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Adaptation to Climate Change in a Rural Economy with Missing Markets

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Africa is likely to suffer some of the most damaging consequences of climate change globally, according to the Intergovernmental Panel on Climate Change (2001). Climate change is expected to worsen Africa's climatic extremes, potentially pushing households and communities beyond their current coping capacity. In general, locations with low rainfall are expected to get even less, while locations with high rainfall are expected to get more.

The economic consequences of climate change vary according to the adaptive capacity of households and communities. Some of the climate adaptive strategies currently available to African crop farmers are water and moisture conservation practices (irrigation, water harvesting, mulching), cultivation of drought resistant crops and varieties, cultivation of land parcels in diverse micro-climates, non-farm employment and income, migration, and receipt of remittances. Expanding the use of these adaptive strategies beyond current rates of adoption involves opportunity costs with potentially important consequences for household income. Opportunity costs and incomes are influenced heavily by the existence (or absence) and performance of markets. Currently, little microeconomic analysis is available to inform policymakers of trade-offs and income potentials associated with alternative adaptive strategies in different market settings.

This paper analyzes the trade-offs, opportunity costs, and income potential of off-farm employment and water trading as adaptive strategies. The setting is a village economy in a rural region with incomes derived from agriculture, tourism, petty commerce, and cottage industries. Some households earn incomes from wage labor and remittances. Households are conceptualized as joint production-consumption units in the agricultural household modeling tradition of Kuroda and

Yotopoulos (1978), Singh, Squire, and Strauss (1986), and Taylor and Adelman (2003), and other authors.

Households are treated as heterogeneous by virtue of technology differences and differing access to labor and water markets. Two types of household are modeled, one type representing small-acreage households with less than two acres of land, and the second type representing large-acreage households with more than two acres of land. The smaller the amount of land held by the household, the simpler its agricultural production technology, the less fertilizer it uses per acre, and the less it irrigates its crops. Households with small acreages also produce a higher share of their own food than households with larger land holdings.

Models of the two types of agricultural households are embedded in a disaggregated rural computable general equilibrium model (CGE) with similarities to one developed by Taylor, Dyer, and Yunez-Naude (2005) for the Central-West region of Mexico. Several versions of the CGE model with differing degrees of market integration are developed. One version represents a village economy with no internal market for irrigation water and no trade linkages to external crop, livestock, and labor markets. In a second version, the village economy external market linkages but no internal water market. In a third version, the village economy has both external market linkages and an internal water market.

The water market, in the versions of the model in which it exists, is a village-level institution. When internal markets are missing in a village, demand equals supply within each household and the relevant price (or wage) signal is a shadow price (or wage) unique to the household. In the model versions in which crop and livestock markets are linked to external markets, prices are exogenous to the village economy.

Month-specific rainfall quantities enter the household agricultural production function as a set of fixed inputs. Climate change is modeled as an exogenous reduction in the rainfall endowment in

certain months during the year. Households with access to off-farm labor markets respond to rainfall shocks by reallocating labor across various agricultural activities, off-farm employment, and leisure, while households in remote locations without employment opportunities reallocate labor between agriculture activities and leisure. Members of households may migrate, depending on returns to labor within the household compared to fixed external wage. For all households, the share of marketed surplus of agricultural outputs changes in response to rainfall shocks.

Data for the analysis are obtained from multiple waves of a household survey conducted on Mount Kilimanjaro in Tanzania. Household production and consumption data and local rainfall data were gathered from a random sample of over 200 households in 15 villages spanning both the short and long growing seasons of the calendar year. Household economic accounts were prepared for various types of households. Elements of the SAM not available from the survey were obtained from regional information in the national agricultural census. Household economic accounts were then embedded within the village SAM. From the household survey data, net incomes were calculated for crops, livestock, and off-farm activities. Starting values of household-provided inputs, rainfall, and irrigation water were imputed by regressing net income on endowments of these inputs. Production is modeled using Cobb-Douglas production functions, whose parameters are estimated from the survey data. Consumption is modeled using a linear demand system and parameters of the system are estimated econometrically.

The model is solved using GAMS (General Algebraic Modeling System). Initially, the model is solved without perturbations to ensure that it replicates the SAM. A rainfall reduction is then introduced and the model is solved again, producing counterfactual estimates of endogenous variables. A key focus of the analysis is the extent to which the trading of irrigation water and access to non-agricultural income cushions the negative impact of rainfall shocks. Households without access to off-farm labor markets and without irrigation water markets are expected to suffer greater income losses

from rainfall reductions than households that are more integrated into regional markets. Outcome variables of particular interest in the analysis are income, migration, and marketed agricultural surplus.

The analysis is stylized and therefore partially, but not fully, reflects the reality of the Kilimanjaro economy. For example, the model has no "shades of grey". Households are categorized as small or large with no "in between" category, and goods and services are either traded or nontraded. The stylistic categorization of markets into existent versus missing markets highlights the role of market linkages in adaptive response to climate change, creating sharp contrasts between villages linked to external markets and those that are not linked. A further departure from the real economy of Kilimanjaro is that irrigation water markets currently do not actually exist in the region. In actuality, irrigation water is allocated by local leadership at the village level with no payment by users. Irrigation water originates from precipitation and condensation at altitudes on the mountain above the zone of human habitation and flows by gravity through irrigation canals constructed during Tanzania's colonial period. The ability to turn an unpriced resource into a market good is one of the advantages CGE models. Indeed, the model is designed so that water can easily be modeled with either a zero price or a positive price.

The current traditional system of irrigation on Kilimanjaro is highly inefficient with water losses due to poor maintenance of canals and ditches and with no return of unused irrigation water to canals. Much of the water goes to waste, yet our survey reveals many farmers receive a far smaller water allocation than desired and would be willing to pay for greater water access. The introduction of water markets in the model addresses what appears to be a feasible policy response to climate change in a setting where water for agriculture is currently scarce and is expected to become scarcer in the future.

The analysis is designed to provide stylized insights on how climate shocks differ according to differences in market conditions and agricultural technology. The results of the analysis lead to conclusions about the differential impacts of climate change on small and large rural households in

settings with missing markets. Simulations obtained using the village model versions described above will be presented at the AAEA meeting in Denver.