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Glaciers and Efficient Water Use in Central Asia

Urs Luterbacher, Valerii Kuzmichenok, Gulnara Shalpykova, and Ellen Wiegandt

Among their many roles, glaciers serve as important reserves of freshwater. Water in the form of glaciers is particularly valuable because it constitutes a stock that tends to be released in periods when water in other forms is scarcest. These general characteristics of water create complex management problems. In addition, the current retreat of many glaciers alerts us that supplies may be changing in the future. When the inherent qualities of water and of glaciers are superimposed on evolving political and economic circumstances, the potential for conflict is substantially enhanced. Central Asia constitutes just such a case. Here, a political structure in which internal relations were managed by a strong central authority under the Soviet system has become one of international relations among upstream and downstream states, in which other asymmetries also play an important role. Formerly interdependent regions vie as autonomous entities for water for irrigation (under conditions of low precipitation) and for energy production. Currently, tensions are high, but there is no overt conflict. Avoiding future outbreaks of violence among the republics, especially between those upstream, where water resources originate, and downstream, where the level of use is highest, will require complex negotiations among the parties. Achieving agreements will require understanding the fundamental issues of water allocation, forecasting the evolution of glaciers, and balancing the needs and wants of the various populations. Our research into these interacting aspects leads to some concrete proposals for solutions for the water management problems in the region.

GLACIERS AND WATER RESOURCES IN CENTRAL ASIA

The Central Asian states of Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan, and Kazakhstan draw their water from the Amu Darya and Syr Darya Rivers. The latter originates in the Tien-Shan and Pamir-Alay Mountains of eastern Kyrgyzstan, at altitudes of 7,000 m, and then flows through Kyrgyzstan, Tajikistan, and Uzbekistan to Kazakhstan and into the Aral Sea. The Amu Darya has its source in the Pamir region of Tajikistan and then forms the border between Tajikistan and Afghanistan before

FIGURE 19.1. The geographical and geopolitical situation.

[AQ3]

becoming the border between Uzbekistan and Turkmenistan and then flowing into the Aral Sea. Kyrgyzstan is thus a vital link in the hydrological system of the region and, in addition, contains 45% of the glaciers of the Central Asian republics of the former Union of Soviet Socialist Republics (USSR).

All Central Asian states are dependent to varying degrees on irrigated crops for survival and draw their water from the Amu Darya and Syr Darya river systems fed by the upland glaciers. Intensive production has led to overuse of water resources and to the drying of the Aral Sea. The resulting water shortages have created tensions with the upstream republics of Kyrgyzstan and Tajikistan, which rely on glacier meltwater for the production of electricity from hydropower. Glacier meltwater provides for irrigation but also serves to fill high-altitude retention lakes constituted by dams placed in certain river basins. How these resources are exploited and distributed depends largely on the entitlements attached to the water and the accompanying rights, privileges, obligations, and limitations related to its use. These constitute property rights, and they act in effect as quotas that control access and limit quantities used. How effectively these rules are designed and followed determines whether use of particular resources will be sustainable.

The prevailing view in economics has long been that private property rights lead to efficiency of resource use. As Dasgupta and Heal (1979: 48–52) show, however, clear definition and effective enforcement of property rights are essential, and flowing water is a resource for which property rights are difficult both to define and to enforce. It cannot be treated as a separate commodity because it is in a "constant state of diffusion" (p. 49) or movement, and a precise unit therefore cannot be allocated to a single individual. In the case of pools of underground water, property rights can be defined as an area of land above them, but it will not be clear whether the water extracted really comes from the area below this surface because of the fluid nature of the resource. In the case of glaciers and the water resources associated with them, similar problems arise: Glaciers are usually situated in relatively remote areas that cannot easily be controlled. What flows from up high is therefore difficult to attribute to a single owner and sometimes even to a single country. Principles for sharing the resource must be designed, a fact recognized by most legal systems even at the international level. There is, however, no international water regime in place.

The interrelation between the inherent characteristics of water and the technologies used to exploit it has frequently led to common-property arrangements and collective structures for allocating and managing water resources to prevent some groups or individuals from overusing them at the expense of others. Without socially imposed limits, the end result is overexploitation and dissipation of the resource (Figure 19.3). The use of a natural resource, such

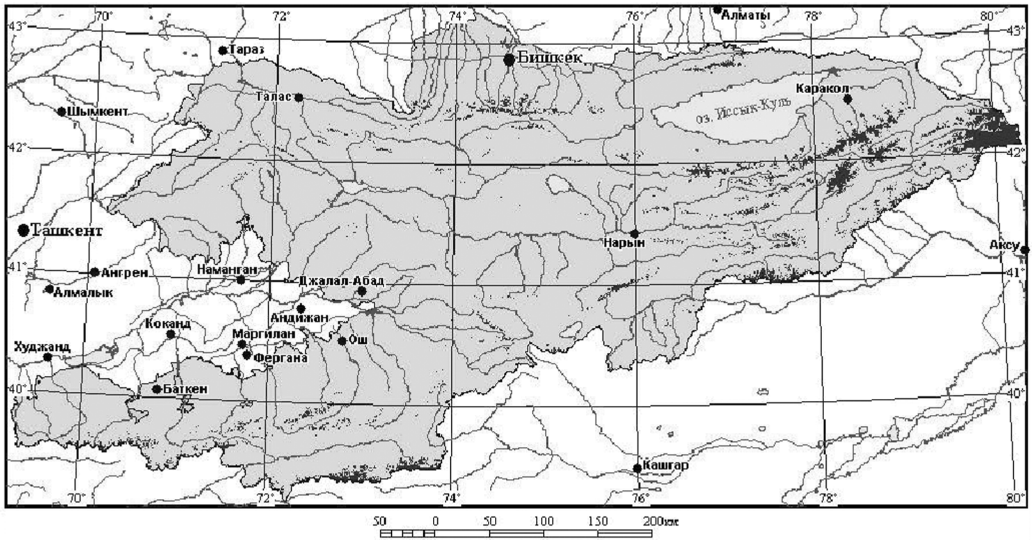

FIGURE 19.2. The glaciers of Kyrgyzstan. [AQ4]

as water for irrigation, depends on the number of producers willing to share in its supply. The operation of the production system (taking into account initial investments) requires a relatively large number of producers, leading initially to increasing returns to scale. As more and more producers join, however, diminishing returns set in. This is illustrated by the S shape of the production curve. The fixed cost per unit of production for each producer crosses the production curve at two points: at A, where the number of producers is sufficient to initiate profitability, and at C, where an excess of producers has eliminated profits or surpluses. The optimum lies at B, which maximizes surplus production over costs. This optimal situation can be maintained by limiting the number of producers entering the process either by exclusion or by taxes, which increase the fixed costs for each entrant. A solution to the problem involving taxes is represented by the thin straight line parallel to the cost line and tangent to the production curve at B, showing that correct taxation of entrants limits their number and ensures maintenance of the scarcity rent.

Inefficiency from overexploitation of a common resource can always be corrected by an appropriate taxation policy. Establishing such a tax is relatively easy in the general case because profit seeking leads to a single maximum. The tax limits the number of users entering production. Dasgupta and Heal (1979) show, however, that such an outcome usually does not obtain when asymmetries are present, as is the case with upstream-downstream relations under differentially defined property rights. In the case, for example, of a downstream firm that must base its production on water that is already being used by an upstream firm, there are two important considerations. One is the degree of use due to the first firm, which may significantly reduce the possible profits for the second firm. The other is the property rights (or legal rights and obligations) that the firms have with respect to each other in terms of clean water. If the first firm has an unlimited right to the water and the second rights only to what remains of it, the second will eventually be driven out of business in the absence of some negotiated arrangement between the two. Conversely, if the first firm is constrained to limit its use in consideration of the needs of second, it may have to cease its activities. Assigning property rights to one side or the other changes the production possibilities and the relations between the two firms. The firms' production possibilities are no

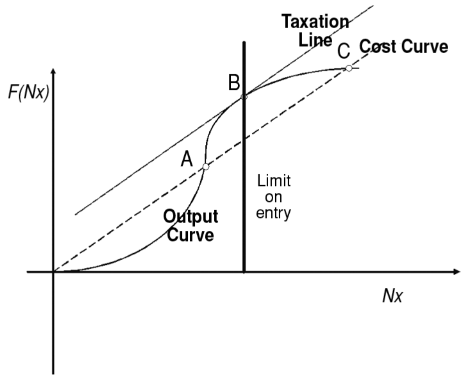

FIGURE 19.3. Limiting natural resource use. *F(Nx)*, use of the resource; *Nx*, number of producers willing to share in its supply.

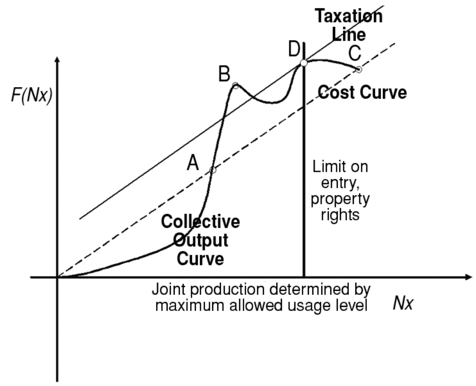

FIGURE 19.4. Multiple taxation equilibrium case due to preestablished property rights.

longer convex, and neither taxation nor buying or selling of rights will bring a uniquely defined equilibrium solutions.

In Figure 19.4, B would represent a higher level of profit than ~~E~~, but joint production will remain at ~~E~~ because property rights permit one firm to keep the other from using the resource more efficiently by restricting usage for the first. If the two firms can agree on a solution that, under redistribution of profits arising from higher efficiency, allows them both to be better off, then they should adopt it. In reality, however, the problem can be more complex, because giving up property rights ultimately raises a credibility problem. If the first firm abandons some of its property rights to the second firm in exchange for a share of higher profits, it has to have a strong guarantee that the second firm will indeed share its profits. Whereas at the domestic level this problem can usually be solved by contract, nothing like this occurs in an international setting between sovereign states. In Central Asia, the situation might be better overall if upstream countries were allowed to produce electricity with enough water for their use (at B) but had to release it to less efficient downstream users (at ~~E~~), but the credibility problem we have mentioned keeps downstream republics from relinquishing their water rights.

In cases where glaciers are present, the most common confrontations among users revolve around the positions that various users occupy between the high-altitude source of the water (the glacier) and the place where the river system enters a sea. A cursory analysis would conclude that upstream users have control and power over downstream users. However, this is not necessarily the case, because downstream users may have more economic and power resources with which they can retaliate against any upstream attempt to cut off the supply of water. Only when an upstream nation has substantial economic and power resources in addition to its location can it impose its goals on downstream users.

CENTRAL ASIA: THE PROBLEM

Reports from Central Asia regularly alert the international community to worsening ecological conditions, the dire social and economic status of its population, and the ensuing potential for serious civil and interstate conflict. The recent riots and upheavals in Uzbekistan and Kyrgyzstan are an illustration of latent hostilities. The situation is particularly complex and delicate because familiar problems of overextensive irrigation agriculture and population increase have become mixed with interstate politics as a result of the collapse of the USSR.

Fluvial water resources play essential roles in the economy and society of the Central Asian states of Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan, and Kazakhstan, all dependent in varying degrees on irrigated crops. Cotton, the most important irrigation crop, is the major source of income and employment in Turkmenistan and Uzbekistan. Its production was encouraged under the Soviet system as a source of hard currency. Overuse of water resources for irrigation, however, is responsible for the drying of the Aral Sea, whose surface area and volume have declined by 35% and 58%, respectively, since the mid-1980s. This has aggravated local climate conditions, reduced the amount of water available for agriculture, and deprived the upstream countries of Kyrgyzstan and Tajikistan of the amounts necessary for their hydropower production, which accounts for 50% of their electricity production. These competing water uses are only made worse by demographic patterns that have led to an increase in population of 140% between 1959 and 1989 (Horsman 2001: 71) and a further projected increase of 35–50% in most of the states between now and 2050 (Population Reference Bureau 2002).

Although tensions over water allocation are not new, they have taken on new significance since the collapse of the USSR. Previously managed from Moscow by a centralized administration, water systems have suddenly come under the control of separate sovereign states that have no history of agreements or coordination structures. This poses important allocation problems. Upstream states Kyrgyzstan and Tajikistan need water for hydroelectric production as well as irrigation, while Kazakhstan and Uzbekistan use water mostly for irrigation. The upstream republics have held up the release of water or threatened to charge for delivery downstream to pressure downstream users to compensate them for the energy production forgone when water is released for downstream irrigation. Despite their control over the source of water, upstream states are implicated in allocation schemes that oblige them to provide water downstream. Soviet patterns of allocation were reaffirmed in the Almaty agreement of 1992 but have never been perceived to be equitable.[1] They continue to reflect the favored status that downstream countries had achieved. Kyrgyzstan and Tajikistan would like to expand irrigation agriculture as well as electricity production. However, their dominant upstream position does not permit them to achieve these goals because of their political weakness in the face of the downstream users' control over coal and gas (Horsman 2001: 74–75). Indeed, after independence Uzbekistan and Kazakhstan introduced market prices for gas and coal. Kyrgyzstan could not pay these higher prices, and its response was to increase electricity production to augment revenues. This meant that the amount of water available for irrigation in Uzbekistan and Kazakhstan was reduced. As a consequence, agreements were not respected. In breaching or threatening to breach those agreements, upstream states became vulnerable to reprisals from downstream states.

The case of Central Asia illustrates two important aspects of the way in which water is distributed and used. One is that upstream republics can control the quantities of water sent downstream but are subject to reprisals because they do not control other critical resources such as gas and coal. The other is that, when users of a natural resource have both unclear property rights and crosscutting powers or access, there is no obvious solution that is both equitable and efficient. Management schemes must therefore be negotiated.

A potential solution for Central Asia would be to compensate for the asymmetry in access to water by industrial and agricultural developments that would benefit all the countries concerned. Two countries or regions could share in the advantages created by the development of water resources in one of them by specializing in complementary activities, for example, concentrating industry in the area less suitable for agriculture, taking advantage of the cheaper electric power made available by dam construction upstream. High-altitude countries could develop high-pressure dams,[2] like those in the Alps, that are not very harmful to countries downstream. These dams also have the advantage of providing large amounts of electric power under peak load conditions. This allows them to serve the industrial needs of firms located relatively far away and thus be useful beyond the boundaries of a given country. The high-altitude but relatively poor countries of Kyrgyzstan and Tajikistan could benefit from such schemes. International organizations such as the World Bank could devise policies that favor such positive spillovers and thus help to resolve otherwise intractable water disputes, in part by offering to be guarantors of future profit sharing.

Under the present system, Kyrgyzstan receives only 10% of the waters of the Syr Darya basin, the remainder being used for irrigation downstream. There may be ways of producing gains in hydropower development that would more than make up for the potential losses in agriculture from slightly diminished irrigation. Of course, such gains will be of interest only if all the countries in the region benefit from them, and this will be the case only if they cover significant regional needs and if all the countries have some institutional control over hydropower use. We will suggest that both possibilities exist. In particular, we will show that the development of hydropower can enhance industrial efficiency for the whole region and that all the countries can profit from it. Moreover, given the legal obligations of the Almaty agreement, a transnational institutional setup for this development can also be established.

GLACIERS AND ENHANCED WATER RESOURCES IN CENTRAL ASIA

To examine future water resource potential, we studied the current and projected extent and water content of key glaciers. Glaciers within Kyrgyzstan make up 47% of the total glacial area in the region. The largest glaciers are situated at an altitude of about 4,000 m. Climate change and the resulting glacier melt and loss of ice mass over time have consequences for the hydrological system of the country, notably by increasing annual water flows of several major rivers. Moreover, water supply will be enhanced not only by additional glacier melt but also by an expected increase in precipitation.

Translating all these characteristics into potential water flows for Kyrgyzstan, we find that they amount to about 51 km^3. Under climate change, these flows could actually increase by 10% because of increased precipitation and glacier melt, making available more than 56 km^3. According to the estimates made by the Institute of Water Problems and Hydropower, this additional water could be used to produce 150 billion kWh of electricity, more than the present combined electricity production of Kazakhstan, Uzbekistan, and Kyrgyzstan, if its potential were fully used. There is therefore considerable potential for growth, and it could be nearly doubled if similar resources in Tajikistan were also used. To examine the impact of this capacity on the country's economy and that of its neighbors, we carried out empirical analyses of present conditions and constructed socioeconomic models to explore future developments in the various countries of the region.

Economic trends for the countries of Central Asia tend to confirm the tendencies noticed for other transitional states. When they abandoned Soviet-style economies in the 1990s, these countries all experienced a period of decline in their gross domestic products. Then, from around 1995 on, expansion resumed. Measurements of value added,[3] both in agriculture and in industry, show the same. For agriculture, however, the rebound was slower for Kazakhstan than for Kyrgyzstan and Uzbekistan, and Kyrgyzstan, originally the lowest agricultural producer of the three, showed the highest growth rates after 1995.

To calculate the effects of specific capacity improvement schemes, we constructed value-added country models involving important sectors of the economy and their water resources input, either direct (as in the case of irrigation) or indirect (as in the case of electricity). We derived the gross domestic product (GDP), the most commonly used measure in national accounts statistics for economic growth, as a sum of gross value added (GVA) by resident producers net of

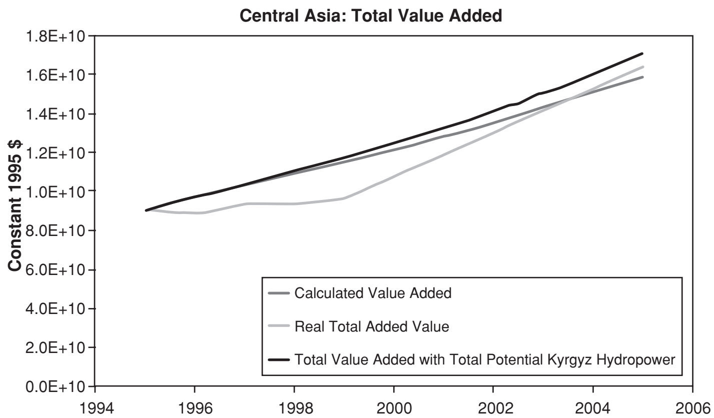

FIGURE 19.5. Total value added.

taxes (taxes − subsidies). Typically, to arrive at the GDP for the economy, economic activity is divided on a sectoral basis and then summed again. Thus, the GDP consists of the GVA generated in the agricultural, industrial, and services sectors. These quantities can then be represented in term of their monetary values by a vector of input (p_i) and output prices (p_o): GVA = Value of Output ($p_o.q_{\text{output}}$) − Value of intermediate inputs ($p_i.q_{\text{input}}$) + Net Taxes. Water enters as an input in the measurement of GVA in each of the three sectors. Thus the total water available in the system must be distributed across these three sets of activities as well as consumption for domestic activities and by the environment, which act as a constraint on the water available for productive activities. While it would be reasonable to assume that consumption by the environment is more or less a static amount, the same is not true for domestic consumption. The latter may increase or decrease depending on the rate of population growth and the assumptions made about per capita water consumption. Thus each scenario, whether baseline, increasing, or decreasing, has implications for the water available for agriculture, industry, and services. Here our data consist of the value added in agriculture and industry for the three countries considered. We then try to determine the evolution of gross value added for each sector. The evolution of gross value in agriculture is represented as the difference between the desired level, which depends on income and available water for irrigation, and the actual level, which dampens the increase and depends on the current level of gross value added. In addition, labor, which can be approximated by the proportion of the total population involved in agricultural activities, also influences the evolution of gross value added (for a complete representation of the dynamic equations corresponding to this verbal description, see the appendix). Industrial value-added evolution depends on income (GDP), electricity production, and the proportion of the population involved in industry. Such equations, along with others representing population evolution, can now be written for each Central Asian country.

Once values are calculated for the levels of gross value added in agriculture and industry for Kyrgyzstan, Kazakhstan, and Uzbekistan, we can compare them with real data. We can also add these series together to get total value-added figures (minus gross value added in services) for each country and then a total gross value-added number for the whole region. Our strategy then allows us to simulate the impact on the whole region of a significant increase in the electricity production of Kyrgyzstan in terms of total value added.

From Figure 19.5 we can see that calculated gross value added for the region as a whole tracks real value added for the three countries, particularly in the later period, and reaches levels significantly higher than the current real ones.

Thus, an increase in Kyrgyzstan's hydroelectric capacity would ultimately benefit all three countries. Moreover, this result could be achieved by constructing hydroelectric dams in mountainous regions where the population density is relatively low. A simple geographic analysis of population densities shows that they are highest in the northern and southwestern regions of Kyrgyzstan, relatively far from elevated areas. The mountains are in the south and southeast, where dam construction and operation would have relatively little impact on resident populations. The crucial factor in achieving added productive capacity of electricity is the negotiation of agreements with neighboring countries regulating the seasonal use of the dams. Kyrgyzstan would need water especially during the winter and would also need to modulate river runoff somewhat during the summer when the demand for irrigation water was high. This adjustment of summer water would seem to involve relatively insignificant quantities and could easily be achieved as dams filled up because of glacier melt.

CONCLUSIONS

We have suggested that freshwater use generates many complex interactions among various users. Often such situations lead to tensions, which in turn can escalate into water-based conflicts as they become tied to other oppositions. The importance of water as the source of life often imbues these conflicts with heavy symbolism. The link between water and agriculture reinforces these symbolic aspects, and, since it is by far the largest user of freshwater, agricultural use is often at the heart of water conflicts. In certain regions, agriculture is impossible without a substantial amount of irrigation. It prevails for reasons of national sovereignty and autonomy of food production and because of the strength of agricultural lobbies. Reliance on irrigation can occur because water is subsidized or because costs are improperly calculated and therefore artificially low. Agriculture's privileged access to water is increasingly being contested, however, as competition among sectors and regions increases. In recent years, traditional agricultural water use has been in competition with requirements for power generation. Upstream-downstream relations tend to accentuate this competition, which can lead to shortages and thus, increasingly, to cross-boundary conflicts over resources. Reducing them requires a new organization of production processes with redistribution of benefits resulting from better use of the comparative advantages of regions.

It is important to understand current water use and the factors that influence it, develop predictors of future availability under conditions of climate change, and evaluate existing legal frameworks regulating cross-boundary use. These can become the basis for developing circumscribed initiatives to foster cooperation. Applying this approach to the Central Asian case, we have come to the following conclusions: The development of Kyrgyzstan's hydropower could lead to significant improvement in the welfare of the whole region by creating higher potential total gross value added. Such a policy would have two additional advantages. It would lessen regional dependence on fossil fuels and even allow their exportation to Western Europe or China, thereby providing outside income to the region. It would also diminish the importance of the largely inefficient agricultural production of the downstream countries, where industrialization based on the availability of cheap electricity from upstream hydroelectric plants could be further developed.

APPENDIX

1. The structuring of value-added relations: $GVA_{economy} = GVA_{agriculture} + GVA_{industry} + GVA_{services.}$
2. The evolution of value-added sectors:[4]
   2.1 Agriculture: GVAAG.=(A*GDP + B*WAT)*(1-ALF*GVAAG) + H*POP, where GVAAG is gross value added in agriculture, GDP is gross domestic product, WAT is water input for agriculture, and POP is population. A, B, ALF, and H are parameters, the

latter representing the proportion of the population involved in agriculture.

2.2 Industry: GVAIN. = C*GDP + K*EL + D*POP, where GVAIN is gross value added in industry, GDP is gross domestic product, and EL is electricity inputs to industry. C, K, and D are parameters, the latter representing the proportion of the population involved in industry.

2.2.1 Electricity: EL. = GAM*WAT (electricity produced by other sources is just an extrapolation from current trends).

2.3. Services: GVAS. = E*GVAS, where E is a parameter.

3. Total value added: GVAG + GVAIN + GVAS

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<AQ3> (Figure 19.1) Please cite in the text.

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