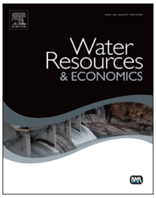
Water Resources and Economics 10 (2015) 31–44

Contents lists available at ScienceDirect

Water Resources and Economics

journal homepage: www.elsevier.com/locate/wre



A cost–benefit analysis of improved irrigation when faced with the risks of climate change on Mount Kilimanjaro

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ARTICLE INFO

Article history:
Received 30 April 2014
Received in revised form
2 January 2015
Accepted 5 January 2015

Keywords:
Water
Irrigation
Contingent valuation
Risk belief
Climate change
Africa
Mount Kilimanjaro

ABSTRACT

This paper uses the contingent valuation method (CVM) to determine farmers' willingness to pay (WTP) for eliminating the risks of crop loss associated with climate change through access to improved irrigation. The data for the analysis was gathered by using a double-bounded survey of 225 randomly sampled farmers in 15 villages on Mount Kilimanjaro. To minimize initial value bias, respondents were randomly assigned initial values. The policy contribution consists of the valuation of improved irrigation in the presence of climate change risks, while the applied welfare contribution comprises empirical evidence about the impact of risk belief on welfare valuation. We argue on conceptual grounds that farmers' belief in risk is important, as it influences their valuation of the irrigation scheme; however, risk belief's subjectivity makes it rather endogenous and therefore challenging to capture. Therefore, we use an Interval Regression Model with an endogenous explanatory variable to correct for the endogenous nature of the risk belief variable and account for the interval nature of the dependent variable. We found farmers' WTP to be between 7% and 21% of their income, and that the investment cost of improving an irrigation scheme could be paid back after a minimum of 13 years of operation.

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http://dx.doi.org/10.1016/j.wre.2015.01.001
2212-4284/

1. Introduction

Changes in rainfall patterns and humidity within the past 80 years have led to anomalies in vegetation and ecology in many parts of Mount Kilimanjaro, especially at lower altitudes and on the northern slope of the mountain [11]. These irregularities mostly take the form of delayed rainfall onset, which extends the dry season and creates agricultural yield uncertainties and food insecurity in the agrarian society that has depended on mountain amenities for centuries [1].

To help local smallholder farmers cope with these risks, policy makers and non-governmental organizations (NGOs) in the Kilimanjaro Region have introduced various safety nets, such as updating the dilapidated gravity flow irrigation systems that have been used on the mountain for nearly 100 years. Improved irrigation schemes can benefit Mount Kilimanjaro farmers in many ways. First, they have the ability to collect and store water for use during unexpected dry periods, especially during the critical period of early crop growth. Second, access to improved irrigation improves farmers' livelihoods by providing them with greater assurance of an adequate harvest during the unreliable short rainy season.[1] Finally, since coffee is the main cash crop on Mount Kilimanjaro, improved irrigation makes it feasible for farmers to adopt water-intensive coffee varieties that can produce more than three times the yield from traditional varieties.

Before investment in improved irrigation schemes is widely promoted, it is important to assess its costs and benefits. Policy makers should be able to answer the question of how long it will take before the accumulated benefits of the improved irrigation scheme cover its investment costs. Cost figures can easily be obtained from local engineers, but estimating the benefits is challenging, depending as it does on a farmer's socioeconomic profile, the crop produced, and the farmer's prior exposure to water-related shocks. Prior exposure to shocks will shape a farmer's risk aversion and change the benefits s/he expects to receive. The more risk-averse a farmer is, the more s/he will benefit from improved irrigation, *ceteris paribus* [19]. Failing to account for this important relationship will bias the true welfare value of improved irrigation [14].

Measuring risk aversion is not easy. In the past, some researchers have set up field-experiment gambling games that are both time-consuming and financially demanding [4,22]. In this study, a subjective probability measurement correlated with risk aversion – risk belief – is used instead. This is a measure of the respondent's skewness toward rainfall distribution, which was captured by a survey specifically designed to measure farmers' perception of rainfall distribution over the past 10 years.[2] We show, on conceptual grounds, that a farmer with a stronger belief that s/he will be negatively affected if a shock happens (*i.e.*, a positively skewed distribution) is more likely to associate a high value with improved irrigation.

We estimate the potential benefits of improved irrigation using the contingent valuation method (CVM) to determine Mount Kilimanjaro farmers' willingness to pay (WTP) for improved irrigation schemes. This approach is well suited to our purpose, allowing us to account for the effects of socioeconomic variables, farmers' risk belief, and non-irrigation-related self-protective action in the valuation of improved irrigation. Risk belief is subjective and found here to be endogenous, and we adopt a corrective approach to address this. It is worth noting that the proposed improved irrigation infrastructure, illustrated in the Appendix, is a closed-pipe system, which has the excludability feature of a private good.

The purpose of this paper is threefold. First, it seeks to estimate the determinants of farmers' WTP for access to an improved irrigation scheme when faced with climate change risks, and to assess whether farmers' risk belief significantly affects their stated WTP. We use an Interval Regression Model with an endogenous explanatory variable to account for the interval nature of the dependent variable and the endogenous nature of risk belief. Second, the paper estimates the mean WTP for improved irrigation. Since WTP is nonlinear in its parameters, mean WTP is computed using the

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[1] In the Kilimanjaro Region, the rainfall pattern consists of four distinct annual periods: two rainy seasons, a long one from March to May and a short one from November to December; and two dry seasons, a long one from June to September and a short one from January to February.

[2] We present the survey in the appendix.