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Applying Interconnected Game Theory to Analyze Transboundary Waters: A Case Study of the Kura-Araks Basin

Market Report	Year Ago	4 Wks Ago	10-12-18
Livestock and Products, Weekly Average			
Nebraska Slaughter Steers, 35-65% Choice, Live Weight.	*	*	*
Nebraska Feeder Steers, Med. & Large Frame, 550-600 lb.	180.66	169.69	183.35
Nebraska Feeder Steers, Med. & Large Frame 750-800 lb.	170.20	163.74	164.80
Choice Boxed Beef, 600-750 lb. Carcass.	197.50	209.13	202.68
Western Corn Belt Base Hog Price Carcass, Negotiated	59.57	45.05	NA
Pork Carcass Cutout, 185 lb. Carcass 51-52% Lean.	73.45	66.84	78.02
Slaughter Lambs, wooled and shorn, 135-165 lb. National.	150.49	134.10	137.49
National Carcass Lamb Cutout FOB.	389.35	377.15	376.01
Crops, Daily Spot Prices			
Wheat, No. 1, H.W. Imperial, bu.	3.15	4.63	4.69
Corn, No. 2, Yellow **Columbus**, bu.	3.07	3.31	3.41
Soybeans, No. 1, Yellow **Columbus,** bu.	9.01	7.29	7.67
Grain Sorghum, No.2, Yellow Dorchester, cwt.	5.46	5.13	5.41
Oats, No. 2, Heavy Minneapolis, Mn, bu.	2.92	2.93	3.32
Feed			
Alfalfa, Large Square Bales, Good to Premium, RFV 160-185 Northeast Nebraska, ton.	*	185.00	*
Alfalfa, Large Rounds, Good Platte Valley, ton.	83.75	102.50	102.50
Grass Hay, Large Rounds, Good Nebraska, ton.	82.50	102.50	87.50
Dried Distillers Grains, 10% Moisture Nebraska Average.	117.50	136.50	141.50
Wet Distillers Grains, 65-70% Moisture Nebraska Average.	44.00	44.00	48.75

*** No Market**

A number of environmental problems are international in nature, including many water management issues. Rivers, for example, do not recognize political boundaries. Therefore, pollution generated in one country can affect neighboring countries, while water extraction in an upstream country can affect water flow and water availability in a downstream country. The situation creates an interdependency among countries, which might lead to disputes over the management of transboundary water. Therefore, coordination among the countries is necessary for effective management of these transboundary resources.

The focus of a recently published study (Khachaturyan and Schoengold, 2018) is the transboundary Kura-Araks Basin (see Figure 1 for its location), which is a major river system in the South Caucasus, with about 11 million people living in the basin. The countries in the basin are Armenia, Azerbaijan, Georgia, Iran, and Turkey, with Armenia, Azerbaijan, and Georgia having over 80 percent of the streamflow. The Kura-Araks Basin is a primary source of water for agricultural, industrial, and municipal uses in the South Caucasian countries. The study determines whether there are economic benefits to be gained from cooperation in the management of the Kura River (shared between Azerbaijan and Georgia), and under what conditions cooperation is an achievable outcome. Azerbaijan withdraws about 35 percent of the total available renewable water resources while Georgia only withdraws about 3 percent.

The development and expansion of irrigated agriculture increased water use in the Kura River Basin of Azerbaijan. The reductions of natural flow, caused

FIGURE 1. The Kura-Araks Basin in the Caucasian countries.

Source: Vener and Campana (2010), the basin is enclosed in blue line.

by overuse of some rivers, worsen the conditions in the basin. In addition to water quantity, water quality is also of significant concern in the region. Water quality degradation occurs from a variety of sources, including municipal and industrial wastewater, extensive use of pesticides and fertilizers in agriculture, and wastewater from mining activities. Given the existing challenges for water management in the basin, it is important to evaluate the feasibility of cooperation between the countries to improve outcomes. Game theory offers a powerful set of tools that can be used to analyze economic and political incentives for cooperation, the strategies of the parties involved, and the possible outcomes in various strategic contexts, including transboundary resources. Therefore, it is frequently used to analyze international agreements. Linking issues can help achieve cooperation and build trust, since a country that benefits from cheating on one issue may cooperate when another country can credibly cheat on another issue in retaliation.

Georgia and Azerbaijan have an upstream-downstream relationship. Hence, actions taken by Georgia, the upstream riparian, have an effect on Azerbaijan, the downstream riparian. However, for cooperation to occur, there need to be benefits of cooperation for both countries. To design an effective treaty that is relevant to policy-makers and negotiators, we need to first identify the strength of each player. In the current analysis, the strength for Georgia is defined to be a large amount of water and its upstream position (as Azerbaijan is dependent on its upstream neighbor for both quality and quality of waters entering its territory), while the strength of Azerbaijan is greater economic resources and large amounts of oil and natural gas resources. The analysis will consider water quantity and water quality, as both are critical issues in the region.

Isolated Negotiations: Water Quantity

As the upstream riparian, Georgia is well-positioned to provide more water to Azerbaijan. While its total and per-capita water withdrawals are lower than Azerbaijan, it has almost twice the estimated renewable water available. More water will allow Azerbaijan to expand both its agriculture and industry sectors, and will allow some diversification beyond the energy industry. Given Azerbaijan's downstream position and dependency on Georgia to receive a continuous and sufficient flow of water, Azerbaijan needs to offer something attractive to Georgia in return for such flow. With more economic resources due to its status as an energy exporter, Azerbaijan has the economic resources to provide better irrigation technology that can increase water use efficiency in Georgia. Due to the higher cost of drip irrigation, we focus on a switch from flood to sprinkler irrigation, which has an average efficiency improvement of 20 percent.

Azerbaijan has two strategies to provide efficient water use technology (e.g., drip irrigation) to save water or not: *technology* or *no technology*. Providing technology means providing financial and technical assistance in order to increase the efficiency of water use in Georgia. Georgia has two strategies: *more water* or *less water*. An agreement between the two countries will specify the technology investment supplied by Azerbaijan and the amount of water supplied by Georgia.

The payoffs associated with this agreement are in Table 1. Each cell has two values, the first corresponding to Azerbaijan's payoff and the second to Georgia's payoff. The cell with strategies *no technology* and *less water* is the status quo situation. The payoff (0, 0) is used for the status quo to provide a baseline for comparison with alternative agreements. *Technology* and *more water* is the cooperative outcome with an associated payoff of (15.22, 1.04) (payoffs are measured in billions of dollars). However, strategies *no technology* and *less water* is the predicted outcome, since each country has an incentive to cheat (and earn more money) with the cooperative result.

Isolated Negotiations: Water Quality

The Kura River is polluted in the industrial part of eastern Georgia from industrial and domestic untreated waste. Much of the nation is served by wastewater treatment plants that were installed during the Soviet era. Many of those plants do not work, or only provide basic treatment. Given the high dependence of Azerbaijan on Georgia for water resources, water pollution problems in Azerbaijan are primarily the result of upstream agricultural and industrial activity combined

with poor treatment facilities. Construction of water filter treatment plants would improve water quality in both Georgia and in Azerbaijan, leading to health benefits. Diarrhea is one of the main diseases caused by contaminated water. The death rate of diarrheal diseases in 2008 was 9.5 and 3 per 100,000 people for Azerbaijan and Georgia, respectively. In contrast, death rates in some countries with high quality water are the following: USA 1.2, Canada 1.6, Netherlands 0.5, France 0.9, Germany 0.6, Sweden 0.5, and Norway 2. If Georgia builds or renovates the treatment facilities, water pollution will decrease and diseases caused by contaminated water will decrease as well.

In contrast to the water quantity game, where the upstream country (Georgia) incurs the cost in order to benefit the downstream country (Azerbaijan), improving water quality in Georgia provides benefits in both countries. But, it is unrealistic for Georgia to make the costly investment in water treatment on its own. Georgia has fewer economic resources to pay for improving treatment facilities. In 2016, per-capita GDP in Azerbaijan and Georgia were $17,400 and $10,000, respectively. In addition, the rate of waterborne disease is higher in Azerbaijan; thus, it suffers more from the polluted water than Georgia does. Finally, poor water quality and poorly maintained treatment facilities have been common in Georgia for years, and politicians have not yet responded to the pollution. Thus, Azerbaijan must provide some additional benefit to Georgia for improving water quality. As a significant exporter of natural gas, Azerbaijan can provide a discount on a portion of Georgia's natural gas imports.

Azerbaijan has two strategies: to provide natural gas to Georgia for a reduced price or not: *cheaper gas* or *no cheaper gas*. Georgia used to buy gas from Russia, but since 2006 has purchased Azerbaijani gas diversifying its importers. In 2016, Georgia imported approximately 90 percent of its natural gas from Azerbaijan and only about 10 percent from Russia. The strategy *cheaper gas* means selling natural gas at a discount relative to current prices. Georgia has two strategies: to invest in pollution reduction technology to provide cleaner water to Azerbaijan or not: *clean water* or *not clean water*. It is costly to clean water, since water is heavily polluted from industrial, municipal, and agricultural uses. This game is presented in Table 1. The cell with the strategies *no cheaper gas* and *no clean water* is the status quo situation.

Issue Linkage and the Interconnected Games: The interconnected game is presented in Table 2. With the interconnected game, each country has four possible strategies. The countries can choose to cooperate on both issues, not to cooperate on both issues, or to cooperate on only one issue. The first number in the cell represents a payoff for Azerbaijan as a result of Azerbaijan's and Georgian's strategies. For example, the payoff in the first upper cell is (17.01, 1.505). This outcome, which is the fully cooperative one, corresponds to Azerbaijan choosing *technology* and Georgia choosing *more water* in the water quantity game, with the result being (15.215, 1.04) payoff, and Azerbaijan choosing *cheaper gas* and Georgia choosing *clean water* in the water quality game, with the result being (1.795, 0.465) payoff. The payoff in the cell corresponding to the third row and fourth column is (-0.325, 4.28). This payoff corresponds to Azerbaijan choosing *technology* and Georgia choosing *less water* in the water quantity game, and Azerbaijan choosing *no cheaper gas* and Georgia choosing *no clean water* in water quality game with the result being (0, 0) noncooperative outcome.

Results: Our results show that interconnected games are welfare improving because they ensure that the cooperative outcome is incentive compatible (i.e., achievable). Intuitively, this result occurs because one country has a highly dominant strategy in one game, while the other has a highly dominant strategy in the other. Since each game requires a fixed investment as a strategy for one country, and a repeated benefit for the other country, full cooperation is not achievable in either independent game, since each country has an incentive to cheat in one game. Thus, while linking issues does not expand the set of economic outcomes, it assures that each country has the fully cooperative outcome instead of the status quo (no agreement). The political feasibility of our results, which is crucial to policymakers who may want to use these issues as a starting point for negotiations, are reasonable in comparison to each nation's economy. The estimated values show a greater gain to Azerbaijan from cooperation than to Georgia ($17.01 billion versus $1.51 billion). However, these values are much closer when examined relative to each country's GDP. Since Georgia's GDP is approximately one-fifth of Azerbaijan's GDP, these values represent about 20 and 9 percent of GDP for Azerbaijan and Georgia, respectively. Since the payoffs are calculated as the net present value of a stream of future benefits, the annual benefit as a percent of GDP is lower (about 1 to 2 percent). Thus, the results are reasonable, since the benefits are large enough to be of relevance to national policymakers, but not so large to be unrealistic. This information can be useful for policymakers when considering potential negotiation on transboundary waters between the countries, without the use of direct financial transfers.

TABLE 1. Payoffs in Isolated Negotiations between Azerbaijan and Georgia: Parameter Values

		Georgia (upstream)			
		Parameter Values (Billions of Dollars)			
	Water Quantity Strategies	More water		Less water	
Azerbaijan (downstream)	Technology	15.22	1.04	-0.33	4.28
	No technology	15.54	-3.24	0	0
	Water Quality Strategies	Clean water		No clean water	
	Cheaper gas	1.80	0.47	-0.30	0.30
	No cheaper gas	2.10	0.17	0	0

Note: Parameter values are based on secondary data about the value of water consumption, the cost of improved irrigation technology, the value of health impacts from poor water quality, water treatment costs, and the use of natural gas in Azerbaijan and Georgia

TABLE 2. Interconnected game for water quantity and water quality between Azerbaijan and Georgia: Parameter Values.

		Georgia (upstream)							
		Parameter Values (Billions of Dollars)							
	Strategies	More water Clean water		Less water Clean water		More water No clean water		Less water No clean water	
Azerbaijan (downstream)	Technology Cheaper gas	17.01	1.51	1.47	4.75	14.92	1.34	-0.63	4.58
	No Technology	17.34	-2.78	1.80	0.47	15.24	-2.94	-0.30	0.30
	Technology	17.31	1.21	1.77	4.45	15.22	1.04	-0.33	4.28
	No technology	17.64	-3.08	2.10	0.17	15.54	-3.24	0.00	0.00

Note: Parameter values are based on secondary data about the value of water consumption, the cost of improved irrigation technology, the value of health impacts from poor water quality, water treatment costs, and the use of natural gas in Azerbaijan and Georgia.

References

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