgyzstan foresees that it will not receive compensation payments, its payoff is not affected by the choices being made downstream. Thus it will simply release the quantity that maximises its own payoff.[23] For example, in the benchmark case of Q=13 without reservoirs, Kyrgyzstan can release anything from 4 to 6 units in an equilibrium and earn 370 talers (see table B3). Uzbekistan then chooses the quantity to pass to Kazakhstan given this behaviour. If Kyrgyzstan has chosen, for example, 6units, then Uzbekistan passes on 0 or 1 units to Kazakhstan.[24] Thus, the combinations (q^s_{ky},q_{uz})= (4,0), (5,0), (6,0) and (6,1), combined with no side payments, constitute subgame perfect equilibria of the game. Table 2 illustrates the subgame perfect equilibria and Pareto optima for all six scenarios.

The table shows that for the case of abundant water (Q=16), there is no conflict between own-payoff maximisation and cooperation, since the Pareto-optimal outcomes are also equilibria of the game. In normal or low water years, sustaining the Pareto-optimum requires the players to deviate from the noncooperative equilibrium. The construction of the Uzbek reservoir widens the range of equilibria and in some cases the range of Pareto optima as well. Interestingly, the reservoirs do not alter the scope for cooperation. Still, in the case of low and normal water years the players can improve their payouts by agreeing on a non-equilibrium solution.

Table 2. Equilibria and Pareto optima of the game

Scenario	Subgame perfect equilibria	Pareto optima
Q=10, no reservoirs	(3,0)	(6,2)
Q=13, no reservoirs	(4,0), (5,0), (6,0), (6,1)	(7,2)
Q=16, no reservoirs	(4,0), (5,0), (6,0), (6,1), (7,0), ..., (7,2), (8,0), ..., (8,3), (9,0), ..., (9,4)	(8,2), (8,3), (9,2), ..., (9,4)
Q=10, with reservoirs	(3,0), (3,1)	(4,2)
Q=13, with reservoirs	(4,0), ..., (4,2), (5,0), ..., (5,3), (6,0), ..., (6,4)	(7,2), ..., (7,5)
Q=16, with reservoirs	(4,0), ..., (4,2), (5,0), ..., (5,3), (6,0), ..., (6,4), (7,0), ..., (7,5), (8,0), ..., (8,6), (9,0), ..., (9,7)	(8,2), ..., (8,6), (9,2), ..., (9,7)

5. Results

In this section we present the results of the experimental data. Our main focus is the efficiency implications of the new Uzbek reservoirs and the possibility of cooperation under the two regimes. For readability we will continue to label the players with the names of the countries they represent, though in fact they were experimental participants.

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[23] This feature eases the game-theoretic analysis, as we do not require a full-fledged backward induction analysis. However, a complete analysis is not difficult.

[24] Note that passing on zero does not imply that the Syr Darya is dry at the Uzbek-Kazakh border. We examine only the Naryn cascade, but as mentioned earlier, the river is also fed from other sources notably the Kara Darya. Since other sources are generally unregulated, their inflow levels are not strategic variables in the game and thus excluded.

5.1. Kyrgyz discharges from Toktogul

The economic efficiency of the outcome crucially relies on cooperation between Kyrgyzstan and Uzbekistan. We therefore first examine the behaviour of the participants representing the Kyrgyz side. Table 3 shows the relative frequency with which the different levels of water release occur in the experimental data.

In low water years we observe that the noncooperative choice is dominant in the data. Recall that with Q=10 (no reservoirs) the noncooperative release is 3 units and the Pareto-optimal choice is 6 units. The choice generating the efficient solution is made in only 5 percent of the cases, while in more than half of the years we observe the noncooperative release. Thus the subjects representing Kyrgyzstan did not show much trust in their downstream counterparts. This may be surprising given the high incidence of trustful choices in previous experiments on reciprocity games. A possible explanation is the high risk that Kyrgyzstan must take when deviating from the noncooperative (3 units) to the Pareto optimal choice (6 units). Under this scenario Kyrgyzstan renounces 477 talers (US$ 47.7m), and to gain maximum benefits relies on receiving at least as much as a side payment from Uzbekistan. To make such a high payment Uzbekistan would need to trust Kazakhstan to cooperate as well. Given that the total benefit from cooperation (the pie that can be divided among the two players on top of the noncooperative payoffs) is only 189 talers (US$ 18.9m), it is quite plausible that the players representing Kyrgyzstan in the laboratory deemed cooperation too risky.

Though the new reservoirs reduce Kyrgyzstan's risk of cooperation considerably for Q=10 (the Pareto optimal release is then only 4 units and requires Kyrgyzstan to renounce only 61 talers), the effect on the likelihood of cooperation is minor. While the frequency of Pareto optimal releases increases significantly from 5.0 to 18.8 percent ($\alpha=0.025$ one-sided, Fisher's two-sample randomisation test) it is still below one fifth, and there is an absolute majority of noncooperative choices. Thus even with the reduced risk for Kyrgyzstan the structure of the game imposes substantial hurdles to cooperation between the riparians.

In normal water years (Q=13) the noncooperative choice is also most frequent, and we even observe a substantial fraction of spiteful decisions (releases of 4 or 5 units, which yields the maximum payoff for Kyrgyzstan but harms Uzbekistan). These may be acts of punishment against the Uzbek player in response to default on side payments. Taking together the three equilibrium options (4,5 and 6 units) we observe noncooperative behaviour in more than 60 percent of the cases. However, the prospect for cooperation is not as bleak as in low-water years. Without reservoirs the Pareto optimal release (7 units) is realised in one third of the rounds, making this the second most frequent option. These results are independent of the new reservoirs, which do not have a statistically significant effect on cooperation.

Table 3. Relative frequency of Kyrgyz choices regarding Toktogul release

	Quantity passed by Kyrgyzstan						
Treatment	3	4	5	6	7	8	9
Q=10, no reservoirs	**0.562**	0.298	0.083	0.050	0.008	0.000	0.000
Q=13, no reservoirs	0.050	0.142	0.083	**0.383**	0.333	0.008	0.000
Q=16, no reservoirs	0.017	0.075	0.050	0.117	0.008	0.258	**0.475**
Q=10, with reservoirs	**0.586**	0.188	0.164	0.023	0.023	0.016	0.000
Q=13, with reservoirs	0.023	0.102	0.039	**0.500**	0.234	0.094	0.008
Q=16, with reservoirs	0.047	0.102	0.031	0.078	0.055	0.305	**0.383**

Note: The modal frequencies are set in bold face.

When water is abundant (Q=16) participants usually do not find it difficult to implement and sustain one of the efficient outcomes (a release of 8 or 9 units). However, note that in high water years there is no conflict between individual payoff maximisation and efficiency, such that this result does not hint at strong efforts to cooperate. In high-water years the new reservoirs are practically obsolete, and consequently they do not have a significant effect on the experimental results.[25]

5.2. Uzbek compensation to Kyrgyzstan

In order for all three countries to benefit from cooperation Uzbekistan needs to compensate Kyrgyzstan for its summer release of water. Table 4 shows Uzbekistan's median side payment to Kyrgyzstan, conditional on the quantity of water that Kyrgyzstan has released in summer. It emerges that Uzbekistan's reluctance to make sufficient payments is a source of cooperation failure. This is particularly pronounced in low water years without reservoirs. Recall that Kyrgyzstan renounces 477 talers ($47.7m) when moving from the noncooperative equilibrium to the Pareto optimum. The experimental Kyrgyzstan players who did so, however, received in the median a mere 25 talers ($2.5m) back as compensation. In the presence of Uzbek reservoirs Kyrgyzstan typically did not receive any reward for releasing the efficient 4 units. This explains the low level of cooperation we observe in low water years despite the fact that reservoirs make cooperation less risky. For Q=13 Kyrgyzstan must forego 98 talers to sustain a Pareto optimal outcome (with and without reservoirs), but the median Uzbek compensation payment also falls short of this (45.5 talers without reservoirs and 92.5 talers with reservoirs). Finally, in high-water years we also observe some use of side payments. Although Kyrgyzstan receives the same payoff in the interval 4 to 9 units, its decision greatly affects Uzbekistan. Therefore, Uzbekistan may choose to use side payments to reward Kyrgyzstan for non-spitefulness thereby sustaining high releases.

Table 4. Median compensation payment from Uzbekistan to Kyrgyzstan

	Quantity passed by Kyrgyzstan						
Treatment	3	4	5	6	7	8	9
Q=10, no reservoirs	0	0	15.5	25	0	—	—
Q=13, no reservoirs	0	0	0	2	45.5	100	—
Q=16, no reservoirs	0	0	0	0	25	80	41
Q=10, with reservoirs	0	0	90	205	0	10	—
Q=13, with reservoirs	0	0	20	0	92.5	170	0
Q=16, with reservoirs	5	0	5	1	0	50	50

Note: Amounts in talers. — No observations.

5.3. Downstream collaboration

The downstream riparians, Uzbekistan and Kazakhstan, rely on Kyrgyzstan's behaviour in order to achieve maximum payoffs. However, even without Kyrgyzstan's good will they often have room for improving their payoffs by cooperating. For each subgame (defined by Kyrgyzstan's release) we can identify a noncooperative equilibrium. In the payoff table this is obtained where Uzbekistan's payoff within one cell of equal releases from Kyrgyzstan is highest. For example, suppose that in a normal water year without reservoirs Kyrgyzstan has chosen to release 6 units. Uzbekistan's payoff is then maximised if it passes either 0 or 1 units. Thus both choices constitute a noncooperative equilibrium for the subgame with a Kyrgyz release of 6 units. The Pareto optimum can also be identified for each subgame separately, and is characterised as the Uzbek choice that maximises the total payoff within the cell. In the above example, Uzbekistan should pass 2 units.

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[25] Note that the Uzbek reservoirs are too small to enable multi-year regulation, i.e. to benefit from storing water inflows in high-water years and using it in low-water years.

As illustrated in table 5, Uzbekistan's choice can fall into one of four categories depending on whether it is a Pareto optimum and/or a noncooperative equilibrium or neither. The table shows that efforts to cooperate between the downstream riparians have been modest. Pareto optima which are not equilibria have only been implemented in very few rounds. Noncooperative equilibrium play is therefore the dominant outcome. In the treatment with reservoirs, virtually all of Uzbekistan's decisions fall into that category. Since Pareto optima often coincide with equilibrium choices in the subgames, this behaviour is not always inefficient. In at least 43 percent of cases the most efficient downstream solution was realised.

Table 5. Frequency of Uzbekistan's passed quantities

Treatment	(A) Pareto optimum, but not equilibrium	(B) Equilibrium, but not Pareto Optimum	(C) Pareto optimum and equilibrium	(D) Other	Total
Q=10, no reservoirs	0.050	0.075	0.717	0.158	1.000
Q=13, no reservoirs	0.075	0.325	0.417	0.183	1.000
Q=16, no reservoirs	0.034	0.184	0.683	0.100	1.001
Q=10, with reservoirs	0.000	0.547	0.430	0.023	1.000
Q=13, with reservoirs	0.000	0.500	0.492	0.008	1.000
Q=16, with reservoirs	0.000	0.336	0.664	0.000	1.000

5.4. The contracts and their adherence

In all six variants of the game participants find it difficult to come to an agreement, and if they do these agreements are frequently broken (Table 6). When water is scarce (Q=10) an agreement is made in only about a third of the rounds, and from these more than three-quarters are broken. The record is best when water is abundant and there is no conflict between short-run self-interest and cooperation. Still, even in those years a majority of contracts are not adhered to. In this case, however, the high rate of broken contracts may just reflect that contracts are not considered necessary and are therefore taken less seriously. Recall that in high water years there is a range of Pareto optimal choices. If the one implemented is different from the one that has been agreed on this then does not necessarily have negative consequences for the players.

Table 6. Frequency of agreements

Treatment	years with agreement	fraction of broken agreements
Q=10, no reservoirs	0.308	0.865
Q=13, no reservoirs	0.525	0.746
Q=16, no reservoirs	0.625	0.587
Q=10, with reservoirs	0.414	0.887
Q=13, with reservoirs	0.508	0.785
Q=16, with reservoirs	0.648	0.663

5.5. Efficiency

The total payoff gained by the three players jointly gives a measure of the efficiency of the experimental outcomes. Figure 3 shows this payoff (in US$ equivalents) for the six treatments of the experiment. Recall that the intercept terms of the payoff functions are unspecified. This implies that only differences between every two bars are meaningful, while the absolute values are partly determined by our choice for the experimental payoff tables.

As expected, high-water years lead to greater economic returns - a finding which is significant for all pairwise comparisons between two water levels in a given treatment ($\alpha<0.0001$, binomial test). The impact of reservoirs, however, is limited to low-water years. In those years reservoirs increase the median total payoff significantly ($\alpha<0.0001$, Fisher's two-sample randomisation test) and substantially by 161 talers (corresponding to \$16.1m in reality).[26] The slight rise in normal water years is not significant. When water is abundant we even observe a slight decrease in economic efficiency, but this difference is not significant and likely due to random variation.

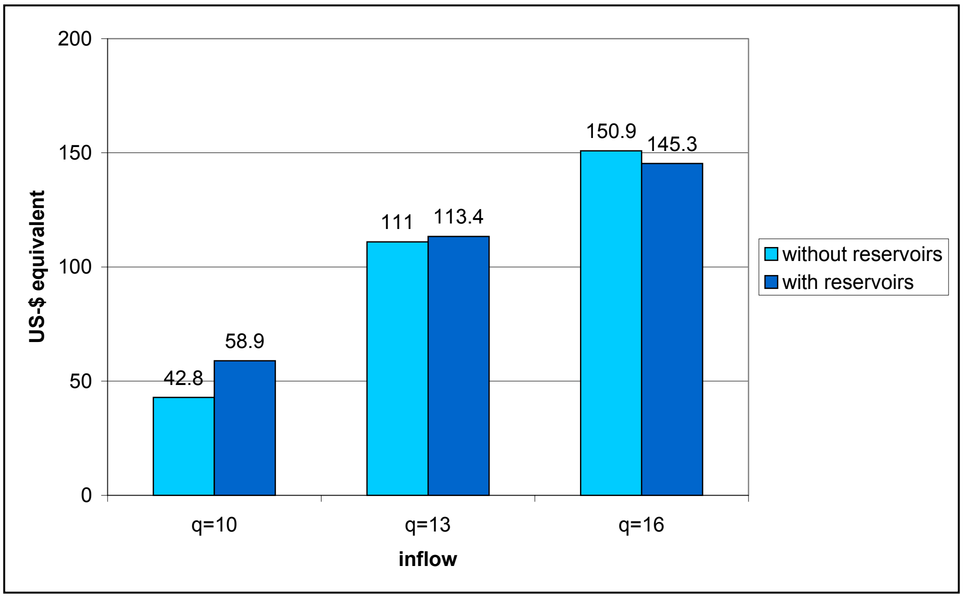

Figure 3. Median total payoff in US\$ equivalents

6. Summary and Conclusions

We examined the likely impact of new Uzbek reservoirs on the Syr Darya economies. This impact crucially depends on two issues. First, the reservoirs change the seasonal distribution of water availability in downstream Uzbekistan and Kazakhstan for any given release by Kyrgyzstan. Thus, payoffs from Kyrgyz water releases to the three countries have to be re-estimated. Secondly, the changed parameters may change the likelihood of regional cooperation. We designed a strategic game to address these issues. Costs and benefits of water releases were computed using data from the region. We then set up a laboratory experiment using the obtained payoff functions.

The theoretical analysis reveals that regional cooperation is still required for basinwide net benefits to be maximised. In this sense the reservoirs do not achieve the goal of Uzbek self-sufficiency. The experimental results strongly suggest that failure to cooperate is systematic. Inefficient noncooperative outcomes prevail in our experiments, in line with past behaviour in the river conflict, but in contrast to most trust games reported in the experimental literature. Experimental participants fail to set up mutually beneficial agreements (particularly in low-water years) and if agreements are made they are frequently broken. Thus our results suggest that failure to implement cooperative agreements should not be attributed to current decision makers' unwillingness alone. Cooperation failure is inherent to the structural features of

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[26] This figure is higher than the theoretical value in table 1. The difference stems mainly from the restrictive assumption on water sharing that we drop in the experimental design. Further influences are the slightly higher incidence of cooperative outcomes with reservoirs and the restriction to integer releases.

theriver conflict. Thus our results leave us pessimistic about decision makers being able to play the game more cooperatively in the future. Rather, they suggest to change the structure of the game, notably the sequence of water release and compensation that appears to make cooperation so difficult. While there are physical limits to synchronising water release and compensation in a barter scheme (due to prohibitive storage costs of energy and fuel), sophisticated installment schemes using money payments may help to reduce the risks to trustful behaviour.[27] Once these mechanisms are developed, new experiments can be designed to test their likely effectiveness.

The enhanced basinwide efficiency effect of the new reservoirs originates mainly from Uzbekistan's reduced dependency on Kyrgyz summer releases, and is limited to low-water years. A possible effect of enhanced cooperation can be detected statistically, but it is relatively small. As an overall effect of the new reservoirs we observe a median efficiency gain of the equivalent of an annual US$ 16.1 million for the low-water years, and no significant effect for normal and high-water years. Though this figure can naturally not be precise, it may provide an order of magnitude for a cost-benefit analysis of constructing the reservoirs. The benefits need to be weighed against the high construction costs. For these no official Uzbek figures are available, but they are estimated in the order of several hundred million dollars.

Of course, our findings have their limits. Though we have made every effort to trace the real economic framework as accurately as possible, no economic model (experimental or theoretical) can guarantee that no salient features of the real situation are lost or distorted when simplifying the economic environment. Undeniably the laboratory environment adds some artificiality as well. Despite these caveats we believe that the experimental methodology widens the scope for economic case studies, when behavioural influences are known to be relevant but natural data are unavailable.

Further, for the first experimental study on the Syr Darya river conflict we had to restrict the analysis to a few representative scenarios. Many future developments are uncertain today. In the long run, population growth, economic development, or world market demand for cotton may alter the parameters of the game. There are also worries that the glaciers and snow fields that feed the Syr Darya will shrink because of climate change. As a consequence, inflow would rise in the short run (because the melting water is added to the natural inflow), but fall in the long run (as glaciers are depleted).[28] This increased scarcity of water could reinforce the conflict in the future.

The relevant long-term future scenarios are also affected by strategic decisions outside our economic analysis. If construction plans for the Kambarata I and II hydropower plants in the Kyrgyz mountains are eventually realised an entirely different situation would arise. Kyrgyzstan would be able to generate an electricity surplus in winter, and use the Toktogul reservoir to re-regulate the Naryn river flow towards an irrigation mode. The Kambarata hydropower stations, however, are projects of a magnitude that Kyrgyzstan cannot shoulder on its own (estimates are in excess of US$ 2bn), and existing cost-effectiveness analyses question their economic viability. Nevertheless, both Russia and Kazakhstan have shown an interest in co-financing the projects (possibly to gain political influence in the region) and further research is needed should these plans materialise.

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[27] In this sense, our data call for a further development of a 'letter of credit' scheme like the one suggested in World Bank (2004a).

[28] According to current estimates the volume of glaciers on the territory of Kyrgyzstan will reduce significantly over the next quarter of a century resulting in a considerable diminution of water in the region's rivers (see for example IPCC, 2001)

While the set-up of the present experiment has been tailored to the Syr Darya river conflict, the methodology introduced is applicable to many other transboundary river conflicts as well. The other great Central Asian river, the Amu Darya, has characteristics that could turn the river into exactly the same problem as the Syr Darya, if upstream Tajikistan proceeds with plans to expand its hydropower capacity. In light of the Syr Darya experience, downstream Uzbekistan and Turkmenistan are seriously concerned that the conflict there may be replicated. On the river Nile there is potential for conflict if upstream Ethiopia decides to develop its substantial hydropower potential thus disrupting the growing season in Egypt. Namibian plans for the Popa Falls hydropower plant on the Okavango river potentially affect wildlife-oriented tourism in Botswana's national parks in the downstream Okavango delta. All these examples share a potential conflict between hydropower in an upstream country and other economic interests in another downstream country. In future it is likely that more conflicts will emerge since only 10 percent of the world's hydropower potential is currently being exploited (Khagram, 2004). This source of energy can therefore be expected to play a much greater role than today, and management of the resulting water conflicts becomes an even more vital issue.

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Appendix A. Data used for model estimation.

Table A.1 Historical flow data (BCM), Toktogul Reservoir, 1988-2003.

Year	Total Inflow	Total Outflow	Summer Inflow	Summer Outflow	Winter Inflow	Winter Outflow
1988	16.52	12.24	13.46	8.80	3.06	3.44
1989	10.13	14.97	7.34	10.97	2.79	4.00
1990	12.99	11.60	10.25	7.09	2.74	4.51
1991	10.74	13.16	7.93	8.51	2.81	4.65
1992	12.05	12.19	9.05	6.55	3.00	5.64
1993	13.64	10.59	10.61	4.41	3.03	6.18
1994	15.24	14.52	12.08	6.72	3.16	7.80
1995	10.89	14.62	7.88	6.33	3.01	8.29
1996	13.70	14.53	10.94	6.16	2.76	8.37
1997	10.83	13.68	8.09	6.08	2.74	7.60
1998	14.49	11.16	11.50	3.68	2.99	7.48
1999	14.47	13.47	11.01	5.07	3.46	8.40
2000	12.62	15.18	9.19	6.48	3.43	8.70
2001	12.56	15.15	9.29	5.91	3.27	9.24
2002	16.67	11.38	13.51	3.65	3.16	7.73
2003	15.67	14.16	12.00	4.90	3.67	9.26
Average	13.33	13.29	10.26	6.33	3.07	6.96
Percentage	100%	100%	77.0%	47.7%	23.0%	52.3%
Minimum	10.13	10.59	7.34	3.65	2.74	3.44
Maximum	16.67	15.18	13.51	10.97	3.67	9.26
Standard Deviation	2.09	1.56	1.96	1.91	0.28	1.94

Source: Primary data provided by JSC Kyrgyzenergo, Bishkek.

Table A.2 Assumed values of exogenous variables and parameters.

Name	Description	Unit	Value	Source
α	Hydropower efficiency	m^3/kWh	0.86	3
E^s	Net energy demand, summer	GWh	2,550	1
E^w	Net energy demand, winter	GWh	4,950	1
ν^s	Technical transmission efficiency, summer	percent	90.0	1
ν^w	Technical transmission efficiency, winter	percent	85.0	1
K	Generation capacity, Bishkek I	GWh	876	1
C^I	Short-run marginal cost, Bishkek I	US$/kWh	0.0150	1
C^{II}	Short-run marginal cost, Bishkek II	US$/kWh	0.0255	2
C_{uz}	Short-run marginal cost, Uzbekistan	US$/kWh	0.0230	1
C_{ka}	Short-run marginal cost, Kazakhstan	US$/kWh	0.0210	1
ρ	Technical transmission efficiency, exports	percent	94.0	1
γ	Share of electricity exported to Uzbekistan	percent	50.0	1
X	Maximum hydropower export volume	GWh	4,000	4
P	Economic value of irrigation water	US$/KCM	20	1
O_{uz}	Optimal irrigation input for Uzbekistan	BCM	4.5	1,3
O_{ka}	Optimal irrigation input for Kazakhstan	BCM	2.0	1,3

References: (1) World Bank (2004a); (2) World Bank (2004b); (3) Antipova et al (2002), and; (4): Peter Graham, Tariff Policy & Utility Reform Project, DFID Bishkek (personal communication, 9 February 2005).

Appendix B. The Payoff Tables

Table B1. Payoff table for Q=10 without Uzbek reservoirs.

Units passed by player 1	Units passed by player 2	Player 1's payoff	Player 2's payoff	Player 3's payoff	Total payoff
3	0	333	12	83	428
3	1	333	-58	139	414
3	2	333	-128	195	400
3	3	333	-198	195	330
4	0	272	148	144	564
4	1	272	78	200	55
4	2	272	8	256	536
4	3	272	-62	256	466
4	4	272	-132	256	396
5	0	76	277	229	582
5	1	76	242	285	603
5	2	76	172	341	589
5	3	76	102	341	519
5	4	76	32	341	449
5	5	76	-38	341	379
6	0	-144	370	314	540
6	1	-144	370	370	596
6	2	-144	335	426	617
6	3	-144	265	426	547
6	4	-144	195	426	477
6	5	-144	125	426	407
6	6	-144	55	426	337
7	0	-364	463	399	498
7	1	-364	463	455	554
7	2	-364	463	511	610
7	3	-364	428	511	575
7	4	-364	358	511	505
7	5	-364	288	511	435
7	6	-364	218	511	365
7	7	-364	148	511	295
8	0	-583	549	478	444
8	1	-583	549	534	500
8	2	-583	549	590	556
8	3	-583	549	590	556
8	4	-583	514	590	521
8	5	-583	444	590	451
8	6	-583	374	590	381
8	7	-583	304	590	311
8	8	-583	234	590	241
9	0	-803	549	478	224
9	1	-803	549	534	280
9	2	-803	549	590	336
9	3	-803	549	590	336
9	4	-803	549	590	336
9	5	-803	514	590	301
9	6	-803	444	590	231
9	7	-803	374	590	161
9	8	-803	304	590	91
9	9	-803	234	590	21

Table B2. Payoff table for Q=10 with Uzbek reservoirs.

Units passed by player 1	Units passed by player 2	Player 1's payoff	Player 2's payoff	Player 3's payoff	Total payoff
3	0	333	117	83	533
3	1	333	117	139	589
3	2	333	47	195	575
3	3	333	-23	195	505
4	0	272	183	144	599
4	1	272	183	200	655
4	2	272	183	256	711
4	3	272	113	256	641
4	4	272	43	256	571
5	0	76	277	229	582
5	1	76	277	285	638
5	2	76	277	341	694
5	3	76	277	341	694
5	4	76	207	341	624
5	5	76	137	341	554
6	0	-144	370	314	540
6	1	-144	370	370	596
6	2	-144	370	426	652
6	3	-144	370	426	652
6	4	-144	370	426	652
6	5	-144	300	426	582
6	6	-144	230	426	512
7	0	-364	463	399	498
7	1	-364	463	455	554
7	2	-364	463	511	610
7	3	-364	463	511	610
7	4	-364	463	511	610
7	5	-364	463	511	610
7	6	-364	393	511	540
7	7	-364	323	511	470
8	0	-583	549	478	444
8	1	-583	549	534	500
8	2	-583	549	590	556
8	3	-583	549	590	556
8	4	-583	549	590	556
8	5	-583	549	590	556
8	6	-583	549	590	556
8	7	-583	479	590	486
8	8	-583	409	590	416
9	0	-803	549	478	224
9	1	-803	549	534	280
9	2	-803	549	590	336
9	3	-803	549	590	336
9	4	-803	549	590	336
9	5	-803	549	590	336
9	6	-803	549	590	336
9	7	-803	549	590	336
9	8	-803	479	590	266
9	9	-803	409	590	196

Table B3. Payoff table for Q=13 without Uzbek reservoirs.

Units passed by player 1	Units passed by player 2	Player 1's payoff	Player 2's payoff	Player 3's payoff	Total payoff
3	0	333	12	83	428
3	1	333	-58	139	414
3	2	333	-128	195	400
3	3	333	-198	195	330
4	0	370	148	144	662
4	1	370	78	200	648
4	2	370	8	256	634
4	3	370	-62	256	564
4	4	370	-132	256	494
5	0	370	277	229	876
5	1	370	242	285	897
5	2	370	172	341	883
5	3	370	102	341	813
5	4	370	32	341	743
5	5	370	-38	341	673
6	0	370	370	314	1,054
6	1	370	370	370	1,110
6	2	370	335	426	1,131
6	3	370	265	426	1,061
6	4	370	195	426	991
6	5	370	125	426	921
6	6	370	55	426	851
7	0	272	463	399	1,134
7	1	272	463	455	1,190
7	2	272	463	511	1,246
7	3	272	428	511	1,211
7	4	272	358	511	1,141
7	5	272	288	511	1,071
7	6	272	218	511	1,001
7	7	272	148	511	931
8	0	76	549	478	1,103
8	1	76	549	534	1,159
8	2	76	549	590	1,215
8	3	76	549	590	1,215
8	4	76	514	590	1,180
8	5	76	444	590	1,110
8	6	76	374	590	1,040
8	7	76	304	590	970
8	8	76	234	590	900
9	0	-144	549	478	883
9	1	-144	549	534	939
9	2	-144	549	590	995
9	3	-144	549	590	995
9	4	-144	549	590	995
9	5	-144	514	590	960
9	6	-144	444	590	890
9	7	-144	374	590	820
9	8	-144	304	590	750
9	9	-144	234	590	680

Table B4. Payoff table for Q=13 with Uzbek reservoirs.

Units passed by player 1	Units passed by player 2	Player 1's payoff	Player 2's payoff	Player 3's payoff	Total payoff
3	0	333	117	83	533
3	1	333	117	139	589
3	2	333	47	195	575
3	3	333	-23	195	505
4	0	370	183	144	697
4	1	370	183	200	753
4	2	370	183	256	809
4	3	370	113	256	739
4	4	370	43	256	669
5	0	370	277	229	876
5	1	370	277	285	932
5	2	370	277	341	988
5	3	370	277	341	988
5	4	370	207	341	918
5	5	370	137	341	848
6	0	370	370	314	1,054
6	1	370	370	370	1,110
6	2	370	370	426	1,166
6	3	370	370	426	1,166
6	4	370	370	426	1,166
6	5	370	300	426	1,096
6	6	370	230	426	1,026
7	0	272	463	399	1,134
7	1	272	463	455	1,190
7	2	272	463	511	1,246
7	3	272	463	511	1,246
7	4	272	463	511	1,246
7	5	272	463	511	1,246
7	6	272	393	511	1,176
7	7	272	323	511	1,106
8	0	76	549	478	1,103
8	1	76	549	534	1,159
8	2	76	549	590	1,215
8	3	76	549	590	1,215
8	4	76	549	590	1,215
8	5	76	549	590	1,215
8	6	76	549	590	1,215
8	7	76	479	590	1,145
8	8	76	409	590	1,075
9	0	-144	549	478	883
9	1	-144	549	534	939
9	2	-144	549	590	995
9	3	-144	549	590	995
9	4	-144	549	590	995
9	5	-144	549	590	995
9	6	-144	549	590	995
9	7	-144	549	590	995
9	8	-144	479	590	925
9	9	-144	409	590	855

Table B5. Payoff table for $Q=16$ without Uzbek reservoirs.

Units passed by player 1	Units passed by player 2	Player 1’s payoff	Player 2’s payoff	Player 3’s payoff	Total payoff
3	0	333	12	83	428
3	1	333	-58	139	414
3	2	333	-128	195	400
3	3	333	-198	195	330
4	0	370	148	144	662
4	1	370	78	200	648
4	2	370	8	256	634
4	3	370	-62	256	564
4	4	370	-132	256	494
5	0	370	277	229	876
5	1	370	242	285	897
5	2	370	172	341	883
5	3	370	102	341	813
5	4	370	32	341	743
5	5	370	-38	341	673
6	0	370	370	314	1,054
6	1	370	370	370	1,110
6	2	370	335	426	1,131
6	3	370	265	426	1,061
6	4	370	195	426	991
6	5	370	125	426	921
6	6	370	55	426	851
7	0	370	463	399	1,232
7	1	370	463	455	1,288
7	2	370	463	511	1,344
7	3	370	428	511	1,309
7	4	370	358	511	1,239
7	5	370	288	511	1,169
7	6	370	218	511	1,099
7	7	370	148	511	1,029
8	0	370	549	478	1,397
8	1	370	549	534	1,453
8	2	370	549	590	1,509
8	3	370	549	590	1,509
8	4	370	514	590	1,474
8	5	370	444	590	1,404
8	6	370	374	590	1,334
8	7	370	304	590	1,264
8	8	370	234	590	1,194
9	0	370	549	478	1,397
9	1	370	549	534	1,453
9	2	370	549	590	1,509
9	3	370	549	590	1,509
9	4	370	549	590	1,509
9	5	370	514	590	1,474
9	6	370	444	590	1,404
9	7	370	374	590	1,334
9	8	370	304	590	1,264
9	9	370	234	590	1,194

Table B6. Payoff table for $Q=16$ with Uzbek reservoirs.

Units passed by player 1	Units passed by player 2	Player 1’s payoff	Player 2’s payoff	Player 3’s payoff	Total payoff
3	0	333	117	83	533
3	1	333	117	139	589
3	2	333	47	195	575
3	3	333	-23	195	505
4	0	370	183	144	697
4	1	370	183	200	753
4	2	370	183	256	809
4	3	370	113	256	739
4	4	370	43	256	669
5	0	370	277	229	876
5	1	370	277	285	932
5	2	370	277	341	988
5	3	370	277	341	988
5	4	370	207	341	918
5	5	370	137	341	848
6	0	370	370	314	1,054
6	1	370	370	370	1,110
6	2	370	370	426	1,166
6	3	370	370	426	1,166
6	4	370	370	426	1,166
6	5	370	300	426	1,096
6	6	370	230	426	1,026
7	0	370	463	399	1,232
7	1	370	463	455	1,288
7	2	370	463	511	1,344
7	3	370	463	511	1,344
7	4	370	463	511	1,344
7	5	370	463	511	1,344
7	6	370	393	511	1,274
7	7	370	323	511	1,204
8	0	370	549	478	1,397
8	1	370	549	534	1,453
8	2	370	549	590	1,509
8	3	370	549	590	1,509
8	4	370	549	590	1,509
8	5	370	549	590	1,509
8	6	370	549	590	1,509
8	7	370	479	590	1,439
8	8	370	409	590	1,369
9	0	370	549	478	1,397
9	1	370	549	534	1,453
9	2	370	549	590	1,509
9	3	370	549	590	1,509
9	4	370	549	590	1,509
9	5	370	549	590	1,509
9	6	370	549	590	1,509
9	7	370	549	590	1,509
9	8	370	479	590	1,439
9	9	370	409	590	1,369

Appendix C: Instructions for the Experiment

General information

We thank you for coming to the experiment. The purpose of this session is to study how people make decisions in a particular situation. During the session it is not permitted to talk or communicate with other participants. If you have a question, please raise your hand and the facilitator will come to your desk to answer it. During the session you will earn money. At the end of the session the amount you have earned will be paid to you in cash. Payments are confidential. We will not inform any of the other participants about the amount you have earned. In the following, all amounts of money are denominated in *talers*, the experimental currency unit.

The participants in this session are divided into groups of three participants. These groups play completely independently. The composition of the groups remains the same throughout the experiment. You do not know which of the other participants are in your group.

There are three types of players in this game: Player 1, player 2, and player 3. Participants play the same role throughout the experiment.

The experiment consists of twenty-four *rounds* with the same decision situation. Each round is structured as explained below.

Payoff structure

In each round the three players must divide a resource. At the end of each round the players receive a payoff depending on how the resource has been divided. The division of the resource takes place as follows:

Player 1 receives a quantity of the resource. Player 1 can then pass on some quantity of the resource to player 2. After player 2 has received a share of the resource, he or she can pass on some quantity of this share to player 3.

Player 1's payoff from the resource depends on two factors: (1) how much of the resource is available, and (2) how much of the resource is passed on to player 2.

Player 2's payoff depends on the quantity of the resource received from player 1 minus the quantity passed on to player 3.

Player 3's payoff depends on the quantity of the resource received from player 2.

The payoff of the three players is listed in the enclosed table.

The three player's payoff also depends on the payments they make to each other in exchange for the resources received. This is explained in more detail below.

The decision situation

Each of the twenty-four rounds consists of two stages. The first stage is the *negotiation* stage. The second stage is the *implementation* stage.

The negotiation stage

In the negotiation stage the players can make a non-binding agreement over (1) the division of the resource, and (2) payments they make between each other. This is done in the following steps:

Step 1: One of the three players is selected to be the proposer. This selection is random and each player is selected to be the proposer with probability one third.

Step 2: The selected player makes a proposal which specifies the following aspects:

- How many units of the resource player 1 passes on to player 2. All integer numbers between three and nine are feasible.
- How many units of the resource player 2 passes on to player 3. Feasible are all integer numbers between zero and the maximum possible (i.e. the number of units passed from player 1 to player 2).
- How many talers player 2 pays to player 1. All integer numbers from 0 to 1,000 are feasible.
- How many talers player 3 pays to player 2. All integer numbers from 0 to 1,000 are feasible.

Step 3: Each of the two other players (apart from the proposer) decides whether to accept or reject the proposal.

Note that an agreement made in the negotiation stage is not binding. It does not commit the players to act in any particular way at the implementation stage.

The implementation stage

In the implementation stage the division of the resource as well as payments between players are implemented. This is done in the following steps:

Step 4: Player 1 decides how many units of the resource to pass on to player 2. This number must be between three and nine (both inclusive).

Step 5: Player 2 decides how many units of the resource to pass on to player 3. Feasible are all integer numbers between zero and the total amount of units received from player 1.

Step 6: Player 2 decides how many talers to pay player 1. All integer numbers from 0 to 1,000 are feasible.

Step 7: Player 3 decides how many talers to pay player 2. All integer numbers from 0 to 1,000 are feasible.

Phases

The experiment is divided into of three *phases*, each consisting of eight rounds. Each round is played exactly the same way as described above. The rounds differ in the quantity of the resource that is available.

The players' payoffs vary with the available quantity of the resource. Therefore a different payoff table is used for each phase. At the outset of a new phase you will be given the relevant payoff table. Please note that the payoff table lists the payoffs of the players *excluding* the payments made between them.

Payoffs

You start with an initial capital of 1,000 talers. Your payoff from each round will be added to this amount. At the end of the session the talers are converted into Pound Sterling at an exchange rate of £2.50 per 1,000 talers. The minimum payoff is £3.