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Water governance and adaptation to climate change in the Indus River Basin

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SUMMARY

Conflicting approaches to water governance at multiple scales within large international river basins may have detrimental effects on the productivity of water resources and consequently the economic activities of the basin. In the Indus River Basin, local scale water productivity decisions are affected by international and intra-national scale water governance. Water availability and productivity is modulated by the Indus Waters Treaty between India and Pakistan, and within Pakistan by the agreements governing water allocation between and within provinces. Much of the literature on governance at multiple scales in the Indus basin, and others, has employed qualitative methods of institutional analysis. This paper extends that approach with quantitative modeling of surface water allocation rules at multiple scales and the consequent economic impact on water use and productivity in the Indus River of Pakistan. The effects of the existing water allocation mechanisms on the ability to adapt to possible future climate conditions are examined. The study is conducted using the Indus Basin Model Revised – Multi-Year (IBMR–MY), a hydro-agro-economic model of the Indus River within Pakistan that simulates river and canal flows, groundwater pumping, water use and economic activities with a distributed, partial equilibrium model of the local scale agro-economic activities in the basin. Results suggest that without changes in response to changing conditions, the current governance mechanisms impede the provinces' ability to adapt to changing climate conditions, in ways that are significant, inflicting economic costs under both high and low flow conditions. However surface water allocation between the provinces does not appear to hinder adaptation. The greatest gains for economic water allocation are achieved at the sub-provincial level. The results imply that adaptive mechanisms for water allocation that allow response to changing climate conditions within provinces may be a promising adaptive response in the Indus Basin.

1. Introduction

Originating in the Hindu-Kush–Karakoram, the Indus River and its six main tributaries: Sutlej, Ravi, Beas, Jhelum, Chenab and Kabul comprise a basin covering four countries: Afghanistan, China, India and Pakistan with a drainage area of about 966,000 km^2. More than 60% of this area is located in Pakistan and the waters from the Indus are vital to agricultural production and the entire economy. The sharing of the Indus River has been contentious for more than a century, escalating after the independence of Pakistan in 1947 (Zentner, 2012). The use and allocation of water within the basin is heavily affected by the institutions and policies that prevail at the international level, as well as at provincial scales. These policies are likely to modulate the effects of climate change on the basin and on the agricultural economy of Pakistan.

While there are several studies that assess the impacts of climate change on the hydrologic response of the Indus basin (e.g., Akhtar et al., 2008; Ali et al., 2009; Immerzeel et al., 2010; Tahir et al., 2011), there are few that assess the role of water sharing policies. Cooley et al. (2009) concluded that most transboundary water agreements are based on the assumption of hydrologic stationarity; that future water supplies will conform to the statistics of the historical record. In the Indus River, like many river basins, there are clear causes for concern that the stationarity assumption will not hold, including dependence on glacier and snowmelt-fed upper basins that may be sensitive to warming temperatures (Archer, 2003; Flowler and Archer, 2006; Condon et al., 2009).

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The role of water sharing policies in mitigating or exacerbating the response of the Indus River Basin to climate change is largely unknown. Within Pakistan, water sharing is dictated by the Indus Waters Treaty, which allocates portions of Indus inflows between Pakistan and India and by the interprovincial Indus Water Apportionment Accord established between provinces in Pakistan in 1991, and various other local water institutions, such as *warabandi* (a rotational method for distribution of irrigation water where farmers are designated certain days/hours for their water withdrawals based on landholdings and the risk of variability of flows is in theory randomly shared). The focus of this study is the allocation of surface water within Pakistan. In particular, the objective is to assess the economic effect of current and alternative surface water allocation schemes at different hierarchical levels under climate change impacts.

The economic analysis is conducted quantitatively with a hydro-agro-economic model that simulates adaptive responses to changing hydrologic conditions and the effects of water allocation schemes. While many studies have estimated climatic-hydrologic consequences of climate change (temperature, precipitation and streamflow), fewer studies have evaluated the effects of alternative water allocation schemes under climate change and the resulted water allocations. While cognizant of the limits to quantitative modeling of all aspect of water sharing policy (e.g. economic, social and political), we believe the paper offers insights that could serve as the basis for assessment of adaptation strategies. In particular, the analysis assesses the presence of economic incentive for allocation schemes at different institutional levels as a necessary but not sufficient basis for evaluating such schemes. Prior to recommendation of any such scheme the practical implications of water re-allocation would need to be investigated.

In addition to surface water resources, groundwater is a also major source of water for irrigators in the Indus basin. This analysis models groundwater as a resource used conjunctively with surface water but does not focus on groundwater nor the effects of informal water markets and other sharing mechanisms as highlighted in Meinzen-Dick (1996), Shah and Raju (1988), Easter et al. (1999), Qureshi et al. (2003).

2. Historical background of water management in the Indus River

Water sharing within the Indus River Basin has long been contentious. At the national level, the Indus Waters Treaty provides the rules for water sharing between India and Pakistan. The establishment of the separate nations of India and Pakistan in 1947 resulted in the partitioning of east and west Punjab and transitional status for former princely states Jammu and Kashmir, which cut across the headwaters of the Indus tributary. This created uncertainties for basin development in both countries. The partition resulted in the headworks of two important Indus canal systems being located in India, while the command areas were in Pakistan. The two countries concluded a "standstill agreement," which maintained the existing flows until 1948 (Mustafa, 2007). The first formal water-sharing statement was established in 1948 when the previous temporary agreement expired (Alam, 2002). This agreement required India to release sufficient water to Pakistan in return for annual payments from the Pakistani government (PILDAT, 2011). However, the tensions between two countries remained high.

In 1954 the World Bank, citing concerns related to the economic progress of the two countries, proposed a water sharing plan based on three principles: (1) water in the Indus Basin is sufficient to meet the needs of both counties; (2) all tributaries in the Indus Basin should be included in the discussion and (3) the negotiations should focus on technical rather than political issues (Alam, 2002; Sharif, 2003). After years of negotiation between India, Pakistan and the World Bank, the dispute was finally resolved with the signing of Indus Water Treaty (IWT) in 1960. The water sharing plan allows India to use the three eastern tributaries of the basin (Sutlej, Ravi and Beas, about 20% of the Indus Basin flows) and Pakistan to use the three western tributaries (Indus, Jhelum and Chenab, about 80% of the Indus Basin flows). After the IWT, the long-term averaged streamflow (1961–2010) from Water and Power Development Authority (WAPDA) are 60.3, 25.5, and 22.1 MAF (million acre-feet, 1 MAF = 1.234 cubic kilometer) for three western tributaries: Indus, Chenab and Jhelum, respectively (Yu et al., 2013). The main provisions of the treaty also included flow and utilization data exchange between India and Pakistan and a permanent commissioner for both countries responsible for any Indus water disputes (PILDAT, 2011).

A major result of the Treaty, in addition to the water allocation agreement, was the construction of infrastructure that comprises the Indus Basin Irrigation System (IBIS). Canals, barrages and dams were to be built for diverting water from western tributaries to replace the water loss at eastern tributaries in Pakistan. IBIS is now the largest continuous irrigation systems in the world, consisting of two major storage reservoirs (Mangla and Tarbela), 19 large river headworks, 46 major canal-systems with a length of 58,000 km, 1.6 million kilometers of water-courses serving 34.5 million acres (13.96 million ha) of contiguous cultivated land (Wescoat et al., 2000; Hussain et al., 2002; Shaikh, 2003).

Within this system, surface water allocations are influenced by provincial and local tensions and compromises. The Indus Basin covers four provinces in Pakistan: Khyber Pakhtunkhwa (KPK, formerly known as North–West Frontier Province), Punjab (PUNJAB), Sindh (SIND) and *Balochistan* (*BLCH*). The provinces of Punjab and Sindh have long history of competing for water, and both attempted to ensure that any agreement with India accounted for their own needs (Alam, 2002). The first interprovincial water-allocation between Punjab and Sindh was signed in 1945. This treaty allocated 75% of the water in the mainstem Indus River (45 MAF out of annual average 60 MAF) to Sindh and the remainder (15 MAF) to Punjab. This treaty further allocated 94% of the water from five eastern tributaries (56.4 MAF out of annual average 60 MAF) to Punjab, with residual water (3.6 MAF) going to Sindh (Mustafa, 2007). After the IWT, most of Punjab's original share of the eastern tributaries was assigned to India. The construction of new storage and canals as described above were included in the IWT to compensate for Punjab's loss. However, that did not prevent disputes over the mainstem Indus between Punjab and Sindh. In particular, Sindh perceived the compensatory water and the storage on the Indus and Jehlum rivers that Punjab received as coming at the expense of Sindh (Mustafa, 2007).

Several committees were constituted to resolve water sharing issues between the provinces, including the Akhtar Hussain Committee in 1968, the Judicial Committees in 1977 and the Haleem Committee in 1983. None of them reached an agreement until 1991 when representatives from four provinces signed the Indus Water Apportionment Accord (referred as the 1991 Accord in the following text) and established the Indus River System Authority (IRSA) in 1992 as the agency responsible for surface water regulation and distribution (Habib, 2004).

The Accord uses a baseline of historical flows (1977–1982) to calculate the water allocations for each province (Table 1). Shortages and surpluses are then shared proportionally based on the baseline. It also calls for a minimum flow of 10 MAF of water into the sea. The water sharing agreement between the four provinces was based on an annual availability of 114.35 MAF inflows from all tributaries (Table 1). The Accord does not dictate surface water allocation within the provinces. Supply surpluses are allocated