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# Equity Basis Selection in Allocation Environments: An Empirical Analysis

David Aadland and Van Kolpin

Successful formation and long-term stability of cooperative ventures is often linked to the perceived fairness of the cost and resource allocations that these ventures employ. Indeed, the lack of a consensus over what basis should be used for gauging equitable allocation can undermine the prospects for collaboration. We use irrigation cost sharing as a context for examining the equity basis selections of cooperative ventures that successfully form and endure. Our analysis reveals that these selections are explained by features of the cooperative environment and inequities in the derived benefits from the irrigation water.

*Key words:* irrigation, cost allocation, equity, probit model

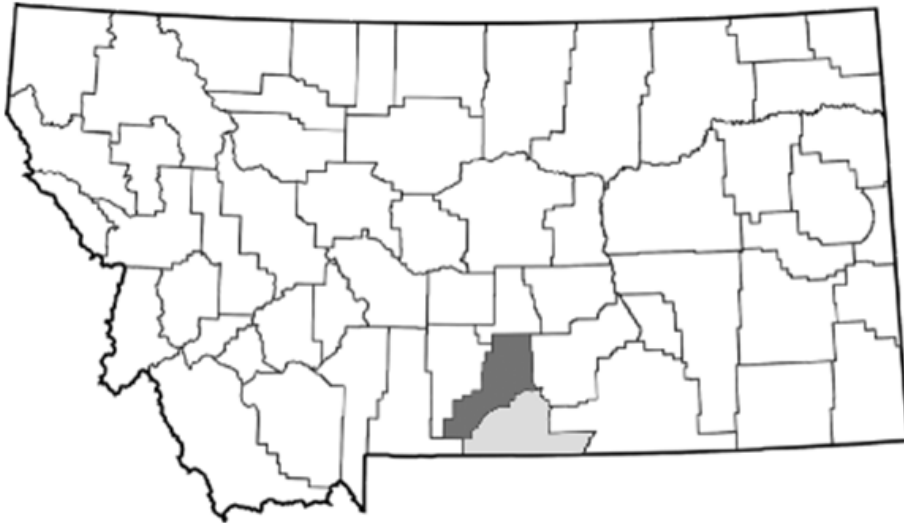
## Introduction

Many cooperative ventures, whether they are simple business partnerships or international collaborations, innately support a variety of alternative bases for gauging the “equitable” distribution of costs and resources. Consider the classic airport problem in which airlines share the costs of common landing strips (Littlechild and Owen, 1973). In this context, it is natural to use either the set of airlines, flights, passengers, or even revenues as a basis for equitable cost distribution. This multiplicity of logically compelling equity bases is a feature common to many cost-sharing applications and can prove to be a significant obstacle to the formation and long-term stability of collaborative agreements. The traditional cost-sharing literature, however, examines the allocation of costs across elements of a given equity basis. Although this is certainly a problem of considerable interest, it does not speak to the issue of why one equity basis is selected over others in any particular application. The goal of this paper is to offer a theoretical motivation for equity basis selections observed in practice and to empirically examine the extent to which observed selections can be predicted in a theoretically consistent fashion by features of the cooperative environment.

Much of the theoretical cost-sharing literature employs axiomatic principles on a given equity basis to derive a unique cost-sharing rule. Alternative rules can be derived by appealing to different sets of principles regarding appropriate/equitable cost sharing. For instance, costs may be distributed across an equity basis in accordance with average cost sharing, serial cost sharing, the nucleolus, the Shapley value, etc. Moulin (2002) presents a survey of popular alternatives. Despite this flexibility, the traditional axiomatic approach operates under the basic premise that the relevant equity basis is exogenously given and determination of the “ideal” cost-sharing rule depends solely on the cost-sharing game’s mathematical structure. As noted above, applications often present a variety of compelling equity bases, not just one. We argue that features of the cooperative environment that affect the distribution of benefits, but not the shared costs, may influence equity basis selection through a collective desire to administer cost sharing over a “level playing field.” Toward that end, we introduce the *benefit inequity principle*, which posits that the greater are the differences in the

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**Figure 1. Montana Counties**

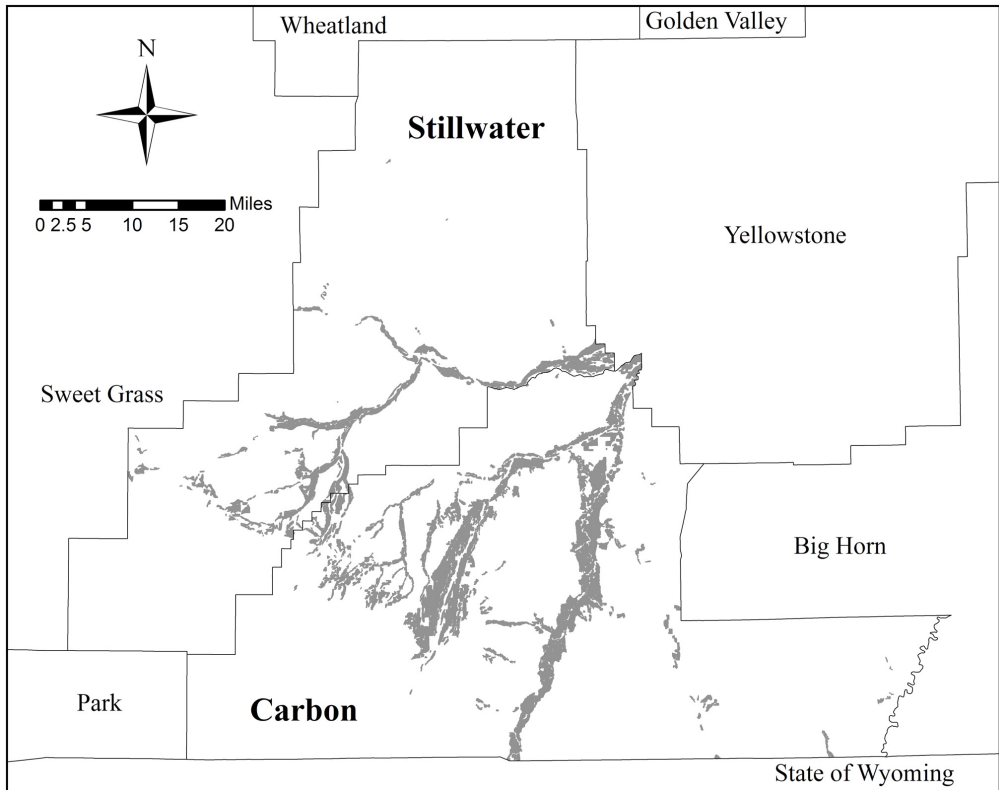
*Notes:* Stillwater County is shaded dark, Carbon County is shaded light, all other counties are white.

pre-tax (before cost-share deduction) benefits realized by elements of a given equity basis, the less likely that basis will be selected to administer cost sharing and assess fairness. Our empirical analysis tests the efficacy of this axiom as a guiding force in the practical selection of equity bases.

We use irrigation cost sharing in two neighboring counties of Montana, USA, as a context for our study. Figure 1 presents a graphical depiction of these counties - Carbon and Stillwater - within the state of Montana. Figure 2 depicts the distribution of irrigated lands within Carbon and Stillwater counties. This context is well suited for our study of equity basis selection, thanks in part to the close geographic and social proximity of the sample. This closeness makes it less likely that unobserved variation in cultural conventions, which may in turn influence cooperative decision making, will bias our estimates. Indeed, Young (1994) notes that equity is “strongly shaped by cultural values, by precedent, and the specific types of goods and burdens being distributed.” Another compelling feature of our data is that the cost-sharing practices observed on the irrigation ditches in this region have proven to be remarkably stable.<sup>1</sup> Moreover, from the time that these ditches were first formed, irrigators have been highly motivated to adopt sharing procedures that minimize the prospects for dispute. For instance, Teele (1900) highlights a statement of expenses for a Montana ditch in the early 1890’s and notes that the amount of money invested in legal expenses was four times that of ditch maintenance and operation combined.

The irrigation ditches in our sample share a common physical structure. The “main” ditch begins at the headgate, which diverts water from the ditch’s source river/stream, and continues in a sequential path through both users’ and non-user’s property. Costs for private ditches that branch off the main ditch are covered by the respective owners and are not shared by the group as a whole. Thus the shared costs are those pertaining to the headgate and main ditch, examples of which include headgate repair, silt and debris removal, and repair of deteriorating earthen ditch banks. The ditches are used to irrigate various cash crops (e.g., alfalfa hay, sugar beets, barley, and corn), water livestock, and irrigate pastures, lawns, and gardens.

<sup>1</sup> Only one ditch in our sample had users who indicated there had been changes made to cost-sharing practices in the recent past. Private communications with irrigators also indicated that ditches have often employed the same practices for over a century.



**Figure 2. Irrigated Land in Carbon and Stillwater Counties**

*Notes:* Irrigated land in Carbon and Stillwater is shaded. Map is constructed from GIS data provided by the Water Resources Division of the Montana Department of Natural Resources and Conservation.

Our data set is constructed from a combination of state and federal sources, as well as our own survey efforts. The data support the conclusion that the benefit inequity principle serves as a guiding force in equity basis selection. In particular, the coefficients of our empirical model have signs consistent with this principle and our independent variables exhibit considerable explanatory power.

Although our paper may be the first to empirically address equity basis selection, it is far from the first to use water resources as a context for economic analysis. For instance, predating our paper by over a century, Teele (1900) examined unsettled water rights and ineffective matching of labor and capital as impediments to agricultural development in the western United States. In regards to game-theoretic analysis, engineers and economic consultants for the Tennessee Valley Authority in the 1930's examined the allocation of shared costs and independently derived solutions closely resembling those formally constructed in the cooperative game theory literature many years later (Straffin and Heaney, 1981). Collective behavior in the context of water resource sharing also plays a primary role in the classic Ostrom (1990), which provides an in-depth empirical and theoretical analysis of the evolution of community institutions that govern various common pool resources. Dayton-Johnson (2000) uses irrigation data from Mexico to examine the joint decision of resource (water) and cost sharing. The paper's empirical analysis concludes that increased economic inequality leads to a decreased likelihood of both water and costs being shared equally across all users. Although the Mexican irrigation ditches in the Dayton-Johnson sample service many more users than the Montana ditches of our sample (an average of 125 households versus 7) and

the Dayton-Johnson data set is not partitioned by equity basis, the impact of economic inequality nonetheless supports the benefit inequity principle.

### Axiomatic Motivation

#### *Relationship to the Traditional Axiomatic Methodology*

Much of the theoretical cost-sharing literature adopts essentially the same methodology as that pursued in the creation of the bargaining solution (Nash, 1950) or the Shapley value (Shapley, 1953). In general, this methodology formulates a mathematical abstraction of the universe of all environments under consideration, identifies desirable properties of a “solution” defined within this universe, and then demonstrates that these properties characterize a unique solution or class of solutions. For instance, the “Shapley program” considers the universe of all TU (transferable utility) games, defines a solution as a value operator, and then demonstrates that the Shapley value is the only solution to satisfy the anonymity, additivity, and dummy axioms.

The approach adopted in our paper differs from that outlined above in several respects. First, each irrigation ditch in our universe of cost-sharing environments has not one, but three distinct “populations” that can serve as the “player” set over which equity is assessed and costs are distributed - namely, the populations of: 1) irrigators using the ditch, 2) acres irrigated by the ditch, and 3) water shares distributed on the ditch; where a “water share” represents a share of stock in ditch ownership and a claim to a share of the ditch’s water capacity. Because each of these populations provides a different basis for equity assessment, we refer to these populations generally as *equity bases* and specifically as the per capita basis, per acre basis, and per water-share basis respectively.<sup>2</sup>

A second dimension where our approach differs from traditional treatments of cost sharing is that we consider the possibility that features of the cooperative environment, in particular those that have no effect on the costs to be distributed, may influence equity basis selection. Ditch maintenance costs are the only values subject to redistribution in our setting. A traditional approach would dictate not only that the equity basis be taken as exogenously given, but also that the universe of cost-sharing games for this equity basis should be characterized solely in terms of those parameters that impact shared costs. We depart from the traditional approach and hypothesize that the benefits accruing across the ditch may influence the equity basis embraced even when these benefits are not themselves subject to redistribution.

A final dimension of difference in our approach is that we do not use axiomatic principles to identify a unique cost-sharing rule that *should* be employed in a framework that is assumed to perfectly reflect the real world. Instead, we use the cost-sharing procedures in practice to determine if the data support the hypothesis that equity basis selection is guided by axiomatic principles, specifically the benefit inequity principle.

The irrigation cost-sharing environments under consideration are characterized by the: 1) maintenance costs incurred on the ditch, 2) population of users that have access to the ditch (the per capita basis), 3) population of acres serviced by the ditch (the per acre basis), 4) population of water shares distributed across users of the ditch (the per water-share basis), and 5) benefits that accrue to these populations, which often vary by the type and scale of water use. Our paper maintains a tight focus on examining the manner in which the underlying environment may impact equity basis selection. Readers seeking a detailed discussion of how the cooperative environment may affect the manner in which costs are distributed across a *given* equity basis are encouraged to

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<sup>2</sup> In principle, additional equity bases could also be considered. As we did not detect the use of alternative equity bases in our sample, we restrict our attention to per capita, per acre, and per water-share bases. Note also that our terminology should not be interpreted as indicating that costs are necessarily shared equally between all elements of the respective basis. Differential treatment of basis elements can be induced by their relative location on the ditch.

consult Aadland and Kolpin (2004).<sup>3</sup> Those interested in axiomatic characterizations of the average and serial irrigation cost-sharing rules given a fixed equity basis and without consideration for the influence of environmental features should consult Aadland and Kolpin (1998).

### *An Equity Basis Selection Principle*

A key axiom underlying our analysis is the benefit inequity principle. The essential idea underlying this principle is that when costs, and not benefits, are subject to redistribution, there may be a fundamental pressure to administer cost sharing over a “level playing field.” That is, an increase in the pre-tax benefit inequity attributed to any particular equity basis may imply a diminished set of circumstances in which that basis will be selected to administer cost sharing and assess fairness. The *benefit inequity principle* dictates that greater inequalities in the pre-tax (before cost-share deduction) benefits realized by elements of a given equity basis will reduce the set of circumstances in which the given equity basis will be adopted.<sup>4</sup>

Readers may note that our formulation of the benefit inequity principle does not specify a precise functional relationship between the benefit inequality realized across bases and the equity basis actually adopted. Instead, it merely states that this relationship is decreasing, *ceteris paribus*, in the benefit inequality attributed to the given basis and, thus, represents a monotonicity principle. This axiomatic feature enables our data to speak to where these lines should be drawn, rather than imposing rigid specifications that may or may not be supported by the data. It is also worth noting that the tendencies toward “inequity avoidance” reflected by the benefit inequity principle need not necessarily be generated by a direct preference for fairness.<sup>5</sup> Cost-sharing participants are well aware that their situation is one of repeated interaction both in terms of irrigation and the local community. Consistent with the “transaction cost” motivations espoused in Allen and Lueck (1993), the apparent preference for equity can also be an artifact of a desire to avoid the costs of conflict fueled by perceived inequity.

## **The Data**

### *Data Sources*

The cost-sharing agreements within our sample represent a set of stable, yet informal, conventions that are “understood” by respective ditch users. As these conventions are not documented in publicly available sources, we surveyed users to obtain information regarding their cost-sharing procedures and the circumstances surrounding their use. Our survey efforts revealed that there are three bases over which costs are shared in our sample - the set of irrigators, the set of irrigated acres, and the set of water shares. As previously noted, we shall refer to these bases as the per capita, per acre, and per water-share bases.

<sup>3</sup> Aadland and Kolpin (2004) examine the collective choice between average and serial cost sharing. In the context of irrigation cost sharing, average cost sharing dictates that all members of a given equity basis share the costs of every maintenance project, whereas serial cost sharing requires only those equity basis members located downstream of a maintenance project to share in its costs. “Excess demand protection” is shown to be a key factor in determining which of these procedures are adopted in practice.

<sup>4</sup> To state this principle more formally, let the universe of all circumstances for a given equity basis selection environment be characterized by  $\Delta \times \Psi$ , where  $\Delta$  is the space of all pre-tax (before cost share deduction) benefit inequity profiles for the candidate equity bases and  $\Psi$  is the space defined by all relevant factors other than benefit inequity. The benefit inequity principle dictates that if  $\delta$  and  $\delta'$  are two elements of  $\Delta$  that differ only in the pre-tax benefit inequity of equity basis  $i$ , then  $\Psi_i(\delta') \subseteq \Psi_i(\delta)$  whenever  $\delta'$  has a larger pre-tax inequity for basis  $i$  than that of  $\delta$ ; where for each  $\xi \in \Delta$ ,  $\Psi_i(\xi) = \{\psi \in \Psi \mid (\xi, \psi) \text{ induces selection of equity basis } i\}$ .

<sup>5</sup> However, there is an ample literature indicating that equity does indeed play a significant role in the preferences of some people and that the existence of such individuals can have broader implications for the overall economic systems in which they interact. See, for instance, Rabin (1993) and Fehr and Schmidt (1999).

We mailed the original survey in March 1998 to every individual with a water right in Carbon and Stillwater counties of Montana. Names and address of the individuals were provided by the Water Resource Division of the Montana Department of Natural Resources and Conservation (DNRC). We then followed the original survey by mailing a shorter postcard survey in November 1999 to increase response rates. The two surveys yielded a total of 270 useable individual responses across 98 irrigation ditches in Carbon and Stillwater counties, an average of approximately 2.75 responses per ditch. These 98 ditches service approximately 2,840 individual parcels, which comprise nearly 150,000 acres of irrigated land. Fourteen ditches were then excluded from the analysis because either: (a) the DNRC records indicate a single-user ditch or (b) respondents indicated that costs were distributed in a manner in which individuals bore the full responsibility for maintaining the portion of the ditch passing through their respective property (in which case one is unable to draw a distinction between the three prospective equity bases as each leads to the same final cost share for the corresponding user). Our final sample therefore includes 84 ditches that can be associated with either a per capita, per acre, or per water-share rule.

The reported equity basis on any particular ditch was generally consistent across respondents. Of the 84 ditches in our sample, 62 ditches exhibited no disagreement between survey respondents over the equity basis employed on their ditch. For the remaining 22 ditches, the reported equity basis was not perfectly consistent across respondents but typically involved a single dissenting respondent. This might be expected given that cost-sharing arrangements, and farmland contracts more generally as documented in Allen and Lueck (1992), tend to be informal oral agreements. Apparent inconsistencies in the equity basis that ditch users “understand” to be in use were resolved by assigning to each ditch the basis stated by the majority of its respondents and, if a tie were to occur (there were six ties), the most common basis in the overall data set was selected to represent the equity basis “of record.”<sup>6</sup> We experimented with other methods for handling the reported inconsistencies; results are briefly discussed below.

In addition to our survey, we relied on several other sources to construct our data set. First, the DNRC provided information on the location and size for the parcels of land serviced by the irrigation ditches in our sample, as well as the primary use for the water (Water Resource Division of the Montana DNRC, 2002).<sup>7</sup> Second, we used the Soil Surveys for Carbon and Stillwater counties (Parker, 1975; Parker, Decker, and Jackson, 1980) to derive estimates of the irrigated and non-irrigated productivity of the land served by a ditch. These estimates were, in turn, used to formulate a measure of the benefits bestowed by access to the irrigation ditch. Finally, we use high-quality spatial climate maps produced by the Oregon Climate Service to generate detailed measures of expected rainfall on each parcel of land serviced by the ditches in our sample, another factor impacting the incremental benefits of irrigation (Oregon Climate Service, 2002).

### *Econometric Variables*

We now turn to the specification of the variables used in our econometric analysis. Because we only consider three equity bases (i.e., per capita, per acre, and per water share), it suffices to consider two dependent variables - PC and PA. PC is a ditch-level binary variable that is equal to one if costs are shared on a per capita basis and zero if an alternative basis is employed. Similarly, PA is a ditch-level binary variable that equals one if costs are shared on a per acre basis and zero otherwise. Given that there are three bases that appear in our sample, it follows that if  $PC=PA=0$ , then costs are distributed on a per water-share basis.

<sup>6</sup> Alternatively, one can simply think of this equity basis as the one a majority of users perceive to be in use. That informal agreements may lead to conflicting perceptions regarding the equity basis effectively employed is hardly surprising. Indeed, even cooperative arrangements that include only two individuals, such as a marriage, can often lead to persistently divergent perceptions regarding agreements that are “understood” to be in place.

<sup>7</sup> Examples of primary use include crop irrigation, watering of livestock, and lawn/garden use.

The motivation behind the selection of our explanatory variables follows Tang (1992), which notes that “The size of the irrigated area, the number of cultivators involved, the distribution of wealth, and the social and cultural differences among cultivators affect their coordination costs and their abilities to develop and sustain institutional arrangements that can solve their problems.” We identify a small number of such factors in the available data that may explain the institutional selection of our specific interest, that of equity basis selection. Each directly or indirectly contributes to (pre-tax) benefit inequality within our three equity bases.

The first such factor is *SIZE*, which is defined from both a per capita and a per acre perspective. The per capita variant of *SIZE* is defined to be the number of users on the ditch.<sup>8</sup> In the majority of the cases, we have precise information regarding the number of users. However, some ditches are incorporated and filed with a single water right in the name of the ditch corporation rather than separate water rights for each user. As a result, we are unable to calculate per capita versions of the explanatory variables for the incorporated ditches in our sample. To handle these missing data, we replace the missing observations with a zero and add an additional dummy variable that captures whether information regarding the number of users was available.<sup>9</sup> The per acre variant of *SIZE* is defined to be the total number of irrigated acres on the ditch.

The second factor is *ATYPICAL*, which is again considered from either a per capita or a per acre perspective. The per capita variant of *ATYPICAL* represents the fraction of ditch users that employ irrigation water in a nonstandard way. We used the Montana DNRC data to make this determination. A user is said to be pursuing nonstandard use if their water right is designated as primarily for something other than crop irrigation or if they irrigate a parcel of land that is less than 1/2 acre - a proxy for someone who is using the land for purposes other than farming or for very small operations. Similarly, the per acre variant of *ATYPICAL* is defined to be the fraction of irrigated acres that employ water in a nonstandard way, i.e., used for something other than crop irrigation or belonging to a parcel less than 1/2 acre in size.

The per capita variant of *TOWN* is a variable that represents the fraction of ditch users that irrigate property within a one-mile radius of a town center. This variable serves as a proxy for the share of landowners who have land that may be particularly suitable for something other than agricultural use. It also serves to capture benefits derived from close proximity to city services and supplies. The per acre variant of *TOWN* is the fraction of irrigated acres within a one-mile radius of a town center.

*SD* represents a measure of variation in the pre-tax benefits accruing to equity basis elements on a given ditch. When the focus is on the per capita basis, one can think of the total acreage irrigated by a user as capturing a measure of the pretax benefits accruing to this user. The per capita variant of *SD* is then defined as the standard deviation of acres irrigated by users on the ditch. When the focus is on the per acre basis, note that larger parcels of land will tend to facilitate larger benefits per acre. Indeed, there is a smaller percentage of land lost to fence lines and natural boundaries, less movement and setup costs of machinery per unit of crop yield, etc. To capture this effect, each acre is assigned a value equal to the parcel size to which it belongs. The per acre variant of *SD* is then defined as the standard deviation of these values across each irrigated acre on the ditch.

The final two variables are factors that influence the incremental economic returns associated with irrigated land. *RAIN* is a variable that captures the minimum expected rainfall on a given ditch. That is, each parcel of land has an expected level of rainfall and *RAIN* represents the smallest expected rainfall attributed to any parcel serviced by the ditch in question. We focus on the minimum expected rainfall because: (a) it serves as a proxy for the risk associated with low levels of rainfall,

<sup>8</sup> Depending on context, we focus on either the per capita basis or the per acre basis. We do not directly use per water share as a basis because this is tantamount to noting the absence of focus on either per capita or per acre bases.

<sup>9</sup> The dummy-variable approach for handling missing data was originally suggested by Cohen and Cohen (1983). However, it has been shown to provide biased estimates of the coefficients in certain circumstances and is no longer widely accepted. Allison (2001) argues that listwise deletion is the preferred alternative out of the conventional methods for handling missing data. For completeness, we estimate the econometric model using both methods. The results are robust to both methods and are briefly discussed in Section 4.

and (b) some of the ditches have fields located near mountainous regions that receive considerably more precipitation than the tillable fields served by the ditch. In such cases, the expected rainfall that the OCS data attributes to some fields is biased upwards relative to expected rainfall elsewhere on the ditch. Our specification of the RAIN variable moderates this bias. YIELD RATIO is defined as the ratio of the expected alfalfa yield (the most common crop) on irrigated land relative to the expected alfalfa yield on the same land when one instead uses dryland farming methods.<sup>10</sup> The variation in soil types, steepness, and elevation across our sample leads to variation in YIELD RATIO. This variable was constructed using the Carbon and Stillwater Soil Surveys.

Table 1 reports the definitions of the variables and various summary statistics. Notice that the sample is unbalanced in the direction of per water-share rules, with the precise distribution being per water-share ( $n = 53$ ), per capita ( $n = 19$ ) and per acre ( $n = 12$ ) rules. Focusing on the user-defined version of the variables, there is an average of approximately seven users with most living outside town. There is substantial variation in irrigated acres across users on each ditch with the average of SD equal to 73 acres. The ATYPICAL variable indicates that most ditches are comprised of larger users who are irrigating crops - only six ditches have users who are irrigating small acreage or are using the water for stock or domestic purposes. There is also substantial variation in RAIN (with the minimum rainfall varying between 108 and 238 millimeters - 4.25 to 9.37 inches - per growing season) and in YIELD RATIO (with a minimum of 1.4 and a maximum of 7.0).

### Econometric Analysis

In this section, we introduce the econometric models and the estimation methods. The primary goal of this section is to investigate whether features of the cost-sharing environment can explain the choice of equity basis and whether this explanatory power is consistent with the benefit inequity principle. In particular, we seek to determine if environmental features that increase the perceived inequity affiliated with an equity basis will decrease the likelihood of this equity basis being selected. However, we also recognize the fact that the inherent simplicity and transparency of a per capita basis may be appealing in its own right. We capture this appeal by adopting a two-stage model econometric model. Stage 1 represents a choice between the relatively transparent per capita equity basis and the somewhat more complex alternatives - the per acre and per water-share bases. Stage 2 represents the choice to be made between the per acre and per water-share bases after the per capita basis option has been eliminated.

#### Probit Models

We consider an irrigation ditch as the unit of observation, which is indexed from  $i = 1, \dots, n$ . In our first model, we restrict irrigators to select a per capita basis or to select from the set of all other alternatives. The stage 1 model is expressed as:

$$(1) \quad PC_i^* = X_i' \beta + \varepsilon_i,$$

where  $PC_i^*$  is a latent variable measuring the propensity of irrigators on ditch  $i$  to collectively choose the per capita basis over the alternatives,  $X_i$  is a column vector of the per capita basis explanatory variables for ditch  $i$  detailed in section 3,  $\beta$  is a column vector of coefficients, and  $\varepsilon_i$  is a normally distributed error term with mean zero. The  $X_i$  vector includes per capita versions of SIZE, ATYPICAL, TOWN, and SD, each of which may impact pre-tax benefit inequities for the irrigators themselves.

<sup>10</sup> Alfalfa hay is not the only crop grown in our sample, nor is it necessarily the most profitable choice. It is, however, the one crop for which we could obtain estimated yields for both irrigated and dryland farming techniques on every soil type present in the region and thus YIELD RATIO serves as a useful proxy for productivity differentials between farming techniques.

**Table 1. Variable Definitions and Descriptive Statistics**

Variable	Definition	Statistics				
		Mean	Std. Dev.	Min	Max	Sample Size
<i>PC</i>	1 if cost-sharing rule is specified on a per capita basis, 0 otherwise	0.23	0.42	0.00	1.00	84
<i>PA</i>	1 if cost-sharing rule is specified on a per acre basis, 0 otherwise	0.14	0.35	0.00	1.00	84
<i>PWS</i>	1 if cost-sharing rule is specified on a per water-share basis, 0 otherwise	0.63	0.49	0.00	1.00	84
<i>SIZE</i>	Number of irrigators (acres)	7.38 (1507.50)	6.78 (2796.30)	2.00 (18.80)	33.00 (21563.50)	63 (65)
<i>ATYPICAL</i>	Fraction of users (acres) using water for stock/domestic purposes or on fields less than one half acre	0.02 (0.00)	0.06 (0.01)	0.00 (0.00)	0.33 (0.05)	63 (65)
<i>TOWN</i>	Fraction of users (acres) within a mile radius of town center	0.13 (0.07)	0.29 (0.17)	0.00 (0.00)	1.00 (1.00)	63 (65)
<i>SD</i>	Standard deviation of irrigated acres across all users (standard deviation of parcel size across all acres)	73.13 (48.10)	64.78 (36.20)	3.19 (1.81)	288.88 (189.47)	63 (65)
<i>RAIN</i>	Minimum rainfall (millimeters) on a ditch parcel during the growing season (May through August)	190.48	30.74	108.44	238.39	65
<i>YIELD RATIO</i>	Ratio of average yield on irrigated to non-irrigated fields	2.27	1.17	1.40	7.00	65

Notes: The  $n = 63$  sample sizes reflect variables that can only be measured for unincorporated ditches. The  $n = 65$  sample sizes reflect variables that are used to distinguish between PA and PWS equity bases. Towns under consideration include Absarokee, Bridger, Columbus, Fromberg, Joliet, Red Lodge, and Roberts.

In stage 2, ditches that did not select the per capita equity basis then decide between per acre and per water-share bases. This model is given by:

$$(2) \quad PA_j^* = Z_j' \gamma + v_j,$$

where  $j$  indexes all ditches that did not choose the per capita equity basis in stage one,  $PA_j^*$  is a latent variable measuring the propensity to choose the per acre basis over the per water-share basis,  $Z_j$  is a column vector of per acre basis explanatory variables for ditch  $j$ ,  $\gamma$  is a column vector of coefficients, and  $v_j$  is a mean-zero, normally distributed error term. The vector  $Z_j$  includes per acre versions of SIZE, ATYPICAL, TOWN, and SD, along with RAIN and YIELD RATIO, which are also thought to impact the pre-tax per acre benefits realized from irrigation.

Equations (1) and (2) are then used to form the necessary probabilities and associated likelihood functions. Estimation requires nonlinear optimization techniques to generate parameter estimates and the associated marginal effects (Greene, 2008).<sup>11</sup> Robust standard errors are calculated to account for possible model misspecification.

<sup>11</sup> The estimation was carried out in NLOGIT version 4.0.

**Table 2. Probit Estimation Results: Choice of Equity Basis for Irrigation Cost-Sharing Rules**

Variable	Stage #1. PC vs. PA/PWS				Stage #2. PA vs. PWS			
	Dependent Variable = PC				Dependent Variable = PA			
	Coef.	Std. Error	ME	Expected Sign	Coef.	Std. Error	ME	Expected Sign
Constant	0.68	0.44			-1.26	2.98		
SIZE	-0.03	0.04	-0.01	-	-0.002**	0.001	-1.40e-3	-
ATYPICAL	-9.74***	3.69	-1.98	-	-123.53**	66.88	-1.04	-
TOWN	2.29***	0.83	0.47	+	2.90*	2.06	0.02	+
SD	-0.02***	0.01	-0.004	-	-0.03*	0.02	-2.30e-4	-
RAIN					0.01	0.01	7.80e-3	+
YIELD RATIO					0.27*	0.17	2.20e-3	+
LR Statistic		31.74***				25.39***		
Sample Size		84				65		
	<b>Number of Actual Rules</b>	<b>Predicted Correct (%)</b>	<b>MS Predicted Correct (%)</b>		<b>Number of Actual Rules</b>	<b>Predicted Correct (%)</b>	<b>MS Predicted Correct (%)</b>	
PC Ditches	19	10 (53%)	15 (79%)					
PA Ditches	12	60 (92%)	60 (92%)	12	6 (50%)	6 (50%)		
PWS Ditches	53			53	50 (94%)	52 (98%)		
All Ditches	84	70 (83%)	75 (89%)	65	56 (86%)	58 (89%)		

Notes: The marginal effects (ME) are computed using the sample means. (\*), (\*\*), and (\*\*\*) indicate significance at the 10, 5, and 1% level, respectively. P-values for the coefficient estimates are based on one-tailed tests. PC = Per Capita; PA = Per Acre; PWS = Per Water-Share; LR = Likelihood Ratio; MS = Maximum Score Estimator. SIZE, ATYPICAL, TOWN and SD are defined with respect to users (acres) when the dependent variable is PC (PA). The coefficient on the missing-data dummy variable in stage #1 is not shown.

*Discussion of the Results*

The estimation results are presented in table 2. Overall, the model has significant explanatory power (likelihood ratio statistic is 31.74 and significant at the 1% level) and is able to correctly predict 83% (70 of the 84) of the equity bases. The maximum score (MS) estimator, a semi-parametric estimator that directly maximizes the number of correct predictions, predicts 75 of the 84 ditches. We highlight several salient features from the coefficient estimates and marginal effects.

First, the significant determinants of the per capita basis are ATYPICAL, TOWN, and SD. All else equal, larger values of SIZE, ATYPICAL, and SD are correlated with greater differences in the benefits realized by irrigators on the ditch and thus the benefit inequity principle would suggest there is pressure to adopt an alternative to a per capita equity basis. We expect that users near town will tend to be more uniform in the benefits received from ditch access and, therefore, smaller values of TOWN suggest a pressure to adopt an alternative to a per capita equity basis. These priors are supported by the econometric results - large rural ditches with atypical users and greater variation in irrigated acres are less likely to choose the per capita equity basis. The coefficients of ATYPICAL, TOWN, and SD are all statistically significant at the 1% level.

We highlight the marginal effects for two of these variables. All else equal, if the fraction of individuals near a town increases from 0.25 to 0.75, the probability of choosing the per capita basis increases by 23 percentage points. Likewise, an increase in SD of 50 acres decreases the probability of choosing the per capita basis by 20 percentage points, respectively. All the coefficients in the PC equation have expected signs - ditches in town have an increased chance of using the per capita basis; while ditches with atypical users and greater variation in irrigated acres are less likely to employ the per capita basis.

When choosing between a per acre and a per water-share basis, users are assumed to appeal to per acre counterparts of the explanatory variables: SIZE, ATYPICAL, TOWN and SD, as well

as RAIN and YIELD RATIO which proxy the economic returns to each irrigated acre. We expect that higher values for SIZE and ATYPICAL are likely to be associated with greater variation in the use and quality of the land, both of which suggest greater variation in the benefits received from irrigating a given acre. As such, the benefit inequity principle would tend to decrease the chance that a per acre basis is chosen. Conversely, we expect that land clustered near a town will be more uniform in both its quality and use, which in turn leads to a greater likelihood of the per acre basis. Therefore, the coefficient on TOWN is expected to be positive.

Recall that the per acre variant of SD is measured as the standard deviation of parcel size across each irrigated acre on an irrigation ditch. All else equal, we expect larger parcels to be more efficient due to fewer natural boundaries and fences, which allow for economies of scale in grazing or farming. Larger values of SD, therefore, imply greater variation in the productivity of each irrigated acre and a reduced likelihood that the per acre basis will be adopted. Finally, RAIN and YIELD RATIO serve as proxies for the variation in benefits received by each irrigated acre. Ample rainfall tends to lessen the incremental per acre benefits of irrigation, reduces the variation in per acre benefits, and makes the per acre basis more likely. A higher YIELD RATIO implies a larger proportional difference between irrigation and dry-land farming techniques, which suggests an increased incentive to employ the best possible irrigation/farming practices. As consequence, we expect the incremental benefits of irrigation to be more uniform with higher YIELD RATIO. In light of the benefit inequity principle, this suggests a positive relationship between YIELD RATIO and the likelihood of per acre basis being adopted.

All the coefficient estimates are statistically significant at the 10% level except for RAIN and have signs consistent with the discussion above. The likelihood ratio statistic is 25.39 and significant at the 1% level, implying that the model has significant explanatory power. The model also successfully classifies 56 of the 65 cost-sharing rules, for an approximate 90% correct prediction percentage.<sup>12</sup>

## Conclusion

Cooperative environments are frequently endowed with multiple prospective bases for assessing the “fairness” of allocation. In the case of our shared irrigation cost environments, per capita, per acre, and per water-share bases are each used. Rather than simply taking equity basis selections as given, we explore whether parameters of the cooperative environment can be used to explain these selections and whether they are consistent with axiomatic principles of collective behavior.

Our results show that features of the cooperative environment are indeed capable of explaining equity basis selection. Using a sample of 84 cost-sharing irrigation ditches, we demonstrate that environmental features enjoy substantial explanatory power in determining the equity basis embraced in practice. This explanatory power is consistent with the benefit inequity principle - that is, greater pre-tax benefit inequity across the elements of an equity basis is a deterrent for its selection. As such, our empirical results are also supportive of an axiomatic approach to cost-allocation applications. We consider the empirical results in our paper as a promising initial investigation into the selection of equity bases in allocation environments, but acknowledge that additional studies using larger data sets in a wider array of cost-sharing contexts are needed.

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<sup>12</sup> The empirical results represent a robust relationship between environmental parameters and the observed equity basis selection. We experimented with several alternative explanatory variables and various definitions of the current explanatory variables. For instance, we examined measures of the slope, roughness, and elevation of the land; ditch length; alternative threshold values for ATYPICAL and TOWN; alternative measures of acre variation such as the absolute difference between smallest and largest users, and a GINI index; rainfall and yield variation; imputation of missing SIZE observations; and self-reported variation in water usage, to name a few. We also estimated the models on restricted samples that deleted ditches with missing data and ditches with significant disagreement on the perceived cost-sharing rule. The coefficients from these various specifications and samples exhibited the expected signs and the models continued to explain a significant amount of the variation in the dependent variables. Results are available upon request.

In addition to the econometric results, previous research and direct statements from the irrigators indicate that equity and conflict avoidance are important determinants in the choice of the equity basis. For example, Rabin (1993), Fehr and Schmidt (1999), and Toler et al. (2009) argue that economic agents prefer equitable arrangements, while Allen and Lueck (1993) argue that agents seek to avoid conflict fueled by perceptions of inequity. Respondents to our own survey also indicate a general concern for fairness and conflict avoidance. Comments include statements such as:

- “If it [cost-sharing rule] ain’t broke, don’t fix it. It ain’t broke.”
- “The old methods have worked for many years and are well understood by all.”

This sentiment is also supported by responses to a question from our survey that was designed for other purposes and was not used in the present analysis. This question asked why the current cost-sharing method continued to be practiced. The majority (85%) of respondents selected “fairness” as being an important reason, more so than any other option.

In closing, we note that an important first step in the forging of stable and mutually beneficial cooperative agreements is the selection of an appropriate basis for equity assessment. To the extent that choices serving as the foundation for successful collaborations in the past can be expected to support successful collaboration in the future, our analysis can be viewed as providing some guidance on the best way to select such a basis. For the specific case of irrigation cost-sharing, our econometric model and features of a prospective irrigation ditch can be used to provide an indication of which equity basis selection is most inclined to lead to a successful collaboration. For cost-sharing projects more generally, our results demonstrate the usefulness of identifying environmental features that impact pre-tax benefit inequality across elements of candidate equity bases. Data from collaborative successes in the past can then be used to identify an appropriate equity basis selection for collaborations yet to be undertaken.

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