Water market transfers in South Africa: Two case studies

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[1] Statistical analyses (discriminant, logit, and principal components) of water transfers in the Lower Orange River showed that water rights were transferred to farmers with the highest return per unit of water applied, those producing table grapes, and with high-potential arable ''outer land'' without water rights. Only unused water (sleeper right) was transferred, while water saved (through adoption of conservation practices) was retained possibly for security purposes. A second study in the Nkwaleni Valley in northern KwaZulu-Natal found that no water market had emerged despite the scarcity of water in the area. No willing sellers of water rights existed. Demand for institutional change to establish tradable water rights may take more time in the second area since crop profitability in this area is similar for potential buyers and nonbuyers. Transaction costs appear larger than benefits from market transactions. Farmers generally use all their water rights in the second area and retain surplus water rights as security against drought because of unreliable river flow. This study indicates that these irrigation farmers are highly risk averse (downside risk). Government policies that increase the level of risk and reduce security of licenses are estimated to have a significant effect on future investment in irrigation. In an investment model the following variables explain future investment: expected profits, liquidity, risk aversion (Arrow-Pratt), and security of water use rights. The study is seen in the light of the New South African Water Act of 1998. According to this act, the ownership of water in South Africa has changed from private to public. This reform may not impede the development of water markets in South Africa since in the well-developed water markets of the United States, western states claim ownership of water within their boundaries. All states in the western United States allow private rights in the use of water to be established and sold. *INDEX TERMS:* 1842 Hydrology: Irrigation; 9305 Information Related to Geographic Region: Africa; 6319 Policy Sciences: Institutions; *KEYWORDS:* agriculture, South Africa, water markets

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1. Introduction

[2] The purpose of this research is to study demand-side responses to water allocation in two irrigation districts in South Africa by investigating how water markets can lead to more efficient water allocation and use. In the first study area, the Lower Orange River, where water is a scarce resource and production is entirely dependent on irrigation water, one of the highest incidences of market trading of water rights in South Africa has occurred. In the second study area, the Nkwaleni Valley, water is similarly a scarce resource with production wholly dependent on irrigation, but no trading of water rights has occurred. This paper endeavors to highlight the benefits from and institutional arrangements facilitating market trading of water rights along the lower Orange River as well as the potential for and institutional changes necessary to facilitate the operation of a water market along the uMhlatuze River in the Nkwaleni Valley. The new South African Water Act of 1998 provides protection to the environment which must be considered in transfers. The diverted use of water is transferred in South Africa, and in section 6 the implication of policies on return flow is discussed in the context of consumptive versus diverted use.

[3] Water marketing has been advocated as one means of reallocating scarce water supplies in South Africa [*Backeberg*, 1997]. Allocation of water through a market offers a number of potential advantages. First, it promotes efficiency in allocation by placing water in the most highly valued uses in a flexible manner. Property rights to water empower water users as their consent is required for any reallocation of water and compensation is required for any transferred water. Decentralized information is brought to bear on water management decisions by enabling individual users to apply first-hand knowledge in determining how much water to apply and which crops to produce. The market process establishes flexibility in response to changes in crop prices and water values as demand patterns and comparative advantage change and crop diversification proceeds. Within a water market, individual users are forced to consider the full opportu-

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nity cost of their water use as well as some external costs related to their water use or transfer. Finally, a water market requires well-defined and enforceable water rights, providing for secure tenure of water and, in turn, stimulating investment in water-saving technology [*Cummings and Nercissiantz*, 1992; *Howe et al.*, 1986; *Anderson and Leal*, 1989; *Pingali and Rosegrant*, 1995].

[4] In a water economy the institutional framework determines the feasibility of water market transactions. Appropriate institutions reduce uncertainty by providing a structure to human relations in the exchange process and affect economic performance through their impression on costs of exchange and production [*North*, 1990]. The ability of a property institution to foster desired behavior depends on how exclusively property rights are defined and how effectively it reduces transaction costs [*Nieuwoudt*, 1990]. Since individuals are driven by self-interest, the institution that evolves as a result of change will allocate resources more efficiently [*Buchanan*, 1986].

2. Tradable Water Rights

2.1. South African Water Act of 1998 and an International Perspective

[5] As water scarcity increases, the need to manage water as a national asset and for overall social benefit becomes imperative in South Africa. In order to achieve this goal the South African government passed a new water bill in 1998 (Act 36 of 1998). Under the act, only basic human needs and environmental sustainability will be guaranteed as a right; the rights of irrigators are seen as of secondary importance. Before the act the rights of irrigators in South Africa were defined in terms of riparian principles, while rights of the environment and basic human needs were not spelled out. The South African Water Act of 1998 provides more protection to third parties such as the environment than is the case with the water law as it operates in the western United States. The South African Water Act was written at a time when environmental concerns were on the forefront.

[6] The South African Government will further act as the custodian of the nation's water resources, and its powers in this regard will be exercised as a public trust. These reforms have changed the institutions that define rights while, constitutionally, ownership of water changed from private to public. However, the South African reforms may by themselves not impede the development of a water market as in the well-developed water markets of the western United States; the western states claim ownership of water within their boundaries either directly in the name of the state or in trust for the people of the state. Western states in the United States allow private rights in the use of water, while in a sense, the ownership of water remains public property. However, the Colorado Supreme Court called such ownership claims by the state as ''legal fictions.''

[7] In the preamble to the act it is clear that the approach to water management is, to a large extent, centrally orientated. However, sections 25(1) and 25(2) of the new South African Water Act (1998) make provision for the temporary and permanent transfer of water entitlement between users. This act thus provides the constitutional framework for future water markets in South Africa (Department of Water Affairs and Forestry, 2003, http://www-dwaf.pwv.gov.za).

[8] Under the new South African Water Act, farmers will eventually have to apply for licenses to use water, which is similar to water markets in Australia [*Agriculture and Resource Management Council of Australia and New Zealand*, 1995; J. Mckay, personal communication, 1999]. South African water licenses are not to exceed 40 years, they must be renewed within 5 years of when the license is issued, and the water must be used beneficially. A major share of South African irrigation water is used for horticultural crops which require a long-run investment. A short review period (5 years after beginning of license) may not provide farmers sufficient incentive to invest in these industries. In the past, under riparian water law, South African farmers had water rights whether or not rights were exercised (sleeper rights). Under the application of the new South African Water Act (1998), only existing lawful use is recognized. Existing lawful use refers to use that has taken place during a period of 2 years prior to the commencement of the new act. Later amendments allowed a user with sleeper rights to apply for verification of his/her right as an existing lawful user. If he/she is successful, then the user rights may be sold.

[9] Water rights are generally based on one of three systems: public allocation, prior (appropriative) rights, and riparian rights. Public allocation involves administered distribution of water. Prior water rights as practiced in the western United States are established by actual use, and a distinction is made between senior rights and junior rights. According to the priority system, rights first established are senior and must first be satisfied. The water rights institution provides certainty in supply as senior (prior) rights are fulfilled before junior rights. Eastern U.S. states share water according to reasonableness. Proportional sharing can be the outcome, but it is not the rule, and the deserving user may get all the water. The eastern states generally have abundant water, and disputes are rare.

[10] Riparian rights practiced in South Africa and Australia link ownership, or reasonable use, of water to ownership of adjacent lands, while rights are a percentage of water available for irrigation. This structure of water rights spreads the risk of variability equally among shareholders, but it provides less certainty to water users than prior appropriation rights as practiced in the western United States as availability of water will be reduced to all users during a drought. An interesting feature of this study is that South African farmers have adapted to this institutional uncertainty.

2.2. Requirements for a Market in Tradable Water Rights

[11] An efficient water market requires (1) well-defined rights that are completely specified in the unit of measurement, reliability, and priority, creating certainty in what is being traded and predictability in the reallocation process; (2) enforceable water rights that secure the net benefits for the rights holder; (3) transferable water rights, ideally separate from land use, that create exposure to the opportunity to realize higher-valued alternatives [*Anderson*, 1983; *Pigram*, 1993]; (4) constitutional guarantee of title ownership and legal sanction of water transfers by the relevant government jurisdiction necessary to provide for secure

water rights; and (5) an efficient administration system to maintain the chain of title over the water rights [*Simpson*, 1992].

2.3. Establishing Tradable Water Rights

[12] As South Africa moves toward a nonracial future, reforms such as embodied in the new Water Act of 1998 (discussed in section 2.1) are essential to reestablishing the entire property-right structure. If the initial assignment of water rights is not perceived as being fair, then it will lead to endless conflict. This can be achieved by basing the initial allocation on historical water use combined with some redistribution of concentrated rights holdings if necessary [*Backeberg*, 1995]. Within individual catchments in South Africa, agreement on the initial allocation may require a sequence of preparation (water balance per catchment), negotiation (procedures to agree on an apportionment as lawful), and implementation (management by local users with some government support). Sacrifices by some users in the interest of equity are possible, but thereafter, the water market should be allowed to take effect [*Backeberg*, 1997]. Water markets are constrained by transaction costs, which if too high, can reduce the level of trading that can be profitably undertaken and negate the economic benefits from the water transfer [*Hearne*, 1995; *Saliba*, 1987].

3. Market Trading of Water Rights Along the Lower Orange River

3.1. Study Area

[13] In this area the study was conducted among irrigation farmers in the Boegoeberg and Kakamas Irrigation Schemes along the Orange River from Boegoeberg to Augrabies in the Northern Cape Province. The study area can be divided into two river reaches. The first stretches from Boegoeberg to Upington and incorporates the Boegoeberg Irrigation Scheme. The second stretches from Upington to Augrabies and incorporates the Kakamas Irrigation Scheme. The area is arid; precipitation declines from 400 to <200 mm/yr in the west. The hottest conditions and highest evaporation rates in South Africa are experienced in this area [*McKenzie et al.*, 1991].

3.2. Data Collection and Characteristics of Respondents

[14] A study to determine characteristics between buyers and sellers of water was conducted among irrigation farmers in the Boegoeberg and Kakamas Irrigation Schemes along the Orange River. A cross-sectional survey (personal interviews) of 54 irrigation farmers was conducted during November 1997. The sample was stratified in terms of buyers and sellers of water rights and a control which encompasses all farmers who had river water rights but did not engage in any water trading activity. A follow-up study is presently (2003/2004) being undertaken in the same area by the senior author and a student, C. G. Gillett.

3.3. Transfers of "Outer Land" Water Rights Along the Lower Orange River

[15] A market for "outer land" water rights emerged along the Lower Orange River in late 1994. "Outer land" is land adjacent to but inland from the canal, coupled to a river water right. Water transactions were driven by the desire of large-scale table grape producers, with large holdings of arable outer land without water rights, to expand their operations.

[16] *Gillett and Nieuwoudt* [2004] report a minimum price of R7201 (US$1 = R6.7) per ha and a maximum price of R10589 (the mean being R9276) for the area in 2002 (adjusted to 2003 rand). The minimum price for 2003 was R10,000 and the maximum was R18,000, showing the volatility in prices. Data over a longer period (1998–2003) showed an upward trend in real water prices. Prices, however, vary significantly from year to year, probably in response to the prices of export table grapes (the rand exchange rate has been volatile causing export prices to vary significantly). The river flow has been reasonably stable from year to year, and it is not expected that irregular water flow would have affected prices much.

[17] The average price in 2003 rands is estimated as R10,215 per ha for the period 1998 to 2003. As the maximum volume of water allowable on 1 ha is 15,000 m^3, the average price is estimated as 68 cents per cubic meter. All the water trades are of a permanent nature. No renting of water takes place as farmers need security of use for their long-run investment in table and wine grapes. According to J. Moller (personal communication, 2003), a prominent farmer in this area, water would probably rent for about R450 per ha or 3 cents/m^3 (The rent of R450 per ha on an investment of R10,215 per ha represents a return or discount rate of 4.4%.) As river flow has been reliable, farmers have stopped planting low-value crops which they could use as a water reserve in times of drought (J. Moller, personal communication, 2003).

[18] The great difference between the minimum and maximum prices of water in any given year is of interest. *Armitage* [1999] reported an even greater variation. The reduced variation is expected to happen if farmers have better information. Closer examination of *Armitage*'s [1999] data shows that there were fewer buyers (9) and more sellers (21), while the number of contracts per buyer varied from 1 to 14, while contracts per seller varied from 1 to 2. Purchase prices vary significantly, indicating that there may be asymmetric information (buyers are better informed about prices than sellers). This is also the case in another river (Crocodile) where large buyers buy and rent water from many at different prices [*Gillett and Nieuwoudt*, 2004].

[19] It is of interest to compare water prices in a different basin (Sunday/Fish River), connected to the Orange River. Water rights in the Sunday/Fish River trade for about R2000 per ha (quota per ha is 9000 m^3) or 22 cents/m^3. The market price of water is significantly lower in the Sunday/Fish than in the Orange River (22 compared to 68 cents/m^3), and water would move from the Fish/Sundays to the lower Orange if transfers are permitted. The third-party effects of a major move of water should be investigated if transfers are permitted.

3.4. Institutional Arrangements Facilitating Water Rights Trading Along the Lower Orange River

[20] Development of the water market was achieved within a centralized nonmarket water allocation system that was highly controlled and regulated by the Department of Water Affairs and Forestry (DWAF). Trading of water rights emerged despite a significant extent of state regulation imparted on the water market. While some regulation of

Table 1. Estimated Discriminant Function Between Buyers and Nonbuyers of Water Rights Along the Lower Orange River[a]

Explanatory Variable	Standardized Coefficient	*F* Value[b]
Retrn	0.632	11.34
Tblgp	0.410	5.86
Potdev	0.409	4.58
Usear2	0.322	3.06
Incont	0.261	1.94
Vine	−0.195	1.11

[a]Here $n = 44$. For the model, F value is 33.2 (significant at the 1% level of probability), Wilks' Λ is 0.157, and the canonical correlation is 0.92.
[b]Statistical significance at the 1% level of probability.

water trades is desirable within the context of a water market, much of the regulation governing transfers of outer land water rights serves to increase transaction costs unnecessarily. The institutional arrangements facilitating market development along the Lower Orange River are discussed below.

[21] Initial allocations of water rights in the study area were contingent to land characteristics of individual farms. Arable land between the river and the canal, "inner land," was allocated a canal water right under the initial settlement of the irrigation scheme in 1933 and in terms of the 1956 Water Act (Department of Water Affairs and Forestry, Upington Regional Office, personal communication, 1997). Land adjacent to but inland from the canal, outer land, was allocated a river water right for a maximum of 30 ha (maximum volume of water allowable is 30 × 15,000 m^3) by the state from October 1977 [*Republic of South Africa*, 1977]. Individual farmers had to apply to the regional DWAF to incorporate the outer land water right into their property. This involved a government process in which farmers were required to obtain a cultivation certificate from an appointed soil scientist from the Department of Agriculture, serving as proof of the extent of their property's outer land that was irrigable, within 2 km of the river, and not higher than 60 m above the river. The application for incorporation and soil scientist's report would be evaluated by DWAF's head office in Pretoria. Following approval, a water right coupled to the land area specified by the "cultivation" certificate, up to a maximum of 30 ha, would be granted to the farmer by the regional DWAF office (Department of Water Affairs and Forestry, personal communication, 1997). Many farmers found it uneconomic to develop their outer land for irrigation purposes owing to the unsuitability of this land in supporting cropping enterprises. This generated a bank of unused water rights that expedited the subsequent reallocation of water from low-potential to high-potential outer land through the market.

[22] Second, the unit of measurement of outer land water rights was completely specified as a maximum allocation of 15,000 m^3 per ha per year. The quantity of the annual water right was set by the DWAF at the beginning of each water year according to hydrological conditions and anticipated demand. Individual farmers' river water rights were found to have a high implied reliability since a river water quota of 15,000 m^3/ha per year was effectively declared in each year since river water quotas were initially allocated in 1977. Only in 1993 was a restriction placed on water extraction, with a 50% reduction in water quotas for the first 4 months of the year due to severe drought. This was restored to its original value for the remainder of the year after favorable rains. The specification of all irrigation water rights as proportional allowed the extent and risk associated with restrictions to be spread equally among all rights holders. Irrigation rights also enjoyed high priority, assuring irrigators of rights senior to industrial water rights and junior only to basic human water requirements and stock-watering requirements. This created certainty among parties as to exactly what was being traded and predictability in the outcome of the reallocation process.

[23] Third, outer land water rights were transferable between irrigation properties and legally sanctioned by the government from May 1993. The delegation of authority for the approval of water transfers, in accordance with a policy as determined by the Minister, was prescribed to DWAF officials in an internal memorandum at the beginning of 1993. However, before individual transfers could proceed, a number of officially determined conditions had to be satisfied. As a result of these regulations, water transfers were not simple voluntary trades between two parties but, rather, negotiated transfers between the two parties and government authorities. In the consideration of applications for the permanent transfer of water rights from one owner's land to another, the following rules applied: (1) It had to be technically possible to supply water to the property to which the scheduling was to be transferred, and all costs, if any, inherent in moving the point of supply had to be borne by the buyer. (2) There had to be sufficient irrigable land on the property to which the water was being transferred. (3) The regional DWAF Office, Department of Agricultural Development, and local extension officers had to support the transfer from an agricultural perspective. (4) The property from which water rights were being transferred could not be encumbered by the Land Bank or have no objection to the permanent transfer of the water indicated by the bank [*Department of Water Affairs and Forestry*, 1993]. Environmental and human needs are protected under the Water Act of 1998 and cannot be disadvantaged by transfers.

3.5. Discriminant Analysis Between Buyers and Nonbuyers of Water Rights Along the Lower Orange River

[24] Discriminant analysis was used to distinguish between those farmers who had bought water rights (buyers) and those farmers who had either sold water rights or not engaged in any water market trading (nonbuyers). Results are presented in Table 1. The dependent variable in the analysis, Bght, was constructed using 1 for farmers who had bought water rights and 0 for farmers who had not bought water rights.

[25] It was hypothesized that water rights would move from lower-valued to higher-valued uses through the market mechanism. Buyers are consequently expected to be growing table grapes (Tblgp = 1.0 if table grapes are grown and 0 otherwise), while nonbuyers are expected to be producers of wine or raisin grapes (Vine = 1.0 if wine or raisin grapes are grown). As all water transfers are from nonusers (sleepers), a nonbuyer in the case of a wine producer is not a seller.

[26] The income from wine grapes in the area is relatively low as this area is not as conducive to the production of exotic wines as is the Western Cape of South Africa. For

instance, the gross income per ha in the area is significantly higher (2003) for table grapes (R130,000) than for wine grapes (R40,000) and raisins (R30,000). Table grapes intended for export are, on occasion, used as raisins if harvested too late.

[27] Water rights are likely to gravitate to the most effective users of water for which the estimated return per unit of water applied (Retrn is a proxy variable calculated as the ratio of farm gross margin from irrigation enterprises to total farm irrigation water requirements) is expected to be the highest. In a water market both buyers and nonbuyers have the incentive to adopt water-saving technology as water has an opportunity cost. Any transaction costs will drive a wedge between buyers and nonbuyers of water rights, consequently forcing buyers to be even more frugal users of water rights. Buyers would likely be making greater use of microirrigation and drip irrigation systems (Iritec = 1.0 if microirrigation and/or drip irrigation is used and 0 otherwise).

[28] An institutional control variable (Incont, the ratio of actual irrigated area to total farm area) measuring the ratio of actual irrigated area to total farm size was included in the analysis. The ratio of this control variable is influenced by the initial state allocation of water rights to inner and outer land as well as the subsequent reallocation of water to undeveloped outer land through the market. No a priori expectation is associated with this variable. Buyers were expected to have proportionally more arable land that could be developed for irrigation purposes (Potdev is the ratio of undeveloped arable land to total potential arable area). The availability of high-potential outer land is expected to be an important factor in influencing farmers' decisions regarding water trading. Buyers are hypothesized as being located in the River Reach from Upington to Augrabies and using only a fraction of their available arable land (Usear2 = 1.0 if located in the river reach from Upington to Augrabies and uses 25–50% of potential arable land and 0 otherwise).

[29] The most significant variable discriminating between buyers and nonbuyers was the estimated return per unit of water applied (Retrn), showing that water rights tended to move to the most effective users of water. The next most important variable was whether or not the farmer grew table grapes (Tblgp), showing that water rights transferred to the highest-valued agricultural uses. These two variables had a correlation coefficient of 0.44, which was non-significant at the 10% level of significance. The third most important variable, Potdev, shows that buyers have proportionally more arable land that can be developed for irrigation purposes than nonbuyers. The location of the farmer in the river reach from Upington to Augrabies and whether he was utilizing 25–50% (Usear2) of his arable land was the next most significant variable. Incont, the ratio of actual irrigated land to total farm size, was the fifth most significant discriminator between buyers and nonbuyers. Finally, the least significant variable, Vine, shows that nonbuyers tend to be wine grape or raisin grape farmers.

[30] The overall F value of 33.2 indicates that the four retained independent variables together distinguish significantly between buyers and nonbuyers. The Wilks' Λ of 0.157 and canonical correlation coefficient of 0.92 indicate that the function is effective in classifying respondents correctly. Explanatory power was checked by comparing predicted with actual group membership. The discriminant function classified 100% of the cases correctly, but the classification results of 100% are upwardly biased since the same cases were used to derive the discriminate function and classify cases. The disparity in size of the two sample groups may also have biased classification in favor of the larger group.

3.6. Follow-Up Study During 2004 in the Lower Orange River

[31] The above findings are supported by a recent study in the same area [*Gillett and Nieuwoudt*, 2004]. In the latter study, 19 farmers who sold water and 14 who bought water were interviewed during December 2003. A logit regression of the results indicated that buyers tend to be producers of the more lucrative table grapes and other horticultural crops with less field crops and other grapes. A principal component analysis was also undertaken because of interrelatedness in variables. This analysis indicated that buyers have a higher turnover per unit of water, use microirrigation, have a high percentage of export grapes, and have a low percentage of other grapes and a low percentage of field crops. A regression (Ridge) was also undertaken to determine which variables are associated with increased future (next 5 years) investment in irrigation. The following variables explained increased investment: high percentage of export grapes, low percentage of other grapes, more livestock, less diversified, less risk averse, and feeling more secure about water rights. Results indicate further the expansion in table grapes driven by expected profits. Farmers who also have livestock are more liquid and better able to finance new investments. The farmers who contemplate new investments are less risk averse (Arrow/Pratt coefficient), as expected. The farmers who feel more secure about their water licenses invest more. The less diversification variable indicates more specialization, probably in table grapes. The results are important as it shows that farmers who are less secure about water rights invest less. As these farmers are highly risk averse according to the study (see also section 5), any uncertainty will impact negatively on future investments. Farmers do not expect that water rights will be taken away, but they generally indicate a high level of uncertainty about rights in this study.

4. Water Allocation in the Nkwaleni Valley

4.1. Data Collection and Characteristics of Respondents

[32] The survey area includes irrigation farmers of the Nkwaleni Irrigation Board (NIB) along the uMhlatuze River in northern Kwa-Zulu-Natal. Sugar cane and, to a lesser extent, citrus are the predominant crops, with >30% of South Africa's grapefruit crop produced in the valley. A survey of irrigation farmers was conducted during May 1998. The total population of 25 farmers composing the NIB were surveyed by means of personal interviews. As no water rights were transferred, two groups were identified, namely, potential buyers and potential sellers of water rights which includes farmers who are neither potential buyers nor sellers.

4.2. Discriminant Analysis of Potential Buyers and Nonbuyers of Water Rights in the Nkwaleni Valley

[33] Discriminant analysis was used to differentiate between those respondents who wanted to purchase water

Table 2. Estimated Discriminant Function Between Potential Buyers and Nonbuyers of Water Rights in the Nkwaleni Valley[a]

Explanatory Variable	Standardized Coefficient	F Value[b]
Sugr	2.295	24.49
Incont	−2.017	14.19
Citrs	−1.595	9.97
Iritec	1.224	8.51
Potdev	1.033	3.83

[a]Here $n = 22$. For the model, F value is 5.86 (significant at the 1% level of probability), Wilks' Λ is 0.353, and the canonical correlation is 0.810.
[b]Statistical significance at the 1% level of probability.

rights (buyers) and those who did not want to buy water rights (nonbuyers). A dependent variable Bght was constructed using 1 for farmers who wanted to buy water rights and 0 for farmers who did not want to buy water rights. Results of the discriminant analysis are presented in Table 2.

[34] Potential buyers of water rights are expected to be those farmers who require additional water for their farm operations or to expand production on previously unscheduled land. As sugar cane and citrus are important crops in the area, dummies for these crops are included to test who is buying water rights. An institutional control variable (Incont, the ratio of actual irrigated area to total farm size) measuring the ratio of actual irrigated area to total farm size was included in the analysis. No a priori expectation is associated with this variable as the ratio of this control variable is ultimately influenced by the historic official allocation of water rights. Potential buyers of water rights were hypothesized to have proportionally more arable land that could be developed for irrigation purposes than nonbuyers (Potdev, the ratio of undeveloped arable land to total potential arable area). Buyers were also hypothesized to be those farmers who had adopted water saving microirrigation or drip irrigation systems (Iritec, the ratio of cultivated land under drip and/or micro irrigation) as a response to irrigation water scarcity. Buyers were also expected to be those farmers who did not have sufficient water in terms of their rights (Suff = 1.0 if respondent does not have sufficient water to irrigate all potential arable land and 0 otherwise) to irrigate all of their available arable land. Crop choice was also expected to be an important variable in determining whether a farmer wanted to buy water rights or not.

[35] The most significant variable discriminating between potential buyers and nonbuyers was whether or not the farmer grew sugar cane (Sugr = 1.0 if sugar cane is grown and 0 otherwise). Potential buyers of water rights have large holdings of sugar cane from which favorable and stable returns from irrigation could be attained. In another climatically similar area, *Bate et al.* [1999] observed that sugar cane under irrigation increased in spite of relatively low returns. This was attributed to the more stability in this industry with fixed domestic prices for sugar cane. As no a priori expectations are associated with the second most important variable, Incont, it is of no further interest. The third most significant variable, Citrs, shows that potential buyers of water rights generally have less citrus than nonbuyers. The sign of this variable may be circumspect but may be attributable to the fall at the time in grapefruit prices. *Bate et al.*'s [1999] observation that seemingly profitable crops such as citrus may not be as attractive as sugar cane because of greater price stability in the sugar industry (the sugar industry uses price discrimination in marketing their product) may also apply. Also, excessive irrigation in citrus causes root rot, so farmers often use drip irrigation.

[36] The fourth most important variable was whether the farmer had adopted water-saving microirrigation and/or drip irrigation systems (Iritec). The least significant variable, Potdev, shows that potential buyers of water rights generally have a greater proportion of their total arable area that can be developed for irrigation purposes than nonbuyers.

[37] The overall F value of 5.86 indicates that the five retained independent variables together distinguish significantly between buyers and nonbuyers. The Wilks' Λ of 0.353 and canonical correlation coefficient of 0.81 indicate a good discriminant function but suggest that some discriminating information has not been extracted by the independent variables. The discriminant function classified 95.45% of cases correctly. Again, this classification rate is biased as the same cases were used to estimate the function and classify cases. Additionally, bias resulting from the small sample size ($n = 22$), which falls short of the acceptable sample size of 30 cases, may have been introduced into the discriminant function.

5. Water Market Institutions and Policy Implications

[38] Although water rights and land were not used in fixed proportions, allowing a farmer to save water and irrigate a larger area or transfer the saved water through the market, no transfers of conserved water had developed in practice. A possible reason for this is that farmers prefer to retain conserved water for water supply security as sufficient supply security is not provided by riparian water law. South African water law is based on riparian principles along with that of Australia. Under riparian water law, farmers own users' rights to a proportion of the river flow, which means that the amount of water available is reduced for all users during a drought. The incentive institutions are different for the prior appropriation water law practiced in the western United States as farmers with senior rights have greater certainty of supply of water.

[39] Certainty of water rights is important for crops such as table grapes as the capital investment is very high for this crop. In *Armitage*'s [1999] study in the Orange River it was found that farmers produce a low-income crop such as lucern for fodder along with a high-income crop such as table grapes. This does not appear to be the case anymore as river flow has been stable in recent years according to J. Moller (personal communication, 2003). The same rationale applies that the low-value crop is grown for water supply security in the sense that in the advent of water scarcity, water can be diverted from the low-value crop to save the capital investment in, say, table grapes. Farmers in the Crocodile River can move water from sugar cane to horticultural crops in advent of drought. The river flow in this area is highly irregular (the main dam in 2004 was only 20% full), and a banana farmer recently (2004) told the senior author that he has to keep water rights in reserve because otherwise, he will not only lose this year's crop but next year's crop also. According to an expert in this river reach, surplus rights will not be recognized, but in the determination of lawful water use rights the fact that river

flow is highly irregular will be considered. In the case of sugar cane some yield is possible when only the current year's crop is adversely affected. The decisions that farmers make under conditions of risk depend on their risk aversion/preference. A survey among irrigation farmers in the lower Orange River and in the Crocodile River shows that farmers are highly risk averse when there is a possibility of income loss (downside risk). Farmers were given the following hypothetical choices. Choice 1 is as follows: A coin is tossed; if it is heads, you win R800,000, but if it is tails, you have to pay R200,000. Choice 2 is as follows: you receive a given amount with certainty. A risk-neutral individual will be indifferent between receiving R300,000 in choice 2 and taking his chance in choice 1. Of farmers surveyed in these two areas, ~80% said that they would rather take R0.0 in choice 2 than taking a chance in choice 1. Standardized Arrow/Pratt risk aversion (original data standardized for the range and scale) coefficient of 3.28 was estimated for farmers, which shows high risk averseness. The implication is that if growers cannot manage their risk by keeping surplus water rights, they may significantly underinvest in irrigation farming.

[40] No temporary water transfers had taken place in the Orange River, which may be explained by the high fixed costs involved in transporting water to the outer land and developing this land for irrigation purposes, and the high fixed transaction cost of hiring a lawyer in the transfer process. The water market that emerged along the lower Orange River (first area studied) was not fully developed since only the reallocation of unused outer land water rights was facilitated through the market function. The discriminant analysis of this area compared buyers with nonbuyers. Among the nonbuyers were raisin and wine producers. No intersectoral trading was permitted nor was market transfer of canal water enacted.

[41] Discriminant analysis results highlight the efficiency improvements resulting from market allocation. The estimated return per unit of water applied was the main variable discriminating between buyers and nonbuyers, showing that water tended to transfer to farmers best able to utilize the water in their farm operations. Water rights also moved to table grape farmers, representing the highest potential valued use of the water rights. In addition, the efficiency gains in bringing fertile undeveloped arable outer land into production are highlighted by results showing that buyers have proportionally more arable land that can be developed for irrigation purposes. Although farmers of lower-valued crops were not sellers of water, they were not buyers as the transfer was from nonusers to high-valued users.

[42] Since transfers generally involved a transfer from nonuse to table grape irrigation, changes in the pattern of water use in the study area due to water market activity may create marginal impacts on lower basin water users and the environment. Agricultural users in lower basins may face increased water salinity as a result of increased upstream irrigation water use. The South African Water Act of 1998 protects in-stream flows to sustain the environment, basic human needs, and international obligations (referred to as the reserve), while equity objectives must be considered. For these reasons, trading of water use rights in the future will only take place over and above the reserve. Procedures to identify negative external effects of a transfer and to resolve conflicts among users by the regional DWAF, along with the definition of a transparent channel for airing grievances arising from water trading activity, may become necessary as water demand rises. Although water trades from downstream to upstream may reduce in-stream flow and harm the environment, the more usual trades are in the opposite direction and are likely to benefit the environment.

[43] The water market in the Nkwaleni Valley (second area studied) appears to be constrained by the lack of willing sellers of water rights. A number of reasons may explain this. First, crops produced by potential buyers (70% sugar cane and 26% citrus) in the Nkwaleni Valley are not vastly more profitable than crops produced by nonbuyers (56% sugar cane and 38% citrus). This contrasts with farmers in the lower Orange River where buyers of water rights invariably produce highly profitable table grapes. Second, transaction costs may exceed the difference in value of water to the potential buyer and seller. Farmers may also wish to retain surplus water for security against drought owing to the unreliable nature of river flow in the region. Finally, farmers appear to be using all their water in their farm operations and may be unwilling to sell water rights for land they have already developed as this would involve sacrificing the development cost of the land.

[44] Initiating institutional change toward market trading of water rights in the Nkwaleni Valley will require that a number of issues be considered. Water rights are well defined but have low reliability, potentially driving down market prices and constraining transfers. The emergence of a market will depend on how well transaction costs are minimized by the administrative function performed by the NIB and DWAF in defining a transparent transfer process, supervising and recording trades, and resolving conflicts among members. The existing framework of NIB control provides for a highly organized water management structure that could support the development of a water market. This would be important in resolving likely third-party effects resulting from market transfers along the uMhlatuze River owing to the small and variable flow of the river and substantial existing demand for water.

[45] In both study areas a water market will depend on the formal sanction of water trading under the Water Act of 1998. Where water trading is permitted under the new Water Act, it is important that the institutional environment promote the market system. However, it can be argued that several principles underlying the new Water Act could inhibit market development. First, while water use allocations will be well defined in the unit of measurement and will be enforceable, the reliability of each use allocation will be highly variable since they will not be held in perpetuity and will not give a guaranteed assurance of supply or quality. In addition, any water use allocation may be temporarily controlled, limited, or prohibited. Variability in water rights that exists under current arrangements may increase under the new Water Act from increased government control over water allocation and assessment of applications for renewal of individual water rights. This will create substantial uncertainty over the security of water rights and may preclude any trading of water use rights. Second, although water use allocations may be made transferable, any transfers will essentially be limited to rentals for the duration of the temporary water use alloca-

tion, thus eliminating the potential benefits accruing from permanent water transactions. Last, farmers will not have sufficient incentive to invest in water-saving irrigation technology and other production inputs if there is uncertainty about water ownership. Investments in the establishment of table grapes average R150,000/ha, and if water rights are less secure, the risk associated with such an investment will be substantially increased.

6. Transfer of Consumptive Versus Diverted Use of Water

[46] In this section the implications of consumptive versus diverted use are discussed as in South Africa water rights refer to water diverted for irrigation. There is, however, a difference between the volume of water actually applied (diverted use) and the water taken up by plants (consumptive use). The reason is that a significant proportion of water applied (diverted) is available for other users as return flow. The transfer of water rights to another user may negatively affect downstream users who are dependant on the return flow of the previous use. Under Colorado water law a transfer may not cause injury to other parties (no damage principle), and other senior water right holders (irrigations) can legally prevent transfer in the event of injury. Although information on consumptive use is more difficult to obtain than on actual use, it solves the problem of avoiding injury on other consumptive users (for instance, farmers). The difficulty in measuring consumptive use and return flow significantly increases the transaction cost of this system, but even costlier litigation is avoided (B. Young, Colorado State University, personal communication, 1998). Therefore, in most western U.S. states, water rights are based on consumptive use with protection of third-party rights to return flows.

[47] Apart from these legal implications a transfer has economic incentive implications. Whether diverted use or consumptive use is transferred has implications regarding to the incentive to conserve water and the opportunity cost price of water. If the opportunity cost price of the diverted use of water (volumetric price) increases then a farmer may (1) shift to crops that are more water efficient, or higher valued, (2) continue with the same crop and acreage and apply less water, or (3) employ more water-saving technology by, for example, moving from flood to drip irrigation. However, according to some experts, no water is saved by adopting water-saving technologies (point 3 above). Some [*Huffaker and Whittlesey*, 1995; *W. M. Frasier et al.*, 1998] contend that increased on-farm efficiency such as use of water-saving technology creates the illusion of water conservation when, in reality, the consumptive (water taken up by plants) use of water may increase. In a hydrological system, water not taken up by the plant will be returned to the basin or aquifer and be available for other users. If farmers are permitted to irrigate a larger area if they use water-saving technology, such as drip irrigation, then it may lead to lower return flow and increased consumptive use of water. This is expected to happen in South Africa as farmers in the rivers studied are permitted to irrigate larger areas if water-saving technologies are adopted. The desirability of the adoption of technologies that reduce return flow needs investigation as it may also reduce water available to the environment. Under the South African Water Act of 1998 the environmental use is protected as a right. According to J. Moller (personal communication, 2003), the return flow in the Orange River is of a high quality and important.

7. Conclusion

[48] Two separate surveys of irrigation farmers along the Lower Orange and uMhlatuze Rivers were conducted in November 1997 and May 1998, respectively. A follow-up survey was undertaken in the Lower Orange River during 2003/2004, where an active water market has developed. Market development for this particular category of irrigation water rights can be attributed to the scarcity of water in this arid region and an increasing demand for river water rights by table grape farmers wanting to expand production. The large number of willing sellers and the role played by the DWAF in administering market transfers, thereby reducing transaction costs and time, facilitated market development. Improving the efficiency of water market trades could be achieved by delegating authority to the regional office of the DWAF to approve transfers, extending support to market transfers of canal water, and ensuring that water extraction is closely assessed as use of river water increases in future.

[49] Discriminant analysis shows that water rights moved to farmers achieving the highest estimated return per unit of water applied, showing that water rights gravitated to the most effective users of water. Second, water rights moved to potentially higher-valued users with the potential to grow table grapes. Buyers had larger amounts of undeveloped arable land, highlighting the efficiency advantage of market trades of bringing undeveloped arable land into production.

[50] An investment model indicated that future investment in irrigation can be explained by expected profits (positive), liquidity (positive), risk aversion (negative), and insecurity of water use rights (negative). As irrigators were found to be highly risk averse (Arrow-Pratt downside risk), the insecurity of water use rights will have a significant negative impact on future investment.

[51] No market trading of water rights had developed along the uMhlatuze River despite the scarcity of water in the region. Forty-one percent of survey respondents wanted to purchase water rights. However, there were no willing sellers of water rights. This may be attributed to the fact that survey farmers in the Nkwaleni Valley were generally found to be using their full water rights allocation in their farming operations, and capital investment in irrigated land may inhibit the sale of water rights from this land. Irrigators may also prefer to retain excess water for water supply security. In addition, the crops produced by potential buyers are not significantly more profitable than crops produced by nonbuyers. As a result, farmers with unused or underutilized water rights may have little incentive to enter into water market transactions. At present, farmers are able to pay only for water extracted up to their maximum water allocation, with any unused water reallocated to industry by the DWAF. Under such a system, farmers with unused water are unable to realize potential rental or sale income from water transfers, and resistance to a potential future water market from industry may develop.

[52] Equity objectives in improving access to water for previously disadvantaged groups will have to be tackled by government intervention in water allocation. However, it is important that existing and potential future water markets

for irrigation water are not stifled as they could have important benefits in improving the use and allocation of irrigation water. Under the new Water Act, overcoming institutional and legal barriers for market performance will require that water use allocations be specified as perpetual or for long periods of time, as in Mexico, with an expiry date closer to 40 years, and be inherently secure and that water trading be permitted through the relevant legislatures.

[53] Evidence from the western United States shows that although the state may claim ownership to water, private use rights to water is established that can be transferred either through sale or rent. This is important for South Africa since according to the new Water Act, the South African government will act as the custodian of the nation's water resources and its powers in this regard will be exercised as a public trust.

[54] In South Africa, water is transferred on the basis of diverted use (water actually applied) and not on consumptive use (water taken up by plants). Farmers are also permitted to irrigate larger areas if they adopt water conservation technologies such as drip irrigation. The latter concession has negative return flow implications that must be considered. Under certain conditions where return flow is high the transfer of diverted use could lead to increased consumptive use of water instead of releasing water. The reason is that the transfer of the diverted use of water in agriculture does not attach a price (opportunity cost) to the consumptive use (water taken up by plants).

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