Transaction Costs and Institutional Performance in Market-Based Environmental Water Allocation

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ABSTRACT. *Policy reforms in the Columbia Basin spurred water rights reallocation for ecological recovery. Transaction costs have caused implementation to lag. This paper examines transaction costs and institutional performance in environmental water allocation. It evaluates spatial and temporal performance trends in watershed cases along three dimensions of adaptive efficiency: water recovery, transaction costs, and program budgets. Performance trends demonstrate intrastate variability and volatility over time due to the importance of local institutional capacity, which is uneven within states. Higher levels of water recovery may coincide with moderate to high transaction costs and program budgets, particularly during initial implementation efforts. This finding reflects investments in multilevel policy reform to strengthen enabling conditions and adapt to unintended consequences.* (JEL Q25, Q58)

I. INTRODUCTION

Competition for scarce and variable freshwater resources has forced complex trade-offs between human and ecological needs. Environmental water requirements are often defined after freshwater diversions and uses exceed limits to ecological degradation. Institutional reforms have sought to reallocate water rights from irrigation to environmental flows through court decisions, administrative rules, and market-oriented transactions (Neuman, Squier, and Achterman 2006; Anderson and Leal 2001; Loomis et al. 2003; Garrick et al. 2009; Jones and Colby 2010).

The precipitous decline of salmon runs in the Columbia Basin (668,000 km^2) in the Pacific Northwest region of the United States has been attributed in part to freshwater diversions. The Columbia Basin experiences spatial and temporal mismatches in water supply and demand that contribute to chronic stream flow deficits in the late summer when the natural low flow of the hydrograph coincides with peak irrigation diversions. Water rights institutions in the western United States allow irrigation diversions to dewater over-allocated streams during late summer fish migration and reproduction in the upper tributaries. Policy reforms in the Columbia Basin states have incorporated environmental flows into the design and implementation of water markets. The market-enabling policy reforms establish limits to freshwater use, tradable water rights, environmental flows as legitimate uses, and public and private financing to restore environmental flows through water transactions.

The incorporation of environmental allocations into water markets and associated institutional reforms has not been seamless, however, due to the prevalence of transaction costs—the resources required to define, transfer, and manage property rights and to solve collective action problems in natural resource allocation (McCann et al. 2005; Cole 2002).[1] Transaction costs stem from multiple interacting sources tied to resource characteristics and users, property rights institutions, and barriers to trade across districts and jurisdictions (Bauer 1997; Bjornlund 2004; McCann and Easter 2004; Coggan, Whitten, and Bennett 2010).

This paper evaluates the effectiveness of market-oriented environmental water allocation by measuring and explaining transaction costs of institutional reform and implementation. Market-oriented environmental water al-

[1] See Coase (1960) and Demsetz (1967) for earlier and narrower definitions of transaction costs.

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location refers to voluntary (incentive-based) and compensated reallocation of existing consumptive water rights to enhance environmental flows. Environmental flows in the Columbia Basin principally involve nonconsumptive, "instream" flow for salmon fisheries. Market-oriented allocation is an alternative to involuntary, uncompensated reallocation through court decree or regulation. Implementation has lagged due to transaction costs. Janet Neuman characterized the lag in implementation by noting the experience of the Oregon Water Trust—the first nongovernmental water trust to enter the water market on behalf of the environment—whose "bank balance of acquisition money remain[ed] quite healthy, as it ha[d] turned out to be harder than expected to spend the money" (Neuman 2004, 439–40). Existing economic analysis of market-based environmental water allocation has yet to address the conceptual, measurement, and analytical issues associated with transaction costs in institutional performance.

In the early 1990s environmental economists began to measure transaction costs to examine institutional barriers and performance trends in water markets across the western United States, Chile, and Australia (Colby 1990a; Thompson 1993; Howitt 1994; Hearne and Easter 1995; Easter, Rosegrant, and Dinar 1998; Challen 2000; Allen Consulting Group 2006). This research relied on a range of conceptual frameworks and methodological approaches, limiting the comparability of findings and insights into institutional performance. These studies measured different types of costs at different stages of the policy cycle and across varying subsets of market actors—buyers, sellers, administrators, and third parties (McCann et al. 2005). Empirical estimates of transaction costs have yet to examine the use of water transactions to restore environmental flows and related public goods, although Colby (1990b, 1118) cites high transaction costs as a constraint on water-marketing activity to enhance instream flows.

This paper fills this gap in the literature by examining the relationship between transaction costs and institutional performance in market-oriented restoration of public goods generated by environmental flows. It follows McCann and Easter (2000) to examine the relationship between "public" transaction costs and institutional performance (see Mettepenningen, Beckman, and Egger 2011). Public transaction costs refer to the costs incurred by a subset of the actors—principally government agencies and nonprofits. In the context of overallocated freshwater ecosystems, public transaction costs include policy reform and implementation expenditures by governmental and nonprofit actors to reallocate private water use rights into the public trust (Challen 2000). Government agencies and nonprofits have an increasing motivation to economize on transaction costs due to limited and often decreasing budgets for fixed or growing policy objectives (Mettepenningen, Beckman, and Egger 2011).

The next section outlines the study motivation to investigate spatial and temporal patterns in public transaction costs and institutional performance within and across state jurisdictions. This section develops adaptive efficiency—defined in terms of long-term efficiency of economic performance—as an evaluative criterion. This discussion of adaptive efficiency is based in the work of Douglass North (1990, 1994). The third section describes the data and methodology used to measure institutional performance in terms of three interacting performance variables: water recovery (water rights acquisitions),[2] transaction costs per unit of water recovered, and total program budgets for transaction-related expenditures on policy reform and implementation. The fourth section presents results and a discussion of spatial and temporal performance trends, and it explores the interactions among these performance indicators in terms of adaptive efficiency. The final section provides concluding remarks by identifying lessons for theory, methods, and policy about transaction costs and institutional performance in market-based environmental water allocation.

[2] Defined as net increases in flow rates through water rights acquisitions to retire historic water uses and rededicate the historically consumed water for ecological purposes instream.

II. INSTITUTIONAL PERFORMANCE AND TRANSACTION COSTS

Institutional Performance: Defining Effectiveness

Institutional performance depends on the policy objectives and criteria for assessment. During the early period of implementation, the Columbia Basin Water Transactions Program (CBWTP) established three objectives (Hardner and Gullison 2007): (1) develop and test market transactions for acquiring water, (2) increase water and streamflow in the tributaries of the Columbia Basin, and (3) restore habitat for fisheries in streamflow-limited reaches. A third-party evaluation of the CBWTP from 2003 to 2006 documented progress on the first two objectives. The analysis documented a diverse portfolio of temporary and permanent transactional tools and increasing water acquisitions (referred to here as water recovered for the environment); it did not, however, compare spatial and temporal trends across and within the states in the basin.

The third objective—habitat restoration—has proven inconclusive; it takes a longer time to demonstrate progress on ecological outcomes, and this objective is affected by other causally relevant limiting factors. Moreover, habitat restoration will require "sophisticated coordination with other organizations and government agencies" (Hardner and Gullison 2007, 2). As such, a definitive link between transactional outcomes and ecological impacts is premature at this stage and scale of implementation. Anecdotal evidence of habitat improvements exists in locations where biologically rich tributaries have become reconnected with the mainstem river. Effort is being devoted to institutionalize best practices in compliance and effectiveness monitoring and to develop evaluation protocols to track and test ecological outcomes.

Long-term institutional performance can be assessed along multiple criteria associated with policy effectiveness. This study assesses policy effectiveness in terms of adaptive efficiency. Efficiency refers to the least cost path to a policy objective based on the (full range of) costs per unit of benefit generated. Neoclassical efficiency is a function of the institutional structure within which costs and benefits are assessed; in other words, the institutional constraints are often taken as given (Bromley 1982, 1989). Adaptive efficiency, on the other hand, reflects the institutional capacity to achieve efficiency over the long term (North 1994). Adaptive efficiency is helpful to understand long-term trajectories of institutional economic performance in contexts of entrenched path dependencies, complexity, uncertainty, and feedback between policy reform and implementation (North 1990).

In the context of market-based environmental water allocation, the evaluative criterion of adaptive efficiency is defined in terms of a relationship between three performance indicators over space and time: water recovery (net increase in flow rates through water acquisitions), average transaction costs (implementation costs per unit of water recovered),[3] and program budgets (total financing available to cover implementation costs of getting to the scale and to invest in strategies that reduce transaction costs over time).[4] Adaptive efficiency is reached in settings

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[3] It should be noted that implementation cost per unit of water is derived as an average cost (total *transaction-related* program budgets divided by the net present value of water recovered in CFS). Average transaction costs metrics are prevalent in water-market analysis for analytical and methodological reasons. Analytically, average costs indicate relative costs across jurisdictions. For example, Colby's 1990 study reported results in terms of average transaction costs per acre foot at the state level. The second reason for the average transaction costs metric is methodological. Marginal transaction costs would require estimates of transaction costs per unit of water *per transaction* rather than transaction costs per unit of water *per subbasin*. Transaction projects may take several years to complete; as such accurate data on transaction-level costs are unlikely. McCann et al. (2005, 532) identify the trade-off between accuracy and precision, and the need to fit transaction costs metrics to the analytical purposes at hand, which in this case focused on a relative indication of transaction costs across jurisdictions and over time (subbasin and annual averages) rather than across transactions and quantity (marginal).

[4] The size of the budget in early years will also reflect the up-front costs of policy enactment to strengthen enabling conditions and adapt to unintended consequences. The overall size of the budget will reflect the transaction costs of getting to scale that are defined by the level of unmet environmental needs. It should be noted that determining environmental needs is an iterative and dynamic process. We have further called the readers' attention to a previous empirical study (Gangaharan 2000) making a related point about high transaction costs in early years in the development of pollution markets.

where market-based environmental water allocation generates (1) relatively high water-recovery levels at (2) low (or declining) transaction costs with (3) sufficient institutional capacity (in terms of program budgets) to cover the transaction costs needed to enact enabling reforms, get to scale, and adapt to unintended consequences.

Transaction Costs: Barriers to Implementation

The prevalence of high transaction costs has been cited as a significant barrier to implementation progress in market-oriented environmental water allocation (Colby 1990b; Neuman 2004; Hardner and Gullison 2007). In the Columbia Basin, the first instream flow transaction occurred seven years after enabling legislation was enacted in Oregon. Other states in the basin encountered a similar implementation lag, and transactional activity has not increased as quickly as anticipated (see Neuman 2004). This lag stems in large part from the high cost of collective action to establish and manage institutions that address exclusion, externalities, and free-riding challenges in water allocation. For example, the evaluation of the CBWTP explicitly identified transaction costs as one of the major challenges for the program (Hardner and Gullison 2007).

Conceptual and methodological advances in transaction costs economics have been used to evaluate environmental policy design and institutional performance. In the natural resource allocation context, transaction costs are defined as the resources required to define, transfer, and manage property rights (McCann et al. 2005). This definition expands and builds on Coasian (Coase 1937, 1960) understanding of transaction costs in natural resource allocation. The Coasian definition of transaction costs emphasizes the costs of exchange comprised by search, bargaining, and monitoring costs incurred during changes in the initial assignment of rights to address externalities. McCann et al. (2005) highlight the importance of transaction costs in environmental policy because property rights are incomplete and evolve for complex and contested natural resources (Barzel 1989; Libecap 1989). Cole (2002) traces the problem of high transaction costs explicitly to two linked collective action challenges: the costs of exclusion and coordination. In short, institutions and institutional change are costly, particularly in freshwater resource settings that have been overallocated to agricultural users.

Transaction costs also occur at multiple levels (Williamson 1998) that include the costs of (1) exchanging property rights, (2) changing the institutional framework governing those exchanges, and (3) overcoming the lock-in costs of past institutional commitments (North 1990; Marshall 2005). These distinctions have antecedents in the sports analogy developed in new institutional economics literature, which separates "playing the game" from changing "the rules of the game" (North 1990; Williamson 1998). A less often noted antecedent to this boundary issue appears in the common pool resource literature that separates collective choice (decision making) from operational-level rules and actions (Ciriacy Wantrup and Bishop 1975; Ostrom 1990; Schlager and Blomquist 2008). The interaction between levels of transaction costs is integral to institutional performance dynamics over space and time.

Past empirical research has been limited primarily to the transaction costs of exchange borne by a subset of actors. Measurement methods include surveys, financial expenditure data, econometric analysis about the value of information, or some combination of the three. In an early example in the western United States, Colby (1990a, 1184) used a survey to estimate "policy-induced transaction costs," including "attorneys' fees, engineering and hydrologic studies, court cases, and fees paid to state agencies . . . and specifically exclud[ing] the price paid for the water rights and costs of implementing a transfer once it has been approved." The findings relied on a sample of willing professionals. McCann et al. (2005) describe a range of methodological techniques for transaction costs measurement in environmental policy analysis. They suggest a combination of survey and financial expenditures data to counteract the biases and weaknesses inherent in either approach on its own.

McCann et al. (2005) establish a framework and typology for transaction costs measurement that guides this study. Measurement relies on boundaries to delimit what counts as transaction costs through all stages of policy design and implementation and across all actors. Empirical typologies include the type of transaction costs, market actors, and timing to capture the ex ante and ex post costs through the full policy cycle. The typology includes multiple levels—policy enactment and implementation—as well as subtypes within each category. In the context of market-based environmental water allocation, policy enactment costs include enabling reforms of water rights institutions to define, transfer, and manage water rights in a cap-and-trade system that allows transactions for environmental flow restoration purposes. Enactment costs also entail the development of nested institutions to organize public and private efforts for planning, water banking, and administrative capacity at multiple scales. The subtypes of implementation costs include project-level costs of transaction prioritization and planning, water rights due diligence, negotiation and price discovery, administrative fees and processing, conflict resolution, monitoring and enforcement, and financing (see also Section III).

In assessing transaction costs, an important question is which transaction costs (the types, actors, etc.) are included in the analysis. Most empirical work is partial in nature, in that studies "have focused on some subset of . . . costs, either regarding the type of cost or who bears them" (McCann et al. 2005, 533). In markets for private goods, the transaction costs of private actors—buyers, sellers, and third parties—are of prime interest. In environmental markets for public goods (i.e., the use of market mechanisms to preserve or enhance public goods), transaction costs analyses often focus on public sector transaction costs (McCann and Easter 2000; Mettepenningen, Beckman, and Egger 2011).

Mettepenningen, Beckman, and Egger (2011) explain the rationale for a focus on public sector transaction costs in the analysis of environmental policy effectiveness: (1) environmental schemes may face declining budgets to reach fixed or intensifying policy challenges, (2) accountability measures require "value for money" in terms of policy outputs per dollar expended in the program budget, and, as a consequence, (3) transaction costs influence trade-offs across competing priorities for public investment. The public and nonprofit organizations brokering transactions in the CBWTP confront an explicit motive to economize on transaction costs as the program faces periodic reauthorization.

The focus on public transaction costs is consistent with the objective of evaluating institutional performance and governance arrangements on the demand side of the public goods market for water. This analysis therefore excludes private transaction costs faced by sellers. This decision is accompanied by two simplifying assumptions that should be tested in future empirical research in a comprehensive benefit-cost framework: (1) The magnitude of transaction costs incurred by sellers in a public good market is expected to be proportional to those incurred by public actors; information and coordination costs are influenced by similar politics, institutional arrangements and local contexts. (2) Nonprofit conservation brokers and regulatory officials serve as extension officers to incentivize and facilitate participation by sellers, building trust and capacity by underwriting the costs of information and coordination faced by prospective sellers. Extension officers argue that public transaction costs incurred to implement water transactions partially serve to shift the burden from sellers to buyers and regulators (Lovrich and Siemann 2004; Neuman 2004). A full accounting of public and private transaction costs and benefits is a promising area of research based on the conceptual and methodological advances developed here for public sector transaction costs.

Research Gaps and Hypothesis

This paper investigates the relationship between transaction costs and institutional performance by examining the spatial and temporal patterns of performance in market-based environmental water allocation. These performance trends are decomposed into three interacting performance variables: water recovery levels, transaction costs per unit of water, and program budgets. How do these three performance indicators interact to shape prospects for adaptive efficiency? The hypothesis is that performance will vary as much *within* states (where authority for water allocation is vested in the western United States) as *across* them. This expectation is formed based on (1) the lock-in costs (path dependency) of historic water users, uses, and biophysical characteristics of the system,[5] and (2) localized drivers of water rights reform and administration capacity, which reflects the importance of local time- and place-specific information and values (Hayek 1945).

Previous research establishes the basis for this working hypothesis about intrastate variability in spatial and temporal performance trends. Colby (1990a) examines the relationship between transaction costs and efficiency in water allocation institutions. Her empirical analysis of "policy-induced" transaction costs (associated with administrative procedures) reveals that transaction costs are "higher in areas where water is more scarce and valuable, transfers are more controversial, and the externalities of water transfers are more likely to be significant" (p. 1189). MacDonnell (1990) finds high degrees of intrastate variation in transaction costs due to differences in institutional capacity to respond to scarcity, conflict, and externalities.

Ruml (2005) provides the basis for the hypothesis in his work on the Coase theorem in the western United States system of prior appropriation (first in time, first in right). His analysis suggests two different institutional contexts for water transactions in the western United States: (1) an appropriative system under statutory rules and (2) irrigation district level systems governed by water user rules. The former is prevalent at the state level, where water transactions can become trapped in a vicious cycle of ill-defined and insecure property rights with high transaction costs; the latter (district level) has fostered isolated pockets of favorable water market conditions governed by a "virtuous cycle" whereby water rights are defined clearly and transferred with low transaction costs. Carey, Sunding, and Zilberman (2002) describe an example of the virtuous cycle via the emergence of an enabling framework within informal networks of "affiliated farms" in the Westlands Water District in California. In that case study, fixed transaction costs are low enough to enable trading for transactions of relatively small volumes.

In the context of market-based environmental water allocation, state-level water rights reforms are a necessary condition. However, adaptive efficiency is expected to depend on additional reform and institutional capacity at the subbasin scale to access local time- and place-specific access to information and coordination (following Hayek 1945). This paper documents evidence for this thesis by elaborating and testing the transaction costs evaluation framework to assess spatial and temporal performance trends within and across state jurisdictions.

Research Setting

Water allocation in the Columbia Basin is governed under the western United States prior appropriation doctrine, which stipulates that the first to establish and maintain a beneficial use is the last to lose access during periods of inadequate supplies. Ecosystems tend to receive the residual flows. The allocation system allows a chronic imbalance between legal rights and claims (i.e., "paper water") and physical availability (i.e., "wet water").

Implementing organizations in the Columbia include nonprofit water trusts, basin organizations, and public agencies that operate at multiple scales. The Northwest Power and Conservation Council (NPCC) has coordinated local recovery efforts along ecoregional boundaries by defining *subbasins*—zones of ecological interactions. The Columbia Basin is particularly well suited to test this hypothesis because four decades of watershed governance reforms ensure that field-level water rights administration and watershed planning align closely with ecoregional boundaries (NPCC

[5] It must be noted that although the physical characteristics vary at multiple scales, the region shares defining features of its hydrology and hydrogeology, such as snowmelt-driven hydrology with peak runoff in the spring and the natural low flow in the hydrograph. The presence or absence of losing reaches and reservoir storage alter the hydrogeologic character but in ways that are not expected to be determinative for performance trends.

2005). Subbasins are therefore the appropriate scale at which to analyze efforts to address the externalities of overallocation incurred by ecosystems and existing water users.

The Columbia Basin includes 62 subbasins. Twelve subbasins and one ecoprovince ($n = 13$) comprise the study area and were chosen based on the need for and presence of transactional activity to address low-flow limitations (Table 1). Subbasins were selected in the study design because of significant unmet demand, which led to their inclusion as priority subbasins in the CBWTP. High levels of unmet demand serve as a control for case selection, but the relative need (and hence marginal ecological and economic benefits of transactions) is assumed to be similar across subbasins, particularly during the early stage of implementation.

These cases enable comparisons both within and across state boundaries in areas where basic enabling conditions and initial impediments to environmental water transactions had been addressed prior to the formation of the CBWTP in 2002. The cases encompass subbasins in Idaho, Montana, Oregon, and Washington, the primary riparian states on the U.S. side of the border.

A set of contextual factors is noteworthy (Table 1). These factors are not expected to have a determinative impact on the direction or magnitude of any of the three performance variables because high or low levels of performance are expected to be possible regardless of the contextual feature. However, these are factors associated with the physical, institutional, and socioeconomic characteristics of the subbasins that can vary as much within the states as across them and therefore favor a mixture of local and state institutional capacity to achieve high levels of performance and adaptive efficiency as outlined in Section II.

The key physical characteristics include the presence or absence of reservoir storage in the form of a federal storage project and associated infrastructure, an environmental flow target (or set of targets), and anadromous (migratory) or resident fisheries. The institutional characteristics include the presence or absence of a water rights adjudication (a court decision to define water rights), a groundwater mitigation rule, and/or a water banking structure. Socioeconomic characteristics are defined by the presence of irrigation districts (and associated infrastructure) versus dispersed users, the proximity to an urban center, and competition for water (as measured via average price per unit of environmental water acquired through the CBWTP).

The cases are all defined by the presence of transactional activity and coordinated by the CBWTP. With regard to water institutions, biophysical setting, and socioeconomic characteristics in the Columbia Basin, the following simplifying assumptions apply to the cases selected:

- Legal and institutional reforms all occur within the broader framework for water allocation under the prior appropriation doctrine.
- All subbasins have high levels of unmet ecological demand where instream flow has been identified as a limiting factor for fish recovery. Insufficient data and analysis exist to compare transactions in terms of their marginal ecological benefits.[6]
- Sellers face roughly similar types and magnitudes of transaction costs across the subbasins; the role of conservation brokers is to serve as extension agents conducting outreach with potential willing sellers to decrease the information costs of learning about new incentives and reallocation options.

III. DATA AND METHODOLOGY

Data

This study compiles data on three interacting performance indicators—water recovery, transaction costs, and institutional capacity (the latter simplified here as "program budgets" to capture a subset of institutional capacity)—that together contribute to adaptive efficiency. The transaction is the common unit

[6] At this stage of implementation, although each unit of water recovered does not generate equal levels of ecological and economic benefits, the volume of unmet demand for environmental assets is high enough across the subbasins selected for analysis that the initial acquisitions are at the high end of the demand curve. An assessment of marginal ecological benefits has not been developed to translate flow increases to differential levels of ecological impact.

TABLE 1
Case Study Subbasins and Contextual Factors

	Physical			Institutional			Socioeconomic		
Subbasin	Size (km^2)	Federal Storage[a]	Anadromous	Adjudication	Groundwater Mitigation	Water Banking	Seller Organization[b]	Urban Proximity[c]	Environmental Water Prices Average $/CFS/trans.[d]
Idaho									
Salmon	36,262	No	Yes	Yes	No	Yes	Dispersed	Rural	$2,394
Montana									
Bitterroot	7,399	No	No	Limited	No	No	Both	Mixed	$1,445
Blackfoot	5,997	No	No	Limited	No	No	Dispersed	Rural	$5,844
Clark Fork	20,770	No	No	Limited	No	No	Both	Mixed	$3,107
Flathead	21,934	No	No	No	No	No	Dispersed	Rural	$8,170
Oregon									
Deschutes	27,744	Yes	No[e]	Yes	Yes	Yes	District	Mixed	$5,883
Grande Ronde	10,613	No	Yes	Yes	No	No	Both	Rural	$8,808
John Day	20,527	No	Yes	Yes	No	No	Dispersed	Rural	$2,848
Umatilla	6,607	Yes	Yes	Yes	No	No	District	Rural	$1,202
Willamette	29,050	No	Yes	Yes	No	No	Both	Mixed	$2,516
Washington									
Upper Columbia	—	No	Yes	Limited	No	No	Both	Mixed	$5,715
Walla Walla	4,558	No	Yes	Limited	Yes[e]	Yes	District	Mixed	$3,982
Yakima	15,990	Yes	Yes	Limited	Yes[e]	Yes	District	Mixed	$9,416

[a] Federal storage project refers to a Bureau of Reclamation project and therefore excludes several storage projects by other federal and state agencies.
[b] Districts and dispersed (individual) diversions coexist in every subbasin. The classification provides a rough indication of the balance between the two broad types.
[c] Reflects the presence or absence of a large or growing population center, which provides a rough indication of the subbasin's proximity to an urban area (given the variable size in sq km, population, population density, or city size are not reliable indicators of the presence of an urban area). "Mixed" character refers to a dense and growing urban or exurban population center where agricultural and urban water users coexist and may compete for water, e.g., Bend, Oregon, in the Deschutes, or Portland, Oregon, in the Willamette, and Missoula in the Bitterroot and Clark Fork). Rural character refers to a subbasin without such a population center, e.g., Upper Salmon, Idaho.
[d] Average water price (2007) dollars per discounted CFS per transaction, data source, Columbia Basin Water Transactions Program, 2003–2007. See Table 4 for details.
[e] The characteristic changed during the early implementation period from 2003 to 2007.

of analysis. The subbasin is the spatial scale, and the temporal scale is aggregated *both* annually and over the full five-year period of analysis. The study period encompasses early implementation ending with the CBWTP third-party assessment in 2007 (Hardner and Gullison 2007), which coincided with the global financial crisis and precipitated several recommendations and changes in program design, including increased focus on ecological and cost-effectiveness monitoring. Water recovery is defined as the increased rate of instream flow (cubic feet per second) generated through transactional activity to acquire or lease water rights.[7] Transaction costs are assessed using financial and survey data about expenditures related to transaction design and implementation activity. Program budgets include financial expenditures for transaction design and implementation activity; the program budgets expressly exclude the cost of water and expenditures for unrelated program activities. The original dataset on transactions, transaction costs, and program budgets was scrutinized to limit error and ensure validity. A verification process involved expert consultation with practitioners to review data sources and collection techniques, including confirmation of survey responses used to account and allocate transaction costs and program budgets. Documentation of metadata (i.e., data about the data) enables replication and longitudinal analysis.

Transactions (Water Recovery)

The transactions data were compiled from state administrative agencies for 880 transactions in Idaho, Montana, Oregon, and Washington between 2003 and 2007.[8] The transactions data are the basis for water recovery (acquisition) metrics and the average transaction costs per unit of water recovered. The absence of consistent standards and registries for transactional activity rendered quality control paramount. The transactions data from administrative agency records were cross-referenced against independent databases maintained by nonprofit organizations. The transactions data characterized 10 attributes of each transaction, including price (when available), quantity, location (subbasin), and contract term.[9]

This dataset relies directly on state administrative records rather than third-party reporting of transactions data.[10] Two limitations of the water recovery transactions data deserve scrutiny for comparative analysis of institutional performance. First, it is necessary, yet still premature, to translate water recovered into ecological outcomes to capture the differential ecological benefits and nonlinearities (i.e., thresholds) in the relationship between water recovery and ecological and economic values. For example, higher ecological benefits could justify disproportionally high transaction costs both within and across subbasins. This linkage becomes important as water recovery levels reach thresholds for ecological functions and dependent goods and services. In this phase of analysis, it is only possible to document water recovery levels and report in Section IV on the subset of cases that have established comprehensive water re-

[7] The absence of comprehensive, systematic, and high-resolution flow targets makes it impossible to use metrics based on water recovered as a proportion of estimated flow needs. As noted in Section II, initial assessments of ecological impact are inconclusive due to a lack of established flow needs (which itself is a key part of the policy enactment and planning transaction costs) and the role of other limiting factors causally linked to ecological conditions.

[8] Of the 880 transactions, 673 occurred in the Columbia Basin study area of the four states.

[9] Official requests were made for transaction data for all available attributes, including priority for the following common elements across data sources: (1) start year; (2) end year; (3) state; (4) subbasin; (5) in/out Columbia; (6) conservation broker/program; (7) seller type and/or project name; (8) contract type (permanent, lease, irrigation efficiency, donations, forbearance agreement); (9) quantity, maximum CFS instream, and total volume (in acre-feet); and (10) price, if available

[10] The Water Strategist dataset (reported by the Stratecon Inc. in a subscription service that was modified recently) has been the standard source for academic studies of western United States water markets (Basta and Colby 2010, Brewer et al. 2011). Those authors acknowledge that there are potential deficits in the transactions data. Environmental water transactions information is a potential weakness of the Water Strategist dataset. For example, a thorough transactions dataset coded and compiled from the *Water Strategist* by Brewer et al. (2008) indicated that Oregon had 77 transactions of all types (agricultural, intersectoral, and environmental) from 1987 to 2005. By contrast, the primary data derived from administrative records in this study yields over 100 environmental water transactions in Oregon in 2004 alone.

covery targets at the stream-reach scale. However, this is an element of the framework that will be tabbed for future research as part of a comprehensive, long-range and integrated cost-benefit assessment.

Second, price data is limited for environmental transactions.[11] This deficiency is partly a function of the unique valuation methods used to establish market-based prices for water rights transacted for environmental recovery purposes, especially in the absence of active water markets. In the Columbia Basin, agricultural-to-environmental transactions occur while the wider water market for agricultural transactions and/or agricultural-to-urban transactions is still nascent and thin. As a result, water costs do not appear to be the primary limiting factor on transactional activity yet, as programs had substantial acquisition budgets that remained unspent due to prohibitive transaction costs (Neuman 2004; Hardner and Gullison 2007).[12]

Transaction Costs

Transaction costs metrics relied on a mixture of primary financial expenditures data and structured questionnaires for auditing and accounting purposes (see below and Figures 1 and 2). The sources for transaction costs data included an audit of transaction-related expenditures from financial records on the demand and regulatory actors of the market: nonprofit and water resource agency conservation brokers and water resource regulatory agencies. For the nonprofits, Internal Revenue Service files supplied total expenses and sufficient accounting details to distinguish the costs paid for water from the costs associated with transaction-related program expenditures. The files were supplied annually under tax disclosure requirements for nonprofit organizations. For the latter (administrative agencies), managers estimated program budgets associated with implementation efforts across the full suite of program design and implementation tasks, including transaction planning, permitting, and monitoring and enforcement.

Program Budgets

The implementation budget is a subbasin-scale aggregation of the financing sources associated with the principal implementing bodies—nonprofit and state water resource agency actors—for their *transaction-related* activity (excluding water costs). Transaction-related expenditures refer to transaction implementation and explicit single-purpose investments in policy design and planning to reduce average transaction costs over time and with scale. As such, this budget is only a subset of total institutional capacity and serves as a proxy for the capacity to cover transaction costs and invest in institutional reforms capable of lowering transaction costs over time. This program budget metric captures the overall size of the budget for these policy enactment and implementation functions; it further enables an assessment of the presence, absence, and relative level of contributions from the nonprofit and agency actors to understand the degree of public (state agency) and private (nonprofit) capacity for implementation in a given subbasin (see Section IV).

Measurement

Performance Variables

The quantity of water in market transactions is traditionally reported as a volume in acre feet.[13] The quantity of water for environ-

[11] Price data for 191 transactions from 2003-2007 is reported by the Columbia Basin Water Transactions Database. The price data are summarized for the full reporting period at the subbasin level as an average price (in 2007 dollars) per (discounted) CFS per transaction. The water cost results indicate that transaction costs are not correlated with average water prices, because some subbasins include high transaction costs and water prices (Upper Columbia, Washington) while others have low transaction costs but relatively high water prices (Yakima, Washington).

[12] Comments from an anonymous reviewer highlight other potential circumstances in which water costs are a primary limiting factor and deserve close attention as part of an integrated cost-benefit analysis: (a) fear that government intervention in the water market through environmental water purchases will cause speculation in water prices and (b) limited ecological benefit at the going market prices.

[13] An acre foot is approximately 325,000 gallons and is the unit of measure necessary to inundate one acre with a foot of water. This unit was established for irrigation water uses based on crop water requirements.

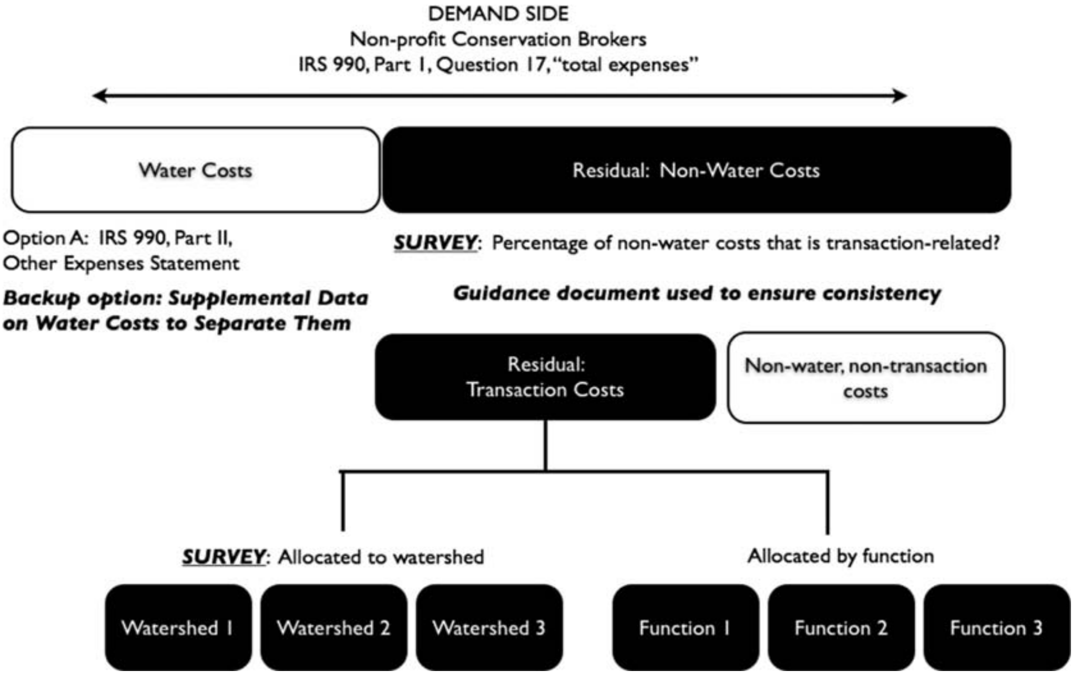

FIGURE 1
Transaction Costs Accounting Scheme: Conservation Broker

mental water transactions is more appropriately reported as a diversion rate, or flow, in cubic feet per second (CFS). Environmental water transactions vary in duration from a permanent transfer to a brief portion of an individual irrigation season. The maximum flow rate[14] (water quantity) recovered by each transaction is discounted into a net present value of CFS over the full term of the contract (in years), following the methodology applied for acre feet transferred (Brewer et al., 2008) and utilizing a 5.5% discount rate. A sensitivity analysis of varying discount rate levels demonstrates that higher discount rates penalize subbasins with relatively higher proportion of permanent or long-term transactions as a percentage of total transactional activity (Section IV includes a breakdown of permanent transactions as a proportion of total transactional activity).

Transaction costs were measured in a three-staged process through scoping interviews, collection of financial expenditure data, and a brief structured questionnaire (Figures 1 and 2; Tables 2 and 3) for auditing and accounting purposes. The questionnaire was tailored to nonprofit conservation brokers, state water resource agencies, and field-level water resource managers ("watermasters") employed by either state agencies or water users associations. The period of analysis encompasses a five-year time frame from 2003 to 2007. The type and distribution of transaction costs included the activity on the demand and regulatory side of the market for environmental flows: the costs incurred by conservation brokers and water resource regulatory agencies for both the state and local field-level staff involved in implementation. In the first stage, scoping interviews with practitioners identified the types of information, coordination, and enforcement costs through the full

[14] The flow rate of a diversion may vary over the season. Maximum flow rate was available for all transactions; however, sensitivity analysis was conducted for the subset of transactions for which average flow rate and total volume (acre feet) were available to ensure that maximum flow rate is a robust indicator of environmental water recovery.

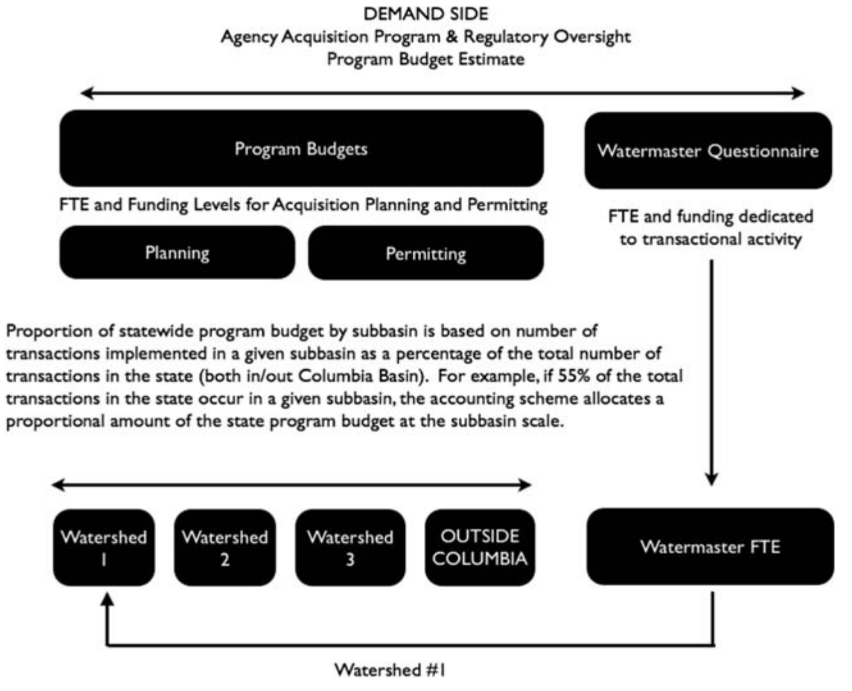

FIGURE 2
Transaction Costs Accounting Scheme: Agency Acquisition Program

TABLE 2
Step-by-Step Summary of Transaction Costs Accounting

Nonprofits	Agencies
1. Internal Revenue Service 990 Forms were gathered. 2. Form 1, response 17 indicates total expenses. 3. Form 2, statement of other expenses indicates all water costs. 4. Water costs are subtracted from total costs. 5. Questionnaire is used to determine proportion of *nonwater costs* that is *transaction related.* 6. Questionnaire is then used to assess the proportion of transaction-related, nonwater costs allocated to each priority watershed. 7. Questionnaire is used to assess the proportion of transaction-related, nonwater costs that is allocated to each function in the project cycle.	1. Program budgets were estimated annually for the planning and permitting functions of the instream water transactions programs. 2. Program budgets were allocated at the subbasin scale based on the proportion of statewide transactional activity occurring in the subbasin.[a] 3. Watermaster questionnaires were used to determine the percentage of their full-time equivalency dedicated to instream transactions. 4. Subbasin agency costs compiled the watermaster staffing and funding levels with the planning/permitting budgets.
Data, methodology, and results were verified by program staff.	Data, methodology, and results were verified by headquarters staff.

[a] The agency contributions included permitting costs and field-level administration. For the permitting component, the intrastate allocation of state-level costs was based on the proportion of transactions occurring within the basin, as noted in note 15. This allocation methodology and the results they generated were verified by agency headquarters.

TABLE 3
Example of Transaction Costs Accounting in Deschutes River Subbasin, 2003–2007 (in 2007 dollars)

Row	Item	Value	Data	Verification Survey
Agency Permitting				
1	Agency permitting	$521,134	Agency program estimates of budget for instream transaction planning and permitting based on pro rata share of statewide totals(see Table 2)	Confirmed by agency headquarters
2	Agency watermaster	$105,000	Watermaster (monitoring and enforcement) survey of percentage of staff position dedicated to instream flow transactions	Confirmed by agency headquarters
Nonprofit Conservation Broker				
3	Nonprofit (total expenditures)	$10,928,244	Internal Revenue Service Form 990, Question 17 (total expenses)	n/a
4	Water Costs	$4,859,747	Internal Revenue Service Form 990, Schedule 1 (itemized “other expenses” including lease, purchase, and irrigation efficiency payments)	Confirmed by organization director
5	Nonprofit (program expenditures)	$6,068,497	Row 3 minus Row 4 of this worksheet	n/a
6	Nonprofit (transaction-related program expenditures)	$4,036,112	Audit of Internal Revenue Service 990 program expenditures reported in Row 5 of this worksheet based on percentage of program expenditures dedicated to transactions activity (i.e., 67% of Row 5 in this instance).	Confirmed by organization director
7	Nonprofit (percentage of transaction-related expenditures allocated to the subbasin)	100%	Survey of organization director	n/a
8	Total program budgets	$4,662,246	Row 1 + Row 2 + (Row 6 × Row 7) of this worksheet	n/a
9	Water recovered	1,278	Net present value of water committed over contract term	n/a
10	Average transaction costs	$3,649	Row 8 / Row 9 of this worksheet	n/a

planning and project cycles within the broad typology of transaction costs identified by McCann et al (2005). These transaction costs included both policy enactment and implementation costs, even though the basic enabling conditions (e.g., tradable water rights and authorization for environmental uses and transactions) had been established prior to the study period. Policy enactment and associated information and coordination costs include policy advocacy and planning activities to close the subbasin, undertake rulemaking, establish water banks and reverse auctions, and conduct long-range water supply and demand planning. Implementation costs include transaction planning, water rights due diligence, seller outreach, contracting, administrative review, injury analysis, monitoring, enforcement, and financing.

The second stage required collection of financial expenditure data as stipulated earlier in this section. Finally, a structured questionnaire and accounting form ($n = 47$) allocated state-level financial data at the subbasin level for both water resource agency and nonprofit financial expenditure data. The water resource agency contributions included environmental water transaction planning, permitting costs, and field-level administration (including monitoring and enforcement). For the permitting component, the allocation of state-level financial expenditures was on a pro rata basis within the states based on the proportion of transactions occurring within the subbasin (Table 2). The data, allocation methodology, and results were confirmed by agency headquarters. The pro rata allocation of the permitting component of state water resource agency expenditures is based on the agencies' experience that permitting includes a set of fixed costs and administratively mandated procedural time lines that will not vary substantially across subbasins or transactions even though the level of clarity about water rights adjudication may differ within a state.[15] The field-level administration component was expected to vary within states, however, and was assessed through a subbasin-level questionnaire of watermasters. Finally, the nonprofit conservation brokers were asked to allocate state-level data at the subbasin level using several points of reference, such as the ratio of subbasin-level program staff to total statewide staffing levels.

The total program budgets for transaction-related expenditures by subbasin were divided by the water recovered within that subbasin to develop average transaction costs per cubic foot per second (CFS). Totals and averages by subbasin were calculated both annually and for the full five-year study period to capture spatial and temporal trends. Tables 2 and 3 and Figures 1 and 2 document step by step the data, methods, and transaction costs accounting scheme.

The overall program budget for the five-year period comprises the third indicator, which aggregates the financial data on transaction costs from conservation brokers and regulatory agencies in each subbasin. This performance indicator reveals the capacity to finance transaction costs and the degree of participation from the nonprofit and government agency sectors. Institutional capacity refers here only to the subset of total capacity represented by the program budgets for the demand side and regulatory functions of markets for environmental flows. Program budgets specifically capture the financial data for the conservation brokers and regulatory agencies. These budgets include only the *transaction-related expenditures.* The survey and verification procedures included an audit of financial expenditures to capture only program activities associated with the typology of policy reform and implementation costs stipulated above.

IV. RESULTS AND DISCUSSION

The results confirm intrastate variation in spatial and temporal performance trends. Performance varied almost as much *within* states as across them as measured using the quantile distribution of the results. Figure 3[16] and Table 4 (spatial) and Figures 4 and 5 (temporal) summarize the findings for the study period by subbasin. The analysis aggregates results

[15] The intrastate allocation rule for the permitting component of agency transaction costs divided statewide permitting expenditure estimates at the subbasin level according to the subbasin's proportion of statewide transactions. This rule implies agency permitting transaction costs are a function of transactional activity and therefore that the average permitting transaction costs will not vary within states. Anecdotal evidence of permitting processing time in terms of days from application date to decision (using incomplete data for lease agreements) confirms this expectation. Processing times were roughly equal across the subbasins for completed transactions, suggesting that the implemented transactions were only those that could be completed in a reasonable time according to administratively defined procedural time lines for both buyer and seller. There is evidence that intrastate distribution in statewide permitting effort could deviate from proportional allocation in future years after "low-hanging fruit"—transactions selected because of their likely approval or straightforward circumstances—give way to more complex and permanent projects, which is already happening in Oregon.

[16] Classification of subbasins as high versus low water recovery and transaction costs is based on quantile levels for spatial trends (see rank in Table 4). Subbasins with middle quantiles were placed in higher or lower levels by cross-referencing the temporal patterns to detect increasing (high) or decreasing (low) water recovery and transaction costs levels. Program budgets were classified as (potentially) sufficient to achieve increasing returns when temporal trends demonstrated increasing water recovery at stable or decreasing average transaction costs over time. The John Day was excluded from the composite map because it is in the middle quantile for each performance variable and reached peak performance in the middle of the study period in 2005 (water recovery increase and transaction costs decrease).

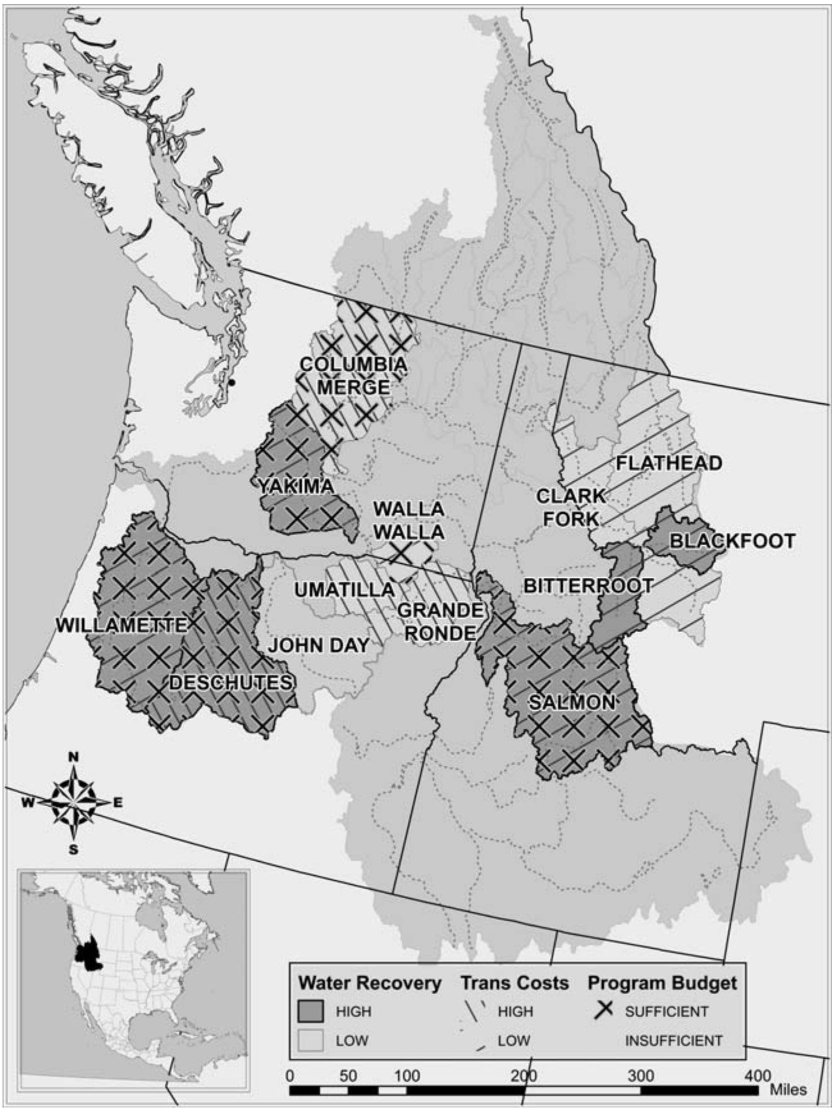

FIGURE 3
Spatial Patterns of Institutional Performance, 2003–2007

for the three performance variables over the five-year period to depict the cross-case quantile[17] distribution of results for water recovery (net present value of CFS by subbasin), transaction costs per unit of water recovered, and program budgets of transaction-related expenditures. Each quantile represents a 20th percentile interval. The temporal trends decompose results into annual totals (water recovery levels and program budgets) and averages (transaction costs per unit of water recovered). The results demonstrate that (1) performance varies as much within as across states and (2) relatively high volumes of water

[17] The reader should refer to the rank (1 = highest, 13 = lowest) for each performance variable (Table 4) to derive the quantile level: high, medium high, medium, medium low, low. An additional set of maps is available for each performance variable to depict this quantile distribution from darker (higher) to lighter (lower) values.

TABLE 4
Performance Measures by Subbasin, 2003–2007

		Water Recovery				Transaction Costs[d]		Water Costs[e]	Capacity		
Subbasin	State	CFS[a]	Rank	#[b]	Permanent[c]	$ per CFS	Rank	$ per CFS	$[f]	Rank	State Budget[g]
Salmon	ID	421	6	30	0%	$940	10	$2,394	$395,718	11	100%
Bitterroot	MT	1,618	1	8	13%	$488	12	$1,445	$789,699	6	0%
Blackfoot	MT	729	4	13	23%	$923	11	$5,844	$673,228	7	0%
Clark Fork	MT	187	9	14	0%	$416	13	$3,107	$77,647	12	0%
Flathead	MT	19	13	9	0%	$2,043	8	$8,170	$38,824	13	0%
Deschutes	OR	1,278	2	337	9%	$3,649	3	$5,883	$4,662,246	1	13%
Grande Ronde	OR	101	12	5	20%	$5,589	2	$8,808	$564,475	8	9%
John Day	OR	348	8	33	6%	$2,623	5	$2,848	$912,369	5	22%
Umatilla	OR	181	10	23	17%	$2,935	4	$1,202	$532,403	9	9%
Willamette	WA	365	7	64	6%	$1,165	9	$2,516	$425,620	10	66%
Upper Columbia	WA	106	11	29	3%	$13,383	1	$5,715	$1,423,977	3	36%
Walla Walla[h]	WA	550	5	35	74%	$2,492	6	$3,982	$1,369,912	4	46%
Yakima	WA	902	3	73	32%	$2,225	7	$9,416	$2,006,088	2	64%

Note: All figures aggregated for study period by watershed from 2003 to 2007 (in 2007 dollars).
[a] Net present value of flow rate protected (cubic feet per second, CFS).
[b] Number of transactions.
[c] Percentage of transactions that are permanent.
[d] Average transaction costs (2003–2007 implementation costs divided by discounted CFS).
[e] 191 transactions in the Columbia Basin Water Transactions Program dataset 2003–2007 summarized at the subbasin level as the average price in 2007 dollars per discounted CFS per transaction.
[f] Budget for transaction costs, i.e., nonwater costs, from 2003 to 2007 in 2007 dollars.
[g] Percentage of program budgets from state water resource agency.
[h] Walla Walla transactions data contains substantial quality gaps and uncertainty, which introduces error into the results for transaction costs per CFS. Thus, only the implementation budget should be considered reliable among the three indicators.

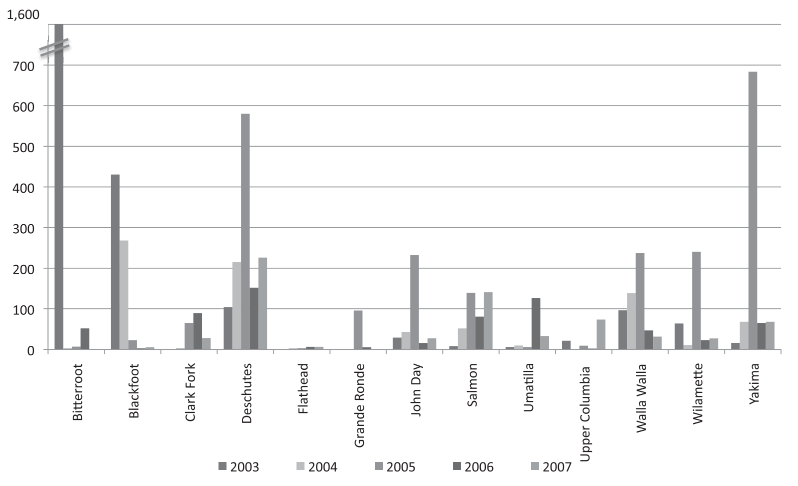

FIGURE 4
Water Recovery (Present Value of Cubic Feet per Second) from 2003 to 2007

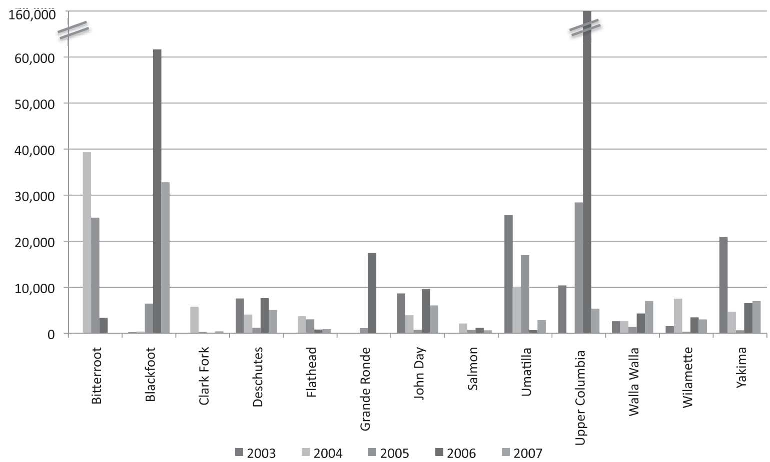

FIGURE 5
Transaction Costs (Dollars per Cubic Foot per Second) from 2003 to 2007

recovery do not always coincide with relatively low transaction costs, particularly in the early years of implementation. The longer-range performance trajectory is illustrated by decomposing the five-year trends into annual levels and tracking trends over time. The longitudinal analysis distinguishes cases that improve performance over time and increase returns to scale from those that encounter barriers in terms of declining water recovery and/or increasing transaction costs over time (Figure 3).

Spatial Trends: Intrastate Variability

Water Recovery

Water recovery levels range from 19 to 1,618 CFS (in present value terms) for the five-year period with substantial intrastate variation. Intrastate performance trends in water recovery levels confirm the expectation that performance would vary as much within states as across them. Subbasins in three of the four states appear in the upper two quantiles (Deschutes, Oregon; Yakima, Washington; and Bitterroot and Blackfoot, Montana); each of these three states also has a case in the lower quantiles (Grande Ronde, Oregon; Upper Columbia, Washington; and Flathead and Clark Fork, Montana).

Oregon subbasins demonstrate the range of recovery levels from relatively higher water recovery levels in the Deschutes to lower levels in the Umatilla and Grande Ronde, where political resistance in the latter has engendered administrative protests and threats of court challenges (described by Pilz [2006]). Washington reached high water recovery levels in the Yakima, reflecting a pulse of transactional activity for drought response in 2005 (Figure 5). Recovery levels were relatively low in the Upper Columbia despite high ecological priorities associated with salmon fisheries in the ecoprovince's Methow and Okanogan tributaries. The Upper Columbia confronted institutional barriers associated with poorly defined water rights and, until more recently, local resistance to environmental water allocation. Idaho's only case, the Salmon, achieved the local water recovery target of 35 CFS. The state government-run Idaho Water Transactions Program focused on a tributary (the Lemhi) of the Salmon prioritized by state law and relied on temporary contracts to build toward longer-term agreements (see Table 4 for the percentage of permanent transactions). Finally, the Montana cases include both the highest and lowest water recovery levels—the Bitterroot and Flathead Rivers, respectively. The Montana cases demonstrate a bias toward transactional activity in the earlier years of the study period, partly due to a longstanding negotiation in the Bitterroot on Painted Rocks reservoir that culminated in 2004 and skewed the initial period of results in that subbasin. Institutional barriers constrained additional progress in Montana during the period of analysis. The lack of comprehensive adjudication or streamlined administrative rules delayed the process of converting forbearance agreements into formal administrative transfers enforceable against upstream/downstream junior appropriators.

Aggregate water recovery levels are not the only relevant metric of transactional activity and may obscure key performance attributes across and within states. The number and average size of transactions are also important. The Montana experience in the Bitterroot reflects a relatively high average level of water recovered per transaction (the influence of a small group of large-volume transactions), while the Deschutes has achieved not only high water-recovery levels but also high numbers of transactions with relatively low average volumes, including permanent deals. The ability to decrease average transaction size is a sign of maturing markets where banking and other market clearinghouse functions decrease fixed transaction costs that impede smaller-sized deals (Carey, Sunding, and Zilberman 2002; Ruml 2005).

Water recovery levels can be benchmarked against environmental flow targets to derive the percentage of the target attained as a proxy for ecological outcomes. The ability to reach flow targets is partly a function of the scale at which targets are established (creek vs. stream vs. subbasin) and the objective of such targets (fish passage, spawning habitat, and/or rearing habitat). For example, the Salmon subbasin of Idaho achieved a flow target derived for a localized environmental flow target of 35 CFS on the Lemhi River. Thus, relative to the other subbasins, the Salmon achieved only moderate levels (i.e., middle quantile) of water recovery yet reached flow targets at localized scales through a portfolio of water transactions fitted to the hydroecological context and legal priorities. Meanwhile the Deschutes achieved the second-highest level of water recovery (and highest quantile), although restoration efforts on the middle Deschutes were one-third the target of 250 CFS established for the upper portion of the subbasin. As targets are reached, effectiveness monitoring is becoming prevalent to examine the sufficiency of these target flows in terms of water quality and other ecological parameters that drive healthy fish habitat.

Transaction Costs

Transaction costs at the subbasin level ranged from $416 to $13,383 per discounted CFS (median: $2,225; also see Tables 2 and 3 for illustration of accounting scheme).[18] The results indicate a similar pattern of spatial heterogeneity within states, albeit with stronger *interstate* variation than with the water recovery trends. For example, subbasins in Washington appear in the upper three quantiles, while the subbasins in Montana appear in the lower three. Spatial trends partly reflect the presence or absence of enabling legal and policy conditions, particularly (1) a court adjudication to define water rights comprehensively (including groundwater-surface water interactions) at the state and/or subbasin levels and (2) water planning to establish environmental water requirements at multiple scales. The absence of completed adjudications can lead to relatively high transaction costs (exemplified in Washington by the Upper Columbia and other cases with partial or outdated adjudications in Washington) or temporary strategies to implement transactions despite incomplete water rights adjudications (e.g., Montana). For example, initial transactions in Montana had relatively low transaction costs despite limited progress toward court adjudication for the state's Columbia Basin subbasins.

Intrastate variation remains pronounced in both the Washington and Oregon cases, the states with arguably the most advanced markets for environmental flows (Neuman,

[18] Converting the cost per CFS to a cost per acre foot (reported for other water market analysis) requires assumptions about the duration of the contract. If the CFS reallocated instream were diverted for a standard irrigation season (180 days), one CFS would be approximately 360 acre feet.

Squier, and Achterman 2006). Oregon exhibits substantial intrastate variation with its five cases ranking from second to ninth highest in transaction costs (Table 4). Washington includes the ecoprovince with the highest transaction costs (Upper Columbia) of all cases and the sixth- and seventh-ranked cases, with relatively more moderate levels in the Yakima and Walla Walla (albeit with substantial interannual variability, as described below). Finally, the relatively low transaction costs in Montana and Idaho stem in part from dependence on a single actor for implementation, the private nonprofits and the state, respectively. Montana lacks agency contributions (Table 4) because most transactions during the study period proceeded outside of the formal administrative procedures through forbearance agreements. Idaho's program is run wholly by the state agency and lacks nonprofit contributions.

Program Budgets

The final performance variable is a subset of institutional capacity: the combined program budgets for conservation brokers and regulatory agencies aggregated at the subbasin level. These budgets for transaction-related expenditures (but excluding water costs) serve as a proxy for capacity to implement transactions *and* invest in policy reform strategies to reduce transaction costs. Program budgets varied both within and across states. In Washington cases, program budgets were relatively high; Idaho and Montana exhibited moderate to low levels of program budgets with substantial intrastate variation in Montana (Figure 3). In Oregon, intrastate differences in program budgets were pronounced and varied from the high of Deschutes (ranked first) to the low of the Willamette (ranked tenth). Reviewing the program budgets in conjunction with the other two performance variables, the greatest surprise is the coincidence of water recovery levels (second highest) and transaction costs (third highest) in the Deschutes case, which highlights the importance of ongoing policy reform activities to strengthen enabling conditions (see the discussion of the performance variables below). This alignment of outcomes became possible because the Deschutes ranked highest in program budgets to cover the costs, which demonstrates the importance of examining performance variables in combination.

Temporal Trends: Performance Trajectories over Time

Ongoing investments in the transaction costs of policy reform underpin a dynamic relationship between transaction costs and institutional performance over time and hence the need for longitudinal assessment of performance trends and trajectories. The transaction costs measured here conflate: (1) the costs incurred to implement water transactions (transaction costs of implementation) and (2) strategic expenditures to invest in the transaction costs of policy reform to reduce impediments and achieve increasing returns to scale (e.g., through water banks and administrative capacity). Conservation brokers reported that 5% to 10% of their transaction-related program budget was dedicated to policy reform strategies to reduce transaction costs; however, the absolute levels (and, by extension, impact) of policy reform investments were much higher in the Deschutes given the size of the program budget.

Temporal performance trends exhibit three different patterns. First, the Deschutes case exemplifies the cases with improving performance over time; these cases invest in the transaction costs of institutional reform to enable market-based reallocation for environmental flows at declining transaction costs and sufficient scale. Two other temporal performance trajectories include cases that were (1) responsive to drought or (2) experienced enduring institutional barriers after initial implementation experience. The Washington cases are prominent examples of the drought-response trajectory whereby water recovery spiked and transaction costs declined during the 2005 drought year (declining from \$20,950/CFS in 2003 to \$645/CFS in the 2005 drought year, before increasing to almost \$7,000/CFS in 2007), but residual institutional barriers tied to the lack of a water rights adjudication hindered implementation progress in nondrought years. Some of the Montana cases reflect the persistence of institutional barriers that limit potential for improved performance over time without reinvestment in market-enabling policy reform.

Temporal performance trends in selected cases within Montana and Oregon are indicative of relatively low and high adaptive efficiency, respectively. The Bitterroot and Blackfoot achieved high water recovery levels and low transaction costs for the full study period. However, the temporal trends indicate declining water recovery levels and increasing transaction costs. Initial transactions used forbearance agreements that avoided administrative scrutiny and worked around the limitations of the prevailing institutional framework. Implementation efforts in western Montana shifted from a public agency (i.e., similar to the Idaho government-run program) to private nonprofits after legislation passed in 1995 enabled private leasing of instream water rights. As a result, staffing levels dedicated to environmental water transactions were lower in Montana than the other states during the study period. However, the state agency in Montana has proven important for sustaining high levels of performance, and initial transactional activity underscored the need for regulatory clarity and administrative oversight. The limited amount of state agency involvement partly explains the declining water recovery levels over time.[19]

In Oregon, several of the cases mirror the Montana experience, with the majority of water recovery occurring in the first two or three years of the five-year term before "hitting the wall" under prevailing institutional arrangements. The Deschutes Basin is a notable and illustrative exception. The Deschutes achieved the second-highest water recovery levels (and the highest number of transactions by an order of magnitude) but also the third-highest transaction costs per unit of water recovered. The Deschutes had the highest program budget ($4.7 million) to cover transaction costs, invest in institutional reforms (water planning and banking) aimed at decreasing transaction costs over time, and generate sufficient financing to get to scale. Thus, the apparent contradiction of relatively high water recovery and high transaction costs is explained by the commitment of the Deschutes River Conservancy to invest in the costs of implementing transactions while simultaneously bearing the costs of investing in (1) communications, basin-level planning, and policy forums to garner public support; (2) collaborative relationships with local irrigation districts; and (3) novel institutional water-banking mechanisms and partnerships. For example, stakeholders developed and implemented a new regulatory program for exchanging existing, senior surface water rights for new groundwater rights, representing a major policy reform that basin stakeholders worked through with the state during the study period. Tracking of trends over the five-year period shows a stable-to-decreasing annual trend in transaction costs per unit of recovered water in the Deschutes. Compared with the volatility in other subbasins, this reflects the pay-off in performance from continued investment in institutional reform and multilevel governance.

Discussion: Interactions of Performance Variables

The combinations of high water recovery and high transaction costs in the Deschutes and of high water recovery and low transaction costs in Montana are illustrative. Consider the three performance variables in terms of the combinations compatible with adaptive efficiency. As Table 5 illustrates, transaction costs can be relatively high or low so long as institutional capacity is sufficiently high to cover and decrease the costs over time. Thus, high transaction costs are not automatically a negative for long-range effectiveness. The Deschutes illustrates that relatively high transaction costs may be necessary during early periods of implementation to decrease transaction costs over time and reach water recovery thresholds for fish recovery.

Table 5 displays the eight logically possible combinations of outcomes, and comments about their feasibility and their implications for adaptive efficiency. The neoclassical efficiency criterion identifies a standard for both a relatively high (high recovery, low transac-

[19] The Montana results underestimate transaction costs because state agency program budgets were not available.

TABLE 5
Combinations of Performance Variables

Water Recovery	Trans Costs	Program Budgets	Cases
High	Low	Sufficient	Efficiency Salmon, ID[a]; Willamette, OR[a]; Yakima, WA
High	High	Sufficient	Potential for long-run efficiency Deschutes, OR
High	Low	Insufficient	Persistence of institutional barriers Bitterroot and Blackfoot, MT[a]
High	High	Insufficient	Implausible due to difficulty of achieving relatively high water recovery when average transaction costs are relatively high and program budgets relatively low
Low	High	Potentially sufficient	Persistence of institutional barriers with increasing recovery at declining costs per unit of water Upper Columbia, WA
Low	Low	Insufficient	Persistence of institutional barriers Clark and Flathead, MT
Low	High	Insufficient	Inefficient Umatilla, OR; Grande Ronde, OR
Low	Low	Potentially sufficient	Path dependency Walla Walla, WA[a]

[a] The Bitterroot, Blackfoot, Salmon, Willamette, and Walla Walla cases have intermediate values (i.e., middle quantiles) for one performance variable. For example, the Salmon, Idaho, case has intermediate/low levels of program budgets (capacity) within the second-lowest quantile. The John Day was excluded as it exists in the middle quantile for all three variables. Cases with "potentially sufficient" levels reflect instances with moderate to relatively high program budgets and evidence of increasing returns (increased levels of water recovery with stable or decreasing transaction costs). The Walla Walla results should be treated with caution due data quality gaps noted in Table 4.

tion costs, high budgets) and relatively low (the opposite) performance combination. If assessed over the longer term in terms of adaptive efficiency, two other combinations are relevant for both high (high recovery, high transaction costs, and sufficiently high capacity to cover the costs) and low values (the opposite, where recovery is low despite low transaction costs because of insufficient program budget capacity.

Table 5 also shows how the cases could be sorted in this scheme to gauge trajectories of performance over time. First, the high-performance combination of high water recovery, low transaction costs, and sufficient program budgets appears to hold in the Willamette, Yakima, and Salmon cases (at least when considering the full five-year study period). Efficiency in these cases depends on prior investments in the policy reform costs of institutional change. These prior investments in policy reform may cause transaction costs to be relatively high prior to the study period and/or borne by actors who are outside of the study scope but involved in water rights reforms that have spillover benefits for market-based environmental reallocation. Second, the longer-range concept of adaptive efficiency holds in the Deschutes, where high water recovery is combined with relatively high transaction costs and also with the program budgets to cover and decrease those costs over time.

Other cases with high water recovery (Rows 3 and 4 in Table 5) show less evidence of adaptive efficiency due to insufficient program budgets and therefore limited investment in the transaction costs of institutional reform. The Montana cases show high water recovery and low transaction costs but relatively low levels of program budgets. As a consequence, institutional barriers persist and make it unlikely that the cases will improve performance over time unless prohibitive implementation transaction costs motivate efforts to invest in the policy enactment transaction costs of institutional reform. The final combination of performance trends with high water recovery, high transaction costs, and low program budgets is implausible, and thus, no such cases were found in this study sample.

The cases with low levels of water recovery are also informative. Without sufficient program budgets to address barriers to implementation and to foster market-enabling institutional change, the cases are likely to be trapped in a low-performance equilibrium. Therefore, even cases with initially low levels of water recovery during the five-year study period can be differentiated to gauge performance trajectories over time. The key difference is marked by those cases with high program budgets to cover the costs of getting to scale and to invest in institutional changes that will decrease transaction costs over time. The Walla Walla and Upper Columbia of Washington reflect such cases. In the Upper Columbia, for example, the initial years of implementation were marked by low water recovery and high transaction costs. However, the subbasin invested in relatively high program budgets, which contributed to increasing water recovery and decreasing transaction costs over time (as evidenced by the annual trend data in Figures 4 and 5). The Montana cases and the Umatilla and Grande Ronde of Northeastern Oregon, in contrast, fall into the low-performance trap due to inadequate investments in the transaction costs of institutional reform; however, this trend has shifted since 2008, when Montana actors became involved in rulemaking to address institutional barriers.

Discussion: Performance Trends and Institutional Change

How do performance trends relate to institutional change? The relationship between water rights adjudication and performance offers insight into this question. Oregon and Idaho are fully adjudicated in the subbasins within the study area through processes that entailed costly court decisions. Adjudications in Montana and Washington remain incomplete, although costly investments in adjudications have occurred in pockets within these states, such as the Yakima in Washington. The presence of adjudication is expected to contribute to relatively high levels of performance as evidenced by the Deschutes and Salmon examples. The absence of adjudication is expected to pose challenges due to incomplete property rights, which helps explain the experience in the Upper Columbia of Washington.

Two sets of outliers are instructive: (1) those without adjudication but with high levels of performance across the three measures and (2) those with adjudication but with low levels of performance. The cases in the former category (e.g., Bitterroot) and latter category (e.g., Grande Ronde) illustrate two essential points. The Montana cases (in the first category) recovered high levels of water despite the absence of water rights reform. After the initial deals, the Bitterroot and Blackfoot subbasins exhausted the potential for deals with low transaction costs within the prevailing institutional setting and found it difficult to build on early success to get to scale. These implementation challenges prompted efforts in 2008 to develop new rules and administrative pathways for environmental leasing to reduce barriers to trade. Thus, an adjudication and/or reinvestment in the transaction costs of policy reform may prove necessary to achieve adaptive efficiency.

The Grande Ronde and Umatilla (in the second category) lack water recovery despite high levels of water rights reform (i.e., via the presence of adjudication). These cases demonstrate that adjudication may prove necessary but insufficient for long-run efficiency unless such water rights reform is coupled with governance reforms by subbasin actors to cooperate in strengthening enabling conditions (e.g., water banking and reverse auctions and addressing unintended consequences of water transactions on a range of stakeholders). The Grande Ronde, for example, involved a permanent transaction that proceeded without consultation with the broader basinwide community (Neuman

2004; Pilz 2006). The transaction triggered a protest from upstream and downstream water users that led to a costly, six-year conflict resolution process in administrative courts; irrigators rallied against the transaction and organized political resistance that threatened to unravel Oregon's legal and regulatory framework for water transactions (Neuman 2004). The Grande Ronde case demonstrates the benefit of linking water rights reforms with basin governance efforts that promote local decision making over water allocation and conservation planning buttressed by complementary higher-level mandates (e.g., state water planning, federal Endangered Species Act) to reinforce local initiatives. By contrast, in the Deschutes and Upper Salmon cases, water rights and multilevel basin governance conditions combined to improve performance over time.

V. CONCLUSIONS

This paper examined transaction costs and institutional performance in market-based environmental water allocation. It developed and tested a transaction costs framework to evaluate market-based environmental water allocation. Performance—water recovery, transaction costs, and institutional capacity (program budgets)—varied as much within states as across states. Five chief lessons emerged. First, institutional responses to public goods failures in water allocation are costly; the transaction costs involve important interactions between the policy reform and implementation costs, which are therefore difficult to separate in accounting frameworks. Second, context matters but is not determinative; differences in context (e.g., physical characteristics, institutions, socioeconomic aspects) favor nested governance arrangements comprised of field, state, and federal institutions that are likely to vary as much within states as across them. Third, clear methodological categories and typologies are needed to define and assess transaction costs and institutional performance through all stages of policy design and implementation. The methodological issues include defining which set of actors are incorporated, particularly to account for and explain the public transaction costs required to deliver water-related public goods at socially desired levels through market-based mechanisms. Fourth, performance varies spatially within states as well as across them. The performance trends suggest that high levels of water recovery depend upon adequate financing for investments in policy reform to reduce transaction costs over time and achieve increasing returns to scale. Such investments explain why performance varies within states in response to ongoing state- and watershed-level policy reforms, such as water banking and water allocation planning in the Deschutes and Salmon examples. These conditions enhance the likelihood of achieving adaptive efficiency. In the environmental water context, adaptive efficiency was defined as sufficient levels of water recovery at low and/or declining transaction costs, with adequate institutional capacity (program budgets) to get to scale. Finally, temporal performance trends *within* cases also demonstrate the importance of reinvesting in the transaction costs of policy reform, especially during early periods of implementation when initial water recovery efforts either require relatively high transaction costs or are only able to proceed at low transactions costs because implementation efforts target transactions that are not affected by persistent institutional barriers, such as the lack of an adjudication or administrative rules. Future research should incorporate public transaction costs and institutional performance into a comprehensive and longitudinal assessment of benefits and costs. Such assessment will evaluate institutional design and track the factors contributing to effective market-based water policy.

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References

Allen Consulting Group. 2006. *Transaction Costs of Water Markets and Environmental Policy Instruments.* Final Report to the Productivity Commission. Melbourne, Australia: Allen Consulting Group.

Anderson, Terry L., and Donald R. Leal. 2001. *Free Market Environmentalism.* Rev. ed. New York: Palgrave Macmillan.

Barzel, Yoram. 1989. *Economic Analysis of Property Rights*. New York: Cambridge University Press.

Basta, Elizabeth, and Bonnie G. Colby. 2010. "Water Market Trends: Transactions, Quantities, and Prices." *Appraisal Journal* Winter: 50–69.

Bauer, Carl J. 1997. "Bringing Water Markets Down to Earth: The Political Economy of Water Rights in Chile, 1976–1995." *World Development.* 25 (5): 639–56.

——. 2004. *Siren Song: Chilean Water Law as a Model for International Reform.* Washington, DC: Resources for the Future Press.

Bjornlund, Henning. 2004. "What Impedes Water Markets?" *Water* 31 (7): 47–51.

Brewer, Jedidiah, Alan Kerr, Robert Glennon, and Gary D. Libecap. 2008. "Water Markets in the West: Prices, Trading, and Contractual Forms." *Economic Inquiry* 46 (2): 91–112.

Bromley, Daniel W. 1982. "Land and Water Problems: An Institutional Perspective." *American Journal Agricultural Economics* 64 (5): 834–44.

——. 1989. *Economic Interests and Institutions*. New York: Blackwell Publications.

Carey, Janice, David L. Sunding, and David Zilberman. 2002. "Transaction Costs and Trading Behavior in an Immature Water Market." *Environment, Development, and Economics* 7 (4): 733–50.

Challen, Ray. 2000. *Institutions, Transaction Costs, and Environmental Policy*. Cheltenham, UK: Edward Elgar.

Ciriacy Wantrup, S. V., and Richard C. Bishop. 1975. " 'Common Property' as a Concept in Natural Resources Policy." *Natural Resources Journal* 15 (4): 713–27.

Coase, Ronald H. 1937. "The Nature of the Firm." *Economica* 4 (16): 386–405.

———. 1960. "The Problem of Social Cost." *Journal of Law and Economics* 3 (October): 1–44.

Coggan, Anthea, Stuart M. Whitten, and Jeffrey Bennett. 2010. "Influences of Transaction Costs in Environmental Policy." *Ecological Economics* 69 (9): 1777–84.

Colby, Bonnie G. 1990a. "Transactions Costs and Efficiency in Western Water Allocation." *American Journal of Agricultural Economics* 72 (5): 1184–92.

——. 1990b. "Enhancing Instream Flow Benefits in an Era of Water Marketing." *Water Resources Research* 26 (6): 1113–20.

Cole, Daniel H. 2002. *Pollution and Property: Comparing Ownership Institutions for Environmental Protection.* Cambridge: Cambridge University Press.

Demsetz, Harold. 1967. "Toward a Theory of Property Rights." *American Economic Review* 57 (2): 347.

Easter, William K., Mark W. Rosegrant, and Ariel Dinar, eds. 1998. *Markets for Water: Potential and Performance.* Boston: Kluwer Academic Publisher.

Gangaharan, Lata. 2000. "Transaction Costs in Pollution Markets: An Empirical Study." *Land Economics* 76 (4): 601–14.

Garrick, D., M. Siebentritt, B. Aylward, C. J. Bauer, and A. Purkey. 2009. "Water Markets and Freshwater Ecosystem Services: Policy Reform and Implementation in the Columbia and Murray Darling Basins." *Ecological Economics* 69 (2): 366–79.

Hardner, Jared, and R. E. Gullison. 2007. *Independent External Evaluation of the Columbia Basin Water Transactions Program (2003–2006).* Amherst, NH: Hardner and Gullison Consulting.

Hayek, Friedrich A. 1945. "The Use of Knowledge in Society." *American Economic Review* 35 (4): 519–30.

Hearne, Robert R., and K. William Easter. 1995. *Water Allocation and Water Markets: An Analysis of Gains-from-Trade in Chile.* Technical Paper 315. Washington, DC: World Bank.

Howitt, Richard E. 1994. "Empirical Analysis of Water Market Institutions: The 1991 California Water Market." *Resource and Energy Economics* 16 (4): 357–71.

Jones, Lana, and Bonnie Colby. 2010. "Weather, Climate, and Environmental Water Transactions." *Weather, Climate, and Society* 2 (3): 210–23.

Libecap, Gary D. 1989. *Contracting for Property Rights*. New York: Cambridge University Press.

Loomis, John B., Katherine Quattlebaum, Thomas C. Brown, and Susan J. Alexander. 2003. "Expanding Institutional Arrangements for Acquiring Water for Environmental Purposes: Transactions Evidence for the Western United States." *International Journal of Water Resources Development* 19 (1): 21–28.

Lovrich, Nicholas P., and Dan Siemann. 2004. *Of Water and Trust: A Review of the Washington Water Acquisition Program.* Seattle: Policy Consensus Center, Washington State University and University of Washington.

MacDonnell, Lawrence J. 1990. *The Water Transfer Process as a Management Option for Meeting Changing Water Demands.* Boulder: Natural Resources Law Center, University of Colorado.

Marshall, Graham. 2005. *Economics for Collaborative Environmental Management: Regenerating the Commons.* London: Earthscan.

McCann, Laura, Bonnie Colby, K. William Easter, Alexander Kasterine, and K. V. Kuperan. 2005. "Transaction Cost Measurement for Evaluating Environmental Policies." *Ecological Economics* 52 (4): 527–42.

McCann, Laura, and K. William Easter. 2000. "Estimates of Public Sector Transaction Costs in NRCS Programs." *Journal of Agricultural and Applied Economics* 32 (3): 555–63.

McCann, Laura, and K. William Easter. 2004. "A Framework for Estimating the Transaction Costs of Alternative Mechanisms for Water Exchange and Allocation." *Water Resources Research* 40: W09S09.

Mettepenningen, E., V. Beckman, and J. Egger. 2011. "Public Transaction Costs of Agri-environmental Schemes and their Determinants—Analyzing Stakeholders' Involvement and Perceptions." *Ecological Economics* 70 (4): 641–50.

Neuman, Janet C. 2004. "The Good, the Bad and the Ugly: The First Ten Years of the Oregon Water Trust." *Nebraska Law Review* 83 (2): 432–84.

Neuman, Janet C., Anne Squier, and Gail Achterman. 2006. "Sometimes a Great Notion: Oregon's Instream Flow Experiments." *Environmental Law* 36 (4): 1125–55.

North, Douglass C. 1990. *Institutions, Institutional Change and Economic Performance.* New York: Cambridge University Press.

———. 1994. "Economic Performance through Time." *American Economic Review* 84 (3): 359–68.

Northwest Power and Conservation Council (NPCC). 2005. *Deschutes Subbasin Plan*. Portland, OR: Columbia River Basin Fish and Wildlife Program.

Ostrom, Elinor. 1990. *Governing the Commons: The Evolution of Institutions for Collective Action.* Cambridge: Cambridge University Press.

Pilz, Robert D. 2006. "At the Confluence: Oregon's Instream Water Rights in Theory and Practice." *Environmental Law Journal* 36 (4).

Ruml, C. Carter. 2005. "The Coase Theorem and Western U.S. Appropriative Water Rights." *Natural Resources Journal* 45 (1): 169–200.

Schlager, Edella, and William Blomquist. 2008. *Embracing Watershed Politics*. Boulder: University Press of Colorado.

Thompson, Barton H., Jr. 1993. "Institutional Perspectives on Water Policy and Markets." *California Law Review* 81 (3): 671–764.

Williamson, Oliver E. 1998. "Transaction Cost Economics: How It Works; Where It Is Headed." *De Economist* 146 (3): 23–58.