IMPLICATION OF RISK IN IRRIGATION WATER TRANSFERS, SOUTH AFRICA

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ABSTRACT

Irrigation farmers in the Lower Orange and Lower Crocodile rivers of South Africa were surveyed during 2003/2004 in order to study the impacts of water transfers and risk and risk aversion on resource use. Irrigation farmers in both areas appear highly risk averse as measured by the Arrow/Pratt risk aversion coefficient (especially for down-side risk). In the Lower Orange River, where water supply is fairly stable, income per cubic meter of water was an important variable in explaining water transfers. In contrast, water supply in the Lower Crocodile River is highly irregular. In the latter river, risk reduction appears to be more important in water reallocation. Results provide support for water markets. Survey data were analysed using principal components, logit and Ridge Regression. A theoretical contribution of the study is to standardise the Arrow/Pratt Absolute Risk Aversion Coefficient for scale and range of data. Policy risk and risk aversion also appear to be important in explaining expected future investment in irrigation farming in the Lower Orange River. Results show that farmers, who view water use rights as not secure, expect to invest less. The latter effect is thus amplified as farmers appear to be highly risk averse. Important policy implications are that farmers should be better informed about the practical implications of the new National Water Act and specifically water licenses.

KEYWORDS

Investment, risk aversion, South Africa, water transfers

INTRODUCTION

In any investment decision both expected risk and expected profits will be considered. It is thus expected in water transfer between farmers that risks along with profit/cubic meter of water will be taken into account. Risks in irrigation farming are multi-dimensional. Risks could arise from irregular water supply, from crops grown, from insecurity of water entitlements etc.

Water marketing is relatively new in South Africa while the new National Water Act (36 of 1998) has implications for water marketing. The main purpose of the research is to study implications of transfers, also considering risk, within the framework of the new Act. More specifically the purpose is to study (a) factors explaining water transfers and (b) variables associated with investment in irrigation. Due to high environmental risk and uncertainty of implications of the New Water Act, these risks will be given special attention. For the purpose of this study, farmers along the Lower Orange River near Kakamas and Boegoeberg who purchased or sold water rights were interviewed during October/November 2003. In another survey farmers along the Lower Crocodile River up and below the Gorge were visited during November 2003 and March 2004. These studies are a follow-up to two early studies in the Lower Orange by Armitage (1999) and in the Lower Crocodile by Bate *et al.,* (1999). These areas differ in important aspects as far as water marketing and risk are concerned some of which are the following. The Lower Orange River is a Government Water Scheme as water is supplied by large irrigation dams upstream. The supply of water in this scheme has also been fairly regular in the past. Only a relative small proportion of the irrigation water in the Lower Crocodile is supplied by a dam upstream. The water market in the Lower Orange is still active while few sales in the Lower Crocodile have been processed in recent times.

Models will be estimated to capture how risks influence decision making in reallocation of water by comparing these two areas as the risk of water supply is different. Risks are also expected to influence investment in irrigation and this will be studied. How farmers react to risk depends on their aversion to risk. The risk aversion of farmers will be measured using the Arrow/Pratt Absolute Risk Aversion Coefficient. Data were analysed using Logit Regression, Ridge Regression and Principal Component Analysis. As the risk associated with policies is also studied, trading of water under the National Water Act 36 of 1998 (NWA) is briefly mentioned. The conceptual model for investment decisions in irrigation technologies in this paper is that of an adoption decision within a risky environment (Antle, 1987).

THEORETICAL CONSIDERATIONS AND STATISTICAL PROCEDURES

Special attention is given to the theoretical measurement of risk, as it is important to the study. The interested reader is referred to the following econometric sources that have further bearing on the research in this paper: Principal Component Analysis (Jolliffe, 1986; Nieuwoudt, 1977), Logistic Regression (Gujarati, 1995) and Ridge Regression (Neter *et al*., 1996).

Application of the New Water Act 36 of 1998

The transformation process from the old approach (prior to NWA) to the application of the NWA involves declaring water use as practised under the old Act as an existing lawful use. The process requires steps such as the verification of existing lawful use in order to issue a license. It may take time to issue licenses and in the interim an existing license is not a prerequisite for a water market as the existing lawful use of water may be traded. Existing lawful use is defined in section 32 of the NWA and refers to water use which has taken place during a period of two years prior to the commencement of the NWA. The latter was amended to allow certain discontinued and contemplated use that do not fall within the two year period to be declared existing lawful water use. The implication for the study is that some sleeper water rights may still be declared as lawful use and may thus be traded.

Economic theoretical considerations

The economic theoretical model was based on the hypothesis that water will be transferred from farmers who have a low return per unit of water or face more risk because of climatic or soil conditions to farmers who are able to achieve a higher return or could produce crops with lower risk. A second objective of the study was to measure the impact of certain economic variables on future investment in irrigation farming. It was hypothesised that future investment will depend on expected income, risk, risk aversion and liquidity. The study used a more general economic model as framework but several other studies provide background foundation. Dinar and Yaron (1992) studied the adoption and abandonment process for different irrigation technologies. They concluded that water price and subsidy on irrigation equipment can be used to speed up the diffusion process. Green *et al*. (1996) used a micro-parameter approach to assess the effects of economic and other variables on irrigation technologies. Backeberg (1997) warned that inappropriate reform of water market institutions could lead to reduced incentives to invest in irrigation.

Risk and risk aversion

It is hypothesised that investment decisions are influenced by risk behaviour of the individual. This is especially true in a situation of high risk and uncertainty as is experienced in the study area. The risk aversion of farmers included in the survey was measured using Nobel Laureate Arrow and Pratt's factor also referred to as the Arrow/Pratt Absolute Risk Aversion Coefficient (APAR). The APAR is defined as $-U''(x)/U'(x)$ where $U''(x)$ and $U'(x)$ is the second and first derivative of a von Neumann-Morgenstern utility function, $U(x)$. In the study the negative exponential utility function, $U(x) = -\exp\{-\lambda x\}$ is assumed for simplicity as it has a constant APAR (λ). This utility function is estimated in this study by asking farmers two questions relating to a hypothetical situation where they were faced with two options in each question. In both questions, the farmer had to choose between an amount dependent on the results of a coin toss, and another amount with certainty. The certain amount was then adjusted until a level was reached where the farmer was indifferent between the two choices. A farmer is risk neutral if the certain amount selected equalled the expected income of the coin toss gamble. For the first question, the gamble was an equal probability of earning R1,000,000 ($1=R6.4) and zero (p=0.5), with an expected income of R500,000. The second question gamble was an equal probability of earning R800,000 and losing R200,000 (p=0.5), with an expected income of R300,000.

Although APAR has been extensively quoted in literature, it has a major weakness in that it cannot be compared between different studies as the coefficient depends on the scale and range of the data. It will be shown mathematically how sensitive APAR is to the range and scale of the data. Standardisation was undertaken by converting the distribution ($x_{min} \leq x \leq x_{max}$) into a distribution ($0 \leq x^* \leq 1$) where xmin and xmax are the minimum and maximum values on the x-scale. This provides a unit-less expression of the absolute risk aversion function. The algebraic derivation below shows the sensitivity of λ to changes in the scale (whether data are expressed in Rands or Dollars) or range of data. Let

$$\begin{aligned} & x^* = (x - x_{min})/(x_{max} - x_{min}) \\ & \therefore x = x_{min} + x^*(x_{max} - x_{min}) \\ & \text{where} \quad U(x) = -e^{-\lambda x} \text{ and } U(x^*) = -e^{-\lambda^* x^*} \\ & \therefore \lambda^* = \lambda(x_{max} - x_{min}) \text{ since } \lambda x_{min} = \text{constant} \end{aligned} \tag{1}$$

In this study λ^* is estimated, which is not affected by the range and scale (xmax – xmin) of the data. It is recommended that in future APAR studies this procedure be adopted to facilitate better comparison between studies.

Study areas

One study was undertaken among irrigation farmers in the Boegoeberg and Kakamas Irrigation Schemes along the Orange River of South Africa. The target population was identified using records obtained from the Department of Water Affairs and Forestry (DWAF) and consisted of farmers who had transferred water entitlements between January1998 and August 2003. A total of 37 farmers were interviewed.

Another study was undertaken amongst irrigation farmers along the Crocodile River above and below the gorge towards Komatipoort during November 2003 with additional interviews conducted during March 2004. The climate in the study area varies from warm subtropical at Nelspruit, above the gorge, to hot subtropical downstream from the gorge. The study was undertaken in the same area visited by Bate *et al.* (1999). A total of 18 farmers were interviewed. Although the number of farmers is small, some of these farmers entered into several contracts, for instance, one farmer leased from 12 lessors.

The efficiency implications of water transfers in the Lower Orange and Crocodile rivers will be first discussed and then the findings from an investment model.

RESULTS OF WATER TRANSFERS IN LOWER ORANGE RIVER

Data show that surveyed farmers held more water entitlements than their actual irrigated area. Sellers had, on average, about 22 percent more hectares of water entitlements than actual area planted, whereas Buyers had 41 percent more hectares of water entitlements. Few temporary transactions took place because farmers need long-term security of water for perennial crops. Excess water entitlements are usually for future development, and not necessarily for insurance against water shortages. Few water shortages had occurred over the last 10 years, which respondents attribute to the Vanderkloof dam, which has stabilised the flow of water in the river.

Arrow/Pratt Absolute Risk Aversion Coefficient (APAR)

The first risk question estimates the risk aversion of the farmer where no unfavourable outcome (loss) is allowed (excludes downside risk). The median APAR obtained for Buyers was 2.44 (n=14) and Sellers 2.12 (n=20). A positive coefficient implies that farmers are risk averse. This indicates that farmers were, on average, risk averse, with Buyers being slightly more risk averse than Sellers.

In the second scenario, farmers are faced with downside risk where there is a chance that they can lose money if they select the uncertain alternative. Farmers are more risk averse (down-side risk) than anticipated in the questionnaire as almost all the farmers picked the most risk averse category. That is they did not pick a choice where money could be lost. The median APAR for down-side risk for both Buyers and Sellers calculated as 3.28 is thus an underestimate. In a choice situation an estimate of 3.28 implies indifference between a certain income of R0.0 and being given a 50% chance on winning R800 000 or losing R200 000. The mean of this gamble is R300 000 which is a significant reward for taking a risk. All but one of the Sellers and 57 percent of the Buyers would rather not receive any amount in order to avoid the possibility of a loss. Faced with downside risk, farmers are more risk averse than when downside risk is excluded, (3.28 exceeds 2.44 and 2.12). The effects of risk on investment in irrigation will be tested in an investment model reported in the last section of the results. The down-side APAR was not used in these regression models due to lack in variability of the estimates.

Principal Component of variables associated with water marketing

Equation 2 shows the dominant loadings of principal components 1 and 3 (No economic meaning could be attached to component 2 and it is not presented).

$$\begin{aligned} &PC1=0.83\ TYPE + 0.86\ EXP -0.72\ OTH -0.60\ FLD +0.57\ HOR + 0.95DRIP + 0.83\ INC \\ &PC3=0.69\ INV + 0.50\ LSTCK -0.36\ RISK -0.47\ SECURE + 0.43\ PROFIT \end{aligned} \quad (2)$$

The first component (PC1) shows positive loadings amongst the following variables; Buyers of water entitlements (TYPE =1 for buyer and =0 for seller); percentage of cropped area planted to export table grapes (EXP); percentage planted to horticultural crops (HOR), percentage of advanced irrigation technology used (DRIP); income per cubic meter of water applied (INC). It also shows negative loadings for percentage of cropland planted to other grapes (OTH), and percentage of land planted to field crops (FLD). This component captures variables associated with the purchase of water entitlements and could be labeled Buyer. This indicates that a water market promotes efficiency in water use and that water is transferred to high income crops (table grapes and horticultural crops). The third component (PC3) shows positive loadings for expected investment (INV), number of livestock owned (LSTCK), and expected profits (PROFIT). It shows negative loadings for the farmer’s risk aversion coefficient (RISK) and the perceived security of licenses index (SECURE). The third component represents an investment relationship as expected investment is positively related to profits and negatively to risk. These relationships (PC1 and PC3) are important and will be further investigated in regression models.

Logit model of Buyers and Sellers of water rights

A logit model was estimated in equation 3 to study which variables could predict whether a farmer is a buyer (TYPE=1) or seller (TYPE =0) of water. In order to overcome likely multicollinearity, a component (PC) was constructed from the crop variables described in equation 2. A crop variable component was chosen as the demand for water as factor of production is a derived demand, derived from product prices. In this component lucrative export grapes and horticultural crops were positive while other grapes and field crops were negative as can be expected from equation 2.

$$TYPE = -1.06\ (Wald=0.2) + 4.17PC\ (Wald=8.1) + 6.59DIV\ (Wald=1.5) - 1.64REVIEW\ (Wald=1.6) \quad (3)$$

The component of crops (PC) was the most significant variable in explaining whether a farmer is a buyer or seller of water (equation 3) with a Wald=8.1. A Wald statistic can be approximated by t-squared for sample sizes greater than 30 which is the case in this study (n=35). Water licenses according to the NWA must be reviewed after five years and this short period (REVIEW) appears to have a modest negative impact on the buying of water rights. It appears as if the buyers of water rights are more specialized in their production (DIV). Equation 3 had a 95 percent classification rate for sellers and 87 percent correct classification rate for buyers. The model was not tested on new data as the sample size was not considered large enough.

WATER TRANSFERS IN THE CROCODILE RIVER

Nature of water transfers

All but one of the trades (permanent and rent) observed in the Lower Crocodile River occurred from farmers above the gorge to farmers below the gorge and all transfers were from up- to down-stream. Wolstenholme (2004) and Bower (2004) attribute the movement of water from above to below the gorge to better growing conditions below. Temperatures above the gorge are not hot enough for the heat loving crops (sugar cane, mangoes, grapefruit, Valencia's and bananas) and not cool enough for temperate crops that require coolness. A major problem in citrus orchards above the gorge is the bacteria Citrus psylla causing greening in citrus. Crops that do well above the gorge are tobacco and macadamias (although White River appears more suited for Macadamias).

Principal Component Analysis of variables associated with transfers

The first component shows that a buyer of water use rights is likely to be large sugar cane producers and less likely to produce nuts (macadamias and pecans). Sugar cane is an appealing crop to farmers because of its drought resistance, liquidity and marketing properties. In addition, due to revealed risk averseness of respondents, these properties of sugar cane are even more appealing because they serve to lower the risk faced from farming by providing a stable source of income and allowing some production of more risky alternatives. It also indicates that farmers with a relatively high Net Present Value (NPV) from crop gross margins per cubic meter of water are more likely to be sellers of water entitlements. It appears as if water moves to lower risk users and that some income may be sacrificed. This supports Bate *et al.* (1999) observation.

Arrow-Pratt Absolute Risk Aversion

Due to insufficient data the APAR for positive outcomes is not reported but for down-side risk all farmers picked the most risk averse choice with an APAR of 3.28 (similar to that in the Orange River study). It is possible that only those who are risk averse have been able to survive in an uncertain environment. When faced with the chance that money could be won or lost, the farmers chose not to take the risk but would rather take a certain amount with zero gain. The importance of these findings is that a great cost is attached to risk whether weather induced or policy induced (insecurity of licenses).

Linear Probability Model (LPM)

A regression model was estimated in standardized form to study which variables explain whether a farmer is a buyer (TYPE=1) or seller (TYPE=0) of water. Due to the dichotomous dependent variable, a Linear Probability Model (LPM) was used to estimate the relationship between explanatory variables and dependent (TYPE) variable. Due to collinearity between the explanatory variables mentioned, Ridge Regression was employed in conjunction with the LPM (Equation 4). The R squared value for the model is 77 percent and the adjusted R squared value is 71 percent.

$$\text{TYPE}=0.49\ \text{BANANA}\ (t=4.6) + 0.34\ \text{DEFICIT}\ (t=3.0) + 0.29\ \text{SIZE}\ (t=2.4) + 0.13\ \text{CANE}\ (t=1.0) \qquad (4)$$

Equation 4 shows that the most important variable distinguishing whether the farmer will be a buyer is whether he produces bananas (BANANA). The DEFICIT variable shows that buyers are farmers who do not have enough water entitlements. Buyers tend to farm a larger area (SIZE), and are likely to produce sugar cane (CANE). In short, buyers farm larger areas with relatively more bananas and sugar cane and probably have a deficit.

It is interesting that the income variable (net present value per cubic meter of water) is not significantly different from zero confirming results from the principal components. This finding implies that the water market does not lead to a higher value use of water in this area. However, the market does allow farmers to transfer water entitlements in order to plant crops that are more suited to their risk preference (sugar cane has lower income but less risk) thus allowing better management of risk.

RESULTS OF INVESTMENT MODEL ON ORANGE RIVER DATA

An investment model was estimated where Y is the percentage that farmers expect to increase or decrease their investment in irrigation. Orange River data were used as the sample size was considered large enough. This regression suffered from high multicollinearity as measured by VIF (Variance Inflation Factor) values. A Ridge Regression was thus undertaken to reduce multicollinearity. The results of this regression are shown in equation 5.

$$\begin{aligned} Y= & \ 0.18\text{EXP}\ (t=1.2) - 0.34\ \text{OTH}\ (t=-2.5) + 0.28\ \text{LSTCK}\ (t=2.4) + .20\ \text{DIV}\ (t=1.6) \\ & - 0.16\text{RISK}\ (t=1.6) - .024\ \text{SECURE}\ (t=2.0) \end{aligned} \qquad (5)$$

The model basically explains future investment (Y) as a function of expected profits (EXP), risk (RISK), and possibly liquidity (LSTCK). These variables are supported by economic theoretical considerations. The R-squared value is 0.55 which is considered good given the conceptual nature of the model. The F value for the model is 5.2 which is significant at the 1 percent level, indicating that all the variables are jointly significant. A ridge trace has shown that regression coefficients stabilize after k=0.15 while the multiple regression coefficient declines only modestly before this point.

The crop variables indicate that table grape producers (EXP) will invest more and that producers of other grapes (OTH) will invest less. Future investment is highly dependent on expected profits. The signs of these variables are expected as recent income per hectare from table grapes (R130 000) significantly exceeds that of wine grapes (R40 000) or raisins (R30 000) ($1=R6.4). Expectations are assumed to be based on past experience. The farmers with more livestock (LSTCK) are expected to invest more. This may be attributed to a better liquidity position of these farmers (livestock is a liquid asset as it may be sold during adverse conditions).

The more risk averse farmers are expected to invest less as the RISK coefficient (APAR) was negative. It was earlier shown that irrigation farmers along the Lower Orange River are highly risk averse, especially as far as down-side risk is concerned. The implication is that policies that increase the risk in agriculture will have a significant negative effect on future investment in irrigation as these farmers will attach a great cost to risk. Farmers who feel that water licenses are not secure (high scores for

SECURE) are further expected to invest less. The fact that both the RISK variable and the SECURE variable entered is significant as both variables measure different dimensions of risk. For instance a risk-neutral farmer will invest less if he feels less secure about his water license.

FURTHER DISCUSSION OF RESULTS

Risk faced by farmers differ in the two areas and will be treated separately.

Lower Orange River

A major reason for water transfers was that buyers could produce lucrative table grapes for export while sellers were generally producers of lower income crops. The rand exchange has strengthened during 2003 and 2004 and export table grape farmers have experienced great losses which will have a significant impact on future trades. Estimates indicate that farmers are highly risk averse as shown by standardised Arrow/Pratt Risk Averse Coefficients. Faced with possible losses (down-side risk), farmers exhibit even greater risk averseness. Their aversion to risk explains why there are no renting in water and only sales in the Lower Orange River. Table grapes require a large long run investment and farmers indicated that they need security of water supply. A common practice was to plant low income short term crops for supply security next to high income crops but this stopped as water supply has been fairly regular in recent years.

Crocodile River

In the Lower Crocodile River some attributes in the purchasing area such as lower production risk (sugar cane) and lower financial risk and better cash flow (bananas and sugar cane) were more important than the income per cubic meter of water. Although this conclusion is self-evident it is interesting that the net present value of gross margin per cubic meter of water used (NPV) was not significant in regression models predicting a buyer of water rights. Water supply in the Crocodile River area is highly irregular while irrigation farmers were found to be extremely risk averse especially as far as down-side risk is concerned. The standardised Arrow/Pratt absolute risk aversion coefficient for down-side risk was at least 3.28.

According to the survey the time duration to complete a permanent transfer in the Orange River is short (one week to two months) while almost no permanent transfers have taken place in the Crocodile River in recent years. Some experts are of the opinion that due to the irregular flow of the Crocodile, the demand for water sometimes exceeds supply and that there is no water to transfer (Comrie, 2004; Joubert, 2004). This is in contrast with the reliable flow of the Orange River. Another expert is of the opinion that farmers below the gorge in the Crocodile River simply expanded production without having allocations to support it (Deacon, 2004) and that their area under irrigation exceeds their entitlements. Due to these problems DWAF are reluctant to process transfers as they first want to verify entitlement of user rights first. Once this risk is removed through licensing the water market is expected to be effective as there are many potential buyers and sellers.

CONCLUSION

Characteristics of buyers and sellers of water differ in the two irrigation areas studied. In the Orange River where water supply appears more stable (due to large irrigation dams) water is transferred from farmers where the return per cubic meter of water is low to farmers where the return is high. In the Lower Crocodile River where water supply is highly irregular, water is transferred from farmers where risk is high to farmers where lower risk crops can be produced. Irrigation farmers appear highly risk averse as measured by the Arrow/Pratt Absolute Risk Aversion Coefficient (standardised for scale and range of data). The empirical investment model shows that farmers who are more risk averse expect to invest less in the future. Policies that increase risk in agriculture will have a significant negative effect on future investment in irrigation. Results show that farmers who feel that water use rights are not secure expect to invest less in the future. This has important policy implications, and measures should be taken to improve the perceived security of water use rights. This could be achieved by keeping farmers more informed about the practical implications of the new National Water Act (NWA) and specifically water licenses. The lack of information available to farmers is evident from the responses obtained during the survey. The insecurity of water use rights is relative as surveyed farmers did not think that these rights will be taken away. The Department of water Affairs and Forestry (DWAF) does supply information to farmers, and much information is available via their website, however, relevant, simplified, and practical information should also be supplied to farmers. In addition, policy makers should make use of feedback from farmers to enable the pragmatic implementation of the NWA institutions.

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