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Efficient groundwater allocation and binding hydrologic externalities

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ABSTRACT

Reallocating water according to its highest marginal value can generate economic gains. However, reallocation of water use often generates third-party effects, or externalities, which prohibit transfers. We develop a spatial-dynamic hydro-economic model to assess the gains from redistributing water across irrigators, taking into account externalities that water use transfers may produce. Water use is optimized across space and time such that return flows in various segments of the watershed do not decrease relative to the flows obtained under current water use. Across a suite of water shortage scenarios in Idaho's Eastern Snake River Plain, the reallocation of water subject to third party externalities generates an 8–16% increase in aggregate annual profit earned by irrigators, relative to the Prior Appropriation-based allocation. The failure to account for the constraints on reallocation that arise due to externalities overstates the benefits from reallocation by 7%.

1. Introduction

Across the western US, groundwater levels in many aquifers have declined due to increased groundwater pumping, reduced recharge, and droughts. These declining groundwater levels have in many cases contributed to declining surface water flows (Cobourn, 2015, Elbakidze et al.,2012; Kuwayama and Brozović, 2013). Though the linkages between groundwater and surface water are recognized by scientists and policymakers, existing property rights for surface and groundwater often do not reflect the hydrologic linkages between these resources. The reason for disjoint administration of surface and groundwater resources in some cases is that respective rights were developed independently and without recognition of hydrologic connectivity. As water availability declined, the failure of property rights institutions to address these hydrologic linkages has led to numerous disputes involving lengthy and costly administrative and legal proceedings (Boehlert and Jaeger, 2010, Jaeger, 2004; Slaughter and Wiener, 2007). For example, in response to a water call placed by senior water users in 2009, the Idaho Department of Water Resources (IDWR) issued curtailment orders affecting 41 thousand acres of irrigated land in the Snake River Plain. Similar curtailment orders were issued in 2014, with the potential to affect 150

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thousand acres of irrigated agriculture (IDWR, 2015).[1] In response to these and other legal disputes, some western states in the US have begun to develop systems of conjunctive management, where surface water and groundwater property rights are jointly administered to reflect hydrologic interdependencies (Cobourn, 2015; Tuthill et al., 2013; Utah Division of Water Resources, 2005).

At times of scarcity, the distribution of water that maximizes social welfare is such that marginal benefits across different users are equal (the "equimarginal principle," Elbakidze and Cobourn, 2013). At this allocation, it is impossible to redistribute the scarce resource across users such that the beneficiaries from the redistribution gain more than is forfeited by the losers, consistent with the criterion of Potential Pareto Optimality (Griffin, 1995). The economists' preferred mechanism for achieving such a distribution is a market with well defined, enforced, monitored, and transferrable rights. Under such conditions, and in the absence of significant transaction costs, Coasian bargaining produces the distribution of the resource that maximizes social welfare (Coase, 1960). This outcome is grounded in the first theorem of welfare economics, which states that the competitive market equilibrium is Pareto optimal (Myles, 1995).

Clearly, the conditions required for achieving such competitive market equilibria through Coasian bargaining are often not met in practice. As a result, resource utilization can be economically suboptimal in terms of Pareto or Potential Pareto Optimality. Specifically, resource utilization is economically suboptimal if a reallocation is feasible such that, either at least one user is better off without reducing the welfare of others (Pareto Improvement), or the gains to winners from redistribution outweigh the losses to losers allowing for Kaldor-Hicks compensation criterion (Potential Pareto Improvement).[2] Given suboptimal distribution of the scarce resource, one policy option to maximize social net benefits is to invoke a centralized distribution strategy that mimics a competitive market equilibrium in terms of the equimarginal principle. The other option is to engage in the development of technologies and institutions that facilitate Coasian bargaining and the formation of competitive markets. Strengthening property rights and minimizing transaction costs, in part through improved accessibility of relevant information, are steps in this direction.

In the western US, the allocation of water, especially surface water, is widely governed by the Prior Appropriation Doctrine (PAD), often summarized as: "first in time, first in right." Under PAD, seniority is assigned to each water right according to the date on which water was first diverted for beneficial use (Griffin, 2016). The older the water right, the greater the seniority. According to PAD, during water shortages senior water rights take precedence over junior water rights in terms of securing access to limited water supplies. In the event of a water shortage, water users with relatively junior rights receive water if and only if the rights of relatively senior water users have been met.

In theory, a PAD-based water distribution can produce a Potentially Pareto Optimal outcome if relatively senior water rights belong to water users with relatively high marginal values for water. In the context of water use for agriculture, an allocation based on PAD would be economically efficient if irrigators with relatively more productive lands owned relatively senior water rights, *ceteris paribus*. In practice, however, those irrigators with relatively more productive lands often hold relatively junior water rights. For example, as a result of settlement and development patterns that minimized diversion and conveyance losses, lands nearest to surface watercourses often have more senior water rights, even though land adjacent to a watercourse may not be the most productive. Such distribution of water rights can be suboptimal because water may not be available for junior irrigators with higher marginal values during shortage. Unless water can be transferred among irrigators, this inefficient distribution will persist. As water becomes scarcer, inefficiencies introduced by fixed PAD are likely to become more substantial and costly (Boehlert and Jaeger, 2010, Griffin and Hsu,1993).[3]

If mechanisms exist to facilitate water transfers, water may be reallocated according to its highest marginal value product, barring legal barriers or other transaction costs (Ghosh et al., 2014, Wescoat,1985). Water markets, acting as a mechanism for optimizing water distribution, have been implemented on a limited scale in the US and other countries (Chong and Sunding, 2006; Hadjigeorgalis, 2009), though practical barriers for water redistribution and trade persist. One of the major obstacles for implementation of water markets or other types of water transfer mechanisms is the presence of third-party hydrologic externalities (Chong and Sunding, 2006; Howe et al., 1986; Young, 1986). These externalities arise whenever a transfer of water from one user to another affects the amount of water available for downstream water rights holders not involved in the transaction, or for the provision of environmental or in-stream flows.

While several studies in the economic literature document the potential gains arising from water transfers, none have quantified the costs associated with constraints to water trade due to hydrologic externalities. The objective of this study is to evaluate potential regional water (re)distribution, while explicitly taking into account the hydrologic externalities that constrain water use transfers. We develop a hydro-economic model that incorporates a set of constraints that reflect how changes in groundwater use influence in-stream flows. These constraints are expressed using spatiotemporal and multidi-

[1] Water disputes have been documented elsewhere in the western US where interconnections between water users have led to disagreements about infringement on water rights. Irrigators in Nebraska were curtailed following lawsuits filed by Kansas irrigators (Mieno, 2014). A lawsuit brought by Montana against irrigators in Wyoming found in favor of the latter, thereby limiting water availability to the former (Fuller, 2014). A dispute between New Mexico and Texas has been ongoing since 2011 when New Mexico sued the Bureau of Reclamation in Federal district court for allocating limited water supplies in favor of Texas irrigators. Numerous lawsuits have also been filed in California, including, but not limited to, disputes between Indian Tribes and irrigators and between irrigation districts and environmental groups.

[2] For a discussion of theoretical caveats relevant to the use of Pareto Optimality versus the use of Potential Pareto Optimality as criteria for economic efficiency, see Griffin (1995).

[3] Increased water scarcity is anticipated under many climate change scenarios for the US (Adams and Peck, 2008; Barnett et al., 2005).