

EQUITY BASIS SELECTION IN ALLOCATION ENVIRONMENTS: AN EMPIRICAL ANALYSIS

Abstract. The successful formation and long-term stability of a cooperative venture is often linked to the perceived fairness of the associated cost or resource allocation. In particular, the effectiveness of such collaborations can be hampered by the lack of a consensus view on what basis should be used for gauging an allocation's "fairness." Standards of equity in traditional cost-sharing applications could be assessed on many dimensions: per capita, per unit of demand, or per unit of revenue, to mention a few. This multiplicity of logically compelling "equity bases" is a feature common to many cost-sharing applications. Our analysis of irrigation cost sharing shows that features of the allocation environment are capable of explaining a substantial amount of the variation in the equity bases employed in practical applications. The observed equity bases are also consistent with the *benefit inequity principle*, which hypothesizes that pre-tax benefit inequity has a monotonic impact on equity basis selection.

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

1. Introduction

Successful formation and long-term stability of a cooperative venture are often linked to the perceived fairness of the associated cost or resource allocation. Whether a venture is a simple business partnership or a global collaboration, such as that which led to the Kyoto protocol, its effectiveness can be hampered by the lack of a consensus view on what basis should be used for gauging an allocation's "fairness." Consider, for instance, the classic airport problem in which multiple airlines share a common landing strip (Littlechild and Owen, 1973). Aside from the issue of how costs should be apportioned amongst the set of players is the more fundamental question of what represents the relevant basis over which principles of equity should be applied. Should concern be focused on the distribution of costs across the set of airlines, the set of flights, the set of passengers, the set of revenues, or perhaps some other basis? Although these various bases are intertwined, each offers a different perspective on notions of fair treatment. This multiplicity of logically compelling fairness bases is a feature that is common to many practical cost-sharing applications. For example, participants of international initiatives to mitigate global climate change must agree whether the burden of reducing greenhouse gases should be distributed according to a per capita, per unit of GDP, per unit of wealth, or some other basis (Ashton and Wang, 2003).¹ What then leads to the selection of one basis over another in practice? Is this choice essentially arbitrary or can parameters of the cooperative environment predict the fairness basis that is embraced? Moreover, if such explanatory power exists, is it consistent with theoretical principles of collective behavior? This paper aims to shed light on these puzzles.

¹ The issue of the appropriate equity basis has become a major obstacle to the effective implementation of agreements to mitigate global climate change. According to Frank E. Loy, the head of the U.S. delegation to international climate meetings during the Clinton administration and former U.S. Under Secretary of State for Global affairs, "if we're going to start talking about per capita emissions and trying to equalize those, we will never, never, never have an international agreement and therefore I think that is a dead-end" (Grossman, 2001).

Much of the theoretical cost-sharing literature employs axiomatic principles to derive a unique cost-sharing rule. This methodology operates under the premise that a collective decision on which allocation rule to employ should depend solely on the mathematical structure of the associated cost-sharing game. While this has proven to be a useful theoretical approach, practical applications often involve a variety of distinct fairness bases, even when their associated cost-sharing games are indistinguishable. We introduce the *benefit inequity principle* which posits that the greater are the differences in pre-tax benefits realized by elements of a given equity basis, the fewer are the circumstances in which this basis will be adopted. Our empirical analysis will test the efficacy of this axiom as a guiding force in the selection of actual cost-sharing procedures.

We use irrigation cost sharing in two neighboring counties of Montana, USA as a context for our study. The context is well suited for our study, 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. Another compelling feature of our data is that the cost-sharing practices observed on the irrigation ditches in this region are long-lived, in many cases over a century old. Although disputes between individual ranchers do arise on occasion, the cost-allocation practices have proven to be remarkably stable.

The irrigation ditches in our sample share a common physical structure. The “main” ditch begins at the headgate, which diverts water from the source stream, and continues in a sequential path through the users’ properties. Costs for private ditches that branch off the main ditch are covered by their respective owners and are not shared by the group as a whole. Thus the costs to be shared are those pertaining to the headgate and main ditch, examples of which include

headgate repair, silt and debris removal, and repair of deteriorating (main) ditch banks. The ditches are used to irrigate hay fields and other cash crops, water livestock, and irrigate lawns and gardens, with some variation in these uses across the ditches.

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

2. Axiomatic Motivation

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 loose terms, this methodology formulates a mathematical abstraction of the universe of all environments under consideration, identifies desirable properties of a “solution” defined on this universe, and then demonstrates that these properties will in fact 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 important 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 – namely, the population of irrigators using the ditch, the population of acres irrigated by the ditch,

and the population of water shares distributed on the ditch. (Note that a “water share” represents a share of stock ownership of the ditch.) As each of these populations provides a different basis for equity assessment, we shall refer to these populations generally as *equity bases*, and specifically as the per capita basis, per acre basis, and per water-share basis respectively.² Recall, the focus of our paper is to investigate whether features of the cost-sharing environment are able to explain the selection of the equity basis used in practice.

A second dimension where our approach differs from traditional treatments of cost sharing is that we consider the possibility that features of the cost-sharing environment, in particular ones that have absolutely no effect on the values subject to redistribution, may influence the choice of allocation procedure. In our setting, ditch maintenance costs are the only values subject to redistribution. A traditional approach would dictate that the universe of cost-sharing games should be expressed in terms of only those parameters that impact the costs to be shared and the player population over which sharing is to occur. We depart from the traditional approach and hypothesize that the benefits accruing across the ditch may influence the equity basis embraced even though these benefits are *not* themselves subject to redistribution.

A final dimension of difference in our approach is that we do not to use axiomatic principles to identify a unique cost-sharing rule that *should* be employed. Instead, we use the cost-sharing procedures actually employed to determine if the data supports the hypothesis that selection of these procedures is guided by axiomatic principles, specifically the benefit inequity principle.

The irrigation cost-sharing environments under consideration are characterized by the maintenance costs incurred on the ditch, the population of users that have access to the ditch (the per capita basis), the population of acres serviced by the ditch (the per acre basis), the population

² In principle, additional equity bases could also be considered. As we were unable to detect the use of alternative equity bases in our sample, we restrict our attention to the bases noted above.

of water shares distributed across users of the ditch (the per water-share basis), and the benefits that accrue to these populations. A comprehensive description of cost sharing on an irrigation ditch would detail the determining factors of which equity basis is selected as well as the manner in which the costs of each individual maintenance project are allocated. As our focus is solely on the question of how equity bases are determined, we will forego any detailed discussion of how costs are distributed across a given equity basis, e.g., serial versus average cost sharing.

A key axiom underlying our analysis is that of the benefit inequity principle. The essential idea behind this principle is that since only costs (not benefits) are subject to redistribution, there may be a fundamental pressure to administer cost sharing over a “level playing field.” That is, greater pre-tax benefit inequity from the perspective of a given equity basis may imply a diminished set of circumstances in which that basis would be selected to administer costs and assess fairness.

Benefit inequity principle: Greater inequality in the benefits realized by elements of a given equity basis will reduce the set of circumstances in which the given equity basis will be adopted.

The reader will 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 in the benefit inequality attributed to the given basis and thus represents a monotonicity principle. This vagueness enables our data to speak to where these lines should be drawn, rather than having rigid specifications that may not be supported by the data.

3. The Data

The cost-sharing agreements within our sample represent a set of stable, yet informal conventions that are “understood” by the respective ditch users. As these conventions are not documented in publicly available sources, we surveyed the 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. Costs are either shared on a per capita basis, a per acre basis, or a per water-share basis. (Our survey also delved into the issue of whether the group who shares responsibility for costs may differ depending on the nature of the project that induced the costs, the subject of which was the focus of Aadland and Kolpin, 2004. As discussed in the previous section, our focus in the present paper is instead on the determination of an appropriate equity basis.)

Our survey yielded a total of 270 usable responses from 101 of the 169 irrigation ditches in Carbon and Stillwater counties. These ditches service 2,840 individual parcels of irrigated land, comprising a total of 150,000 acres. Three ditches were excluded from the analysis because there was only one reported user and therefore no need for cost sharing. An additional 14 ditches were excluded because the respondents either (*a*) reported no cost sharing or (*b*) they did not select any of the cost-sharing options in the survey, instead choosing “Other” without specifying in their written comments how costs were actually shared. Our final sample therefore includes 84 ditches that can be associated with either a per capita, per acre, or per water-share rule.

As might be expected given the informal nature of the cost-sharing arrangements, the reported rules were not always consistent across users. Apparent inconsistencies in the cost-sharing rule that ditch users “understand” to be in use were resolved by assigning to each ditch the rule stated by the majority of its respondents and, if a tie were to occur (there were seven ties)

the most common rule in the overall data set was selected to represent the cost-sharing arrangement “of record.” (Alternatively, one can simply think of this cost-sharing rule as the one a majority of users perceive to be in use. That informal agreements may lead to conflicting perceptions regarding the rule 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.)

In addition to our survey, we relied on several other sources to construct our data set. First, the Water Resource Division of the Montana Department of Natural Resources and Conservation (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 use³ for the water (Water Resource Division, 2002). Second, we used the Soil Surveys for Carbon and Stillwater counties (USDA, 1975 and 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 spatial climate maps produced by the Oregon Climate Service to generate measures of expected rainfall along the ditches in our sample, another factor impacting the incremental benefits of irrigation (Oregon Climate Service, 2002).

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

³ Examples of primary use include crop irrigation, watering of livestock, and lawn/garden use.

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.

The motivation behind the selection of our explanatory variables was to identify a small number of factors in the available data that may directly or indirectly contribute to (pretax) benefit inequality within our three equity bases.

The first such factor is *SIZE*, which is defined to be the number of users on the ditch when the per capita basis is the “focal basis”.⁴ 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. For the incorporated ditches in our sample, we therefore do not have a useable measure of *SIZE*. To handle this 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 (Cohen and Cohen, 1983). When the per acre basis is our focus, *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 focus. For a per capita focus, *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 (an imperfect proxy for someone who is using the land for purposes other than farming or whose operations may be small in scale). For a per acre focus, *ATYPICAL* is defined to be the fraction of irrigated acres managed by users who employ water in a nonstandard way.

⁴ Depending on context, the focal basis is either per capita or per acre. We do not directly use per water share as a focal basis as this is tantamount to noting the absence of focus on either per capita or per acre bases.

For a per capita focus, TOWN is a variable that represents the fraction of ditch users that irrigate property within a 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. For a per acre focus, TOWN is the fraction of acres irrigated by users who have operations within a mile radius of a town center.

ACRE DIFF is a variable that represents the absolute difference in scale of the operations on a given ditch. It is defined to be the difference between the irrigated acres of the biggest and smallest users on the ditch and thus captures a measure of the maximal benefit gap present.

GINI measures the relative dispersion of irrigated acres across users on each unincorporated ditch. GINI is calculated as

$$GINI_i = (2\mu_i n_i^2)^{-1} \sum_{j=1}^{n_i} \sum_{k=1}^{n_i} |acre_{i,j} - acre_{i,k}|, \quad (1)$$

where μ_i is the average number of irrigated acres per user on ditch i , n_i is the number of users on ditch i , and $acre_{i,j}$ is the total number of acres irrigated by user j on ditch i . The Gini coefficient has a long tradition of measuring relative income or wealth inequality (see, for instance, Sen, 1973 and Lambert, 2002). The coefficient ranges from a minimum of zero (when all users have equivalent acreage) to a maximum of one (in an infinite population with all users except one having no acreage).

The final two variables are proxies for the economic returns associated with each acre. 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 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 the second proxy for economic returns to an irrigated acre and 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 dry-land farming methods. 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. Due to the manner in which the data are recorded, we do not have information on SIZE (number of ditch users), TOWN, ACRE DIFF and GINI for the 21 incorporated ditches. For the 63 unincorporated ditches, there is an average of approximately seven users with most users living outside town. There is also substantial variation in both ACRE DIFF (with a mean of 207) and GINI (with a mean of 0.363). 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 substantial variation in RAIN (with the minimum rainfall varying between 108 and 245

millimeters per growing season) and in YIELD RATIO (with a minimum of 1.4 and a maximum of 7.0).

4. 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 actual choice of equity bases and whether this explanatory power is consistent with the benefit inequity principle.

We consider two different estimation frameworks. In the first, we treat the choice of equity basis as a two-stage binary decision estimated with sequential probit models. In stage one, the agents choose whether the equity basis should be per capita or selected amongst the remaining two alternatives. If not, then in stage two the agents choose between per acre and per water-share equity bases. The design of this framework is intended to reflect a spirit typical of many interactions between these ranchers (as gleaned from our personal communications with them). In particular, there is a wide spread sentiment that it is often best to “go simple unless there is a compelling reason to the contrary.” In our irrigation context, per capita allocations are transparent and easy to calculate so ranchers may naturally focus on the per capita basis unless there is sufficient benefit inequity to induce them to carry out more sophisticated analyses and select from amongst alternative bases. Our two-stage framework reflects this rationale in that it effectively assumes that agents use a small set of simple structural indicators to determine if the per capita basis is an equitable choice and, if not, a more sophisticated set of structural indicators is used to narrow the choice between the per acre and per water-share variants.

A possible disadvantage of the two-stage approach is that it restricts decisions to be made sequentially, such that the second-stage decision between per acre and per water-share bases is

made without consideration of the per capita basis. With a multinomial logit model (our second estimation procedure), we relax this assumption by allowing agents to consider all three equity bases simultaneously and use the full set of explanatory variables. However, because the multinomial logit model effectively imposes the “independence of irrelevant alternatives” (IIA) assumption, we perform a Hausman test to see if agents do indeed decide between per acre and per water-share bases independent of the per capita rule (Hausman and McFadden, 1984).

4.1 Binomial Probit

We begin by assigning the 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. This choice of equity basis is in turn assumed to depend on structural characteristics as indicated by the following equation:

$$PC_i^* = X_i' \beta + \varepsilon_i, \tag{2}$$

where PC_i^* is a latent variable measuring the likelihood of choosing the per capita basis for ditch i , X_i is a column vector of explanatory variables for ditch i thought to influence the choice of equity basis, β is a column vector of coefficients, and ε_i is a normally distributed error term with mean zero. By assuming a normal distribution, we then form the likelihood function conditional on the observed data. Letting F denote the cumulative density function associated with the error term, we can write the probability that the i^{th} ditch chooses the per capita equity basis (indicated by $PC_i = 1$) as:

$$P_i = \Pr(PC_i = 1) = \Pr(PC_i^* > 0) = \Pr(\varepsilon_i > -X_i'\beta) = F(X_i'\beta). \quad (3)$$

The probability that the i^{th} ditch adopts either the per acre or per water share basis ($PC_i = 0$) is therefore given by $1 - P_i = F(X_i'\beta)$. Assuming independence of error terms, we can then write the (log) likelihood function as

$$\ln(L) = \sum_{i=1}^n [PC_i \ln(P_i) + (1 - PC_i) \ln(1 - P_i)]. \quad (4)$$

The problem of forming and maximizing (4) by choosing β , given normally distributed error terms, is referred to as the probit model. This estimation procedure requires nonlinear optimization techniques to generate estimates of the β parameters and the associated marginal effects (Greene, 2008).⁵

In stage two, 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

$$PA_j^* = Z_j'\gamma + v_j, \quad (5)$$

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 likelihood of choosing the per acre equity basis, Z_j is a column vector of explanatory variables for ditch j thought to influence the choice of equity basis, γ is a column vector of coefficients, and v_j is a mean-zero, normally distributed error term. The log

⁵ The estimation was carried out in Gauss 8.0 using the Constrained Maximum Likelihood (CML) module and Newton's method for the nonlinear optimization.

likelihood function is then formed and maximized to obtain estimates of γ and the associated marginal effects.

4.2 Multinomial Logit

We also consider a model where agents on each ditch choose simultaneously from amongst the per capita, per acre, and per water-share equity bases. The model can be written as

$$PC_i^* = X_i' \beta_1 + \varepsilon_{1,i} \quad (6.1)$$

$$PA_i^* = Z_i' \beta_2 + \varepsilon_{2,i} \quad (6.2)$$

where the disturbances $\varepsilon_{1,i}$ and $\varepsilon_{2,i}$ are assumed to be independent and follow a type 1 extreme value distribution (Greene, 2008).⁶ This leads to the following probabilities

$$P_{1,i} = \Pr(PC_i = 1) = \exp(X_i' \beta_1) / (1 + \exp(X_i' \beta_1) + \exp(Z_i' \beta_2)) \quad (7.1)$$

$$P_{2,i} = \Pr(PA_i = 1) = \exp(Z_i' \beta_2) / (1 + \exp(X_i' \beta_1) + \exp(Z_i' \beta_2)) \quad (7.2)$$

$$P_{3,i} = \Pr(PWS_i = 1) = 1 - P_{1,i} - P_{2,i} \quad (7.3)$$

and log likelihood function

$$\ln(L) = \sum_{i=1}^n [PC_i \ln(P_{1,i}) + PA_i \ln(P_{2,i}) + PWS_i \ln(P_{3,i})]. \quad (8)$$

⁶ The multinomial logit model typically includes the same set of regressors for each choice category. However, our intention for using the multinomial logit model is to allow for the simultaneous selection of per capita, per acre and per water share bases. Equations (6.1) and (6.2) are therefore the same as equations (2) and (5) except for the error distribution. The estimation is implemented by stacking all the regressors in a single vector and restricting the appropriate coefficients to equal zero.

Because the multinomial logit model assumes independent and homoscedastic error terms, it implies that the log-odds ratio between any two choices does not depend on the third choice. As mentioned above, we test the IIA assumption using a Hausman test.

4.3 Discussion of the Results

The estimation results are presented in Table 2. Let us begin with the stage-one estimation results using all 84 ditches. Consistent with the “go simple unless...” hypothesis, we consider a set of four readily observable explanatory variables: SIZE, ATYPICAL, TOWN and ACRE DIFF. Larger values of SIZE, ATYPICAL, and ACRE DIFF 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 equity basis other than per capita. The effect of TOWN is not as clear, although we expect that users near town will tend to be more uniform in the benefits received from ditch access. Our 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 ACRE DIFF are all statistically significant at the 5% level. In terms of goodness-of-fit, the likelihood ratio test indicates that the model explains a significant amount of the variation in the use of the per capita equity basis. The model correctly predicts 70 of the 84 ditches while a maximum score (MS) estimator, a semi-parametric estimator that directly maximizes the number of correct predictions, predicts 76 of the 84 ditches.⁷

⁷ The coefficient estimates for the MS estimator have the same sign as those from the probit model and are available upon request.

In stage two, the 65 remaining ditches choose between per acre and per water-share bases. Agents on the ditch appeal to four similar explanatory variables: SIZE, ATYPICAL, TOWN and GINI, as well as RAIN and YIELD RATIO which proxy for 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.

GINI does not directly speak to variation in the benefits received on individual acres. However, larger values of GINI tend to indicate that variation in benefits can be more fully explained by just the variation in the number of acres, suggesting that a per acre basis is more likely to be adopted. Finally, RAIN and YIELD RATIO each 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, thus reducing the variation in acre benefit and making 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 except for RAIN and have signs consistent with the discussion above. The probit model correctly predicts 59 of the 65 ditches – the same percentage predicted by the MS estimator, which directly maximizes the number of correct predictions.

Finally, we discuss the estimation results from the multinomial logit model. The multinomial logit model allows the simultaneous selection from amongst the three equity bases. Overall, the model has significant explanatory power (likelihood ratio statistic is 60.48, significant at the 1% level) and is able to correctly predict 76% (64 of the 84) of the equity bases. 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 ACRE DIFF. 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 33.7 percentage points. Likewise, an increase in ACRE DIFF of 200 acres decreases the probability of choosing the per capita basis by 40.0 percentage points, respectively. All the coefficients in the PC equation have the expected sign – 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.

Second, all variables except RAIN are significant factors in the choice of a per acre basis. For example, if the ratio of yield from irrigated to non-irrigated land doubled from 2 to 4, the probability of choosing the per acre basis would increase by 17.8 percentage points, all else equal. An increase in the Gini index from 0.25 to 0.50 leads to an increase in the probability of choosing the per acre basis by 12.2 percentage points, all else equal.

Third, although the magnitude of the coefficients between the probit and multinomial logit models differs, they are qualitatively similar. This provides a degree of confidence that the two-stage approach and the IIA assumption of the multinomial logit are reasonable. Furthermore, the Hausman statistic to test the IIA assumption in the PA equation of the multinomial logit is 0.025. Therefore, we fail to reject the IIA hypothesis and the choice between per acre and per water-share bases can apparently be made independent of the per capita basis.

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 standard deviation and normalized ACRE DIFF; rainfall and yield variation; imputation of missing SIZE observations; and self-reported variation in water usage, to name a few. The coefficients from these various specifications exhibited the expected signs and the models explained a significant amount of the variation in the dependent variables. In sum, the empirical analysis appears to indicate a robust and stable relationship between features of the allocation environment and the chosen equity basis.

5. Conclusion

Cooperative environments are frequently endowed with multiple bases for assessing the “fairness” of a proposed allocation. Rather than simply take this equity basis selection as given, we have sought to determine whether parameters of the cooperative environment could be used to effectively explain this selection. Moreover we have sought to establish whether this

explanatory power, to the extent that it existed, was consistent with axiomatic principles of collective behavior. Our results have confirmed that both of these questions can be answered affirmatively. Using irrigation cost-sharing data, we have demonstrated that features of the cost-sharing environment 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. The significance of our results are even more compelling when one considers the noise introduced in the data by informal agreements that are “understood” to be employed in cooperatives.

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. Our analysis can be viewed as providing some guidance on the best way to select such a basis. Indeed, the understanding of how environmental features can be used to explain the foundations for successful, well-established cooperative ventures can in turn be used to help construct the foundations for ventures yet to be undertaken.

6. References

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Table 1. Variable Definitions and Descriptive Statistics

Variable	Definition	Statistics				
		Mean	Std. Dev.	Min	Max	Sample Size
PC	1 if cost-sharing rule is specified on a per capita basis, 0 otherwise	0.226	0.421	0.000	1.000	84
PA	1 if cost-sharing rule is specified on a per acre basis, 0 otherwise	0.143	0.352	0.000	1.000	84
PWS	1 if cost-sharing rule is specified on a per water-share basis, 0 otherwise	0.631	0.485	0.000	1.000	84
SIZE	Number of irrigators (acres) on unincorporated (all) ditches	7.381 (1303)	6.781 (2549)	2.000 (19)	33.000 (21563)	63 (84)
ATYPICAL	Fraction of users (acres) on unincorporated ditches where water is used for stock/domestic purposes or field is less than half an acre	0.018 (0.001)	0.062 (0.004)	0.000 (0.000)	0.333 (0.027)	63 (63)
TOWN	Fraction of users (acres) on unincorporated ditches with at least one field within a mile radius of the center of town	0.132 (0.112)	0.289 (0.259)	0.000 (0.000)	1.000 (1.000)	63 (63)
ACRE DIFF	Difference between maximum irrigated acres and minimum irrigated acres for unincorporated ditches	207.384	186.862	7.000	993.000	63
GINI	Gini coefficient for acre dispersion for unincorporated ditches	0.363	0.165	0.013	0.654	63
RAIN	Minimum rainfall (millimeters) on a ditch parcel during the growing season (May through August)	193.321	30.669	108.440	245.330	84
YIELD RATIO	Ratio of average yield on irrigated to non-irrigated fields	2.153	1.067	1.389	7.000	84

Notes: The reduced sample sizes reflect variables that can only be measured for unincorporated ditches. Towns under consideration include Absarokee, Bridger, Columbus, Fromberg, Joliet, Red Lodge, and Roberts.

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

Variable	Stage #1. PC vs. PA/PWS Binomial Probit			Stage #2. PA vs. PWS Binomial Probit			PC vs. PA vs. PWS Multinomial Logit					
	Dependent Variable = PC			Dependent Variable = PA			Dependent Variable = PC			Dependent Variable = PA		
	Coef.	P Value	ME	Coef.	P Value	ME	Coef.	P Value	ME	Coef.	P Value	ME
Constant	0.602*	0.081	--	-4.965*	0.069	--	1.835**	0.015	--	-7.032*	0.080	--
SIZE	-0.009	0.404	-0.002	-0.003***	0.001	-4.4e-4	-0.011	0.430	-0.001	-0.005**	0.013	-4.1e-4
ATYPICAL	-9.514**	0.029	-1.828	-309.96**	0.024	-44.140	-25.883***	0.008	-2.694	-297.04**	0.026	-25.863
TOWN	2.041**	0.031	0.392	4.987**	0.020	0.710	6.484***	0.007	0.674	5.666**	0.018	0.493
ACRE DIFF/GINI	-0.008***	0.003	-0.002	3.999**	0.044	0.569	-0.018***	0.002	-0.002	5.591**	0.046	0.487
RAIN				0.015†	0.130	0.002				0.018	0.181	0.002
YIELD RATIO				0.585**	0.014	0.083				1.019***	0.008	0.089
LR Statistic	31.74***			28.87***			60.48***					
Hausman Statistic	--			--			0.680			0.025		
Sample Size	84			65			84					
Cost Sharing Type	Actual	Predicted Correct (%)	MS Predicted Correct (%)	Actual	Predicted Correct (%)	MS Predicted Correct (%)	Actual	Predicted Correct (%)	MS Predicted Correct (%)			
No. of PC Ditches	19	10 (53%)	15 (79%)	--	--	--	19	11 (58%)	--			
No. of PA Ditches				12	8 (67%)	8 (67%)	12	6 (50%)	--			
No. of PWS Ditches	65	60 (92%)	61 (94%)	53	51 (96%)	51 (96%)	53	47 (89%)	--			

Notes. The marginal effects (ME) are averages across the sample. (†), (*), (**), and (***) indicate significance at the 15, 10, 5, and 1 percent level, respectively. P-values for the coefficient estimates are based on one-tailed tests. PC = Per Capita; PA = Per Acre; PWS = Per Water-Share; MS = Maximum Score Estimator; LR = Likelihood Ratio. The “missing observation” dummy variables are omitted to conserve space. SIZE, ATYPICAL and TOWN are defined with respect to users (acres) when the dependent variable is PC (PA). ACRE DIFF (GINI) is used when PC (PA) is the dependent variable.