Probability Weighting and Fertilizer Use in a State-Contingent Framework

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Overview

- Limited use of fertilizer by African farmers has been a major source of policy concern in Africa.
- This study assesses the fertilizer adoption (intensity) responses of food insecure farmers in Malawi.
- An incentivized field experiment, eliciting risk attitudes of farmers, is combined with a detailed farm household survey.
- A **state-contingent production model** with **rank-dependent utility** preferences is estimated.
  - **Over-weighting of small probabilities was associated with less use of fertilizer** on all maize types and **particularly so on the more risky improved maize types.** *We call this "**probabilistic risk aversion**"*

Earlier studies

- Many studies on the relationship between risk attitudes and input use
  - Most studies have been carried out within the Expected Utility (EU) model
- Often combined with a stochastic production function
  - Classifying inputs as risk-increasing or risk-reducing
  - The EU model does not take into account probability weighting or loss aversion
- Many studies in Behavioral and Experimental Economics have showed that most people do not behave according to the EU model

Risk Attitudes, Shocks and Technology Adoption

- We are only aware of one paper applying CPT to input use decisions.
  - Liu and Huang (2013) found that more risk averse farmers use more pesticide on cotton, while more loss averse farmers use less pesticide on cotton.
  - **Over-weighting of small probabilities (alpha<1) was associated with higher pesticide use**
    - This finding is consistent with pesticide being a risk-substituting input

Holden and Quiggin (2017)

- Applied CPT and a state-contingent model of production under uncertainty to model decisions of farmers in Malawi on whether to adopt a new Drought Tolerant (DT) maize. Key findings were
  - **More risk averse households were more likely to adopt DT maize**, less likely to adopt other improved maize varieties and less likely to dis-adopt traditional local maize
  - **Exposure to past drought shocks stimulated adoption of DT maize** and dis-adoption of local maize.
  - More loss averse households were more likely to adopt DT maize
  - **Probability weighting had no significant relation**

Theoretical framework

- **State-Contingent Framework**
  - Chambers and Quiggin (2000)/Holden and Quiggin (2017)
  - Focus on the relationship between input demand and technology adoption as adaptation to climate change
    - As responses to shocks and adaptation to climate risk and change
    - Adaptation processes as change in state-contigent production technology
      - Changes in the set of inputs and state-contingent outputs

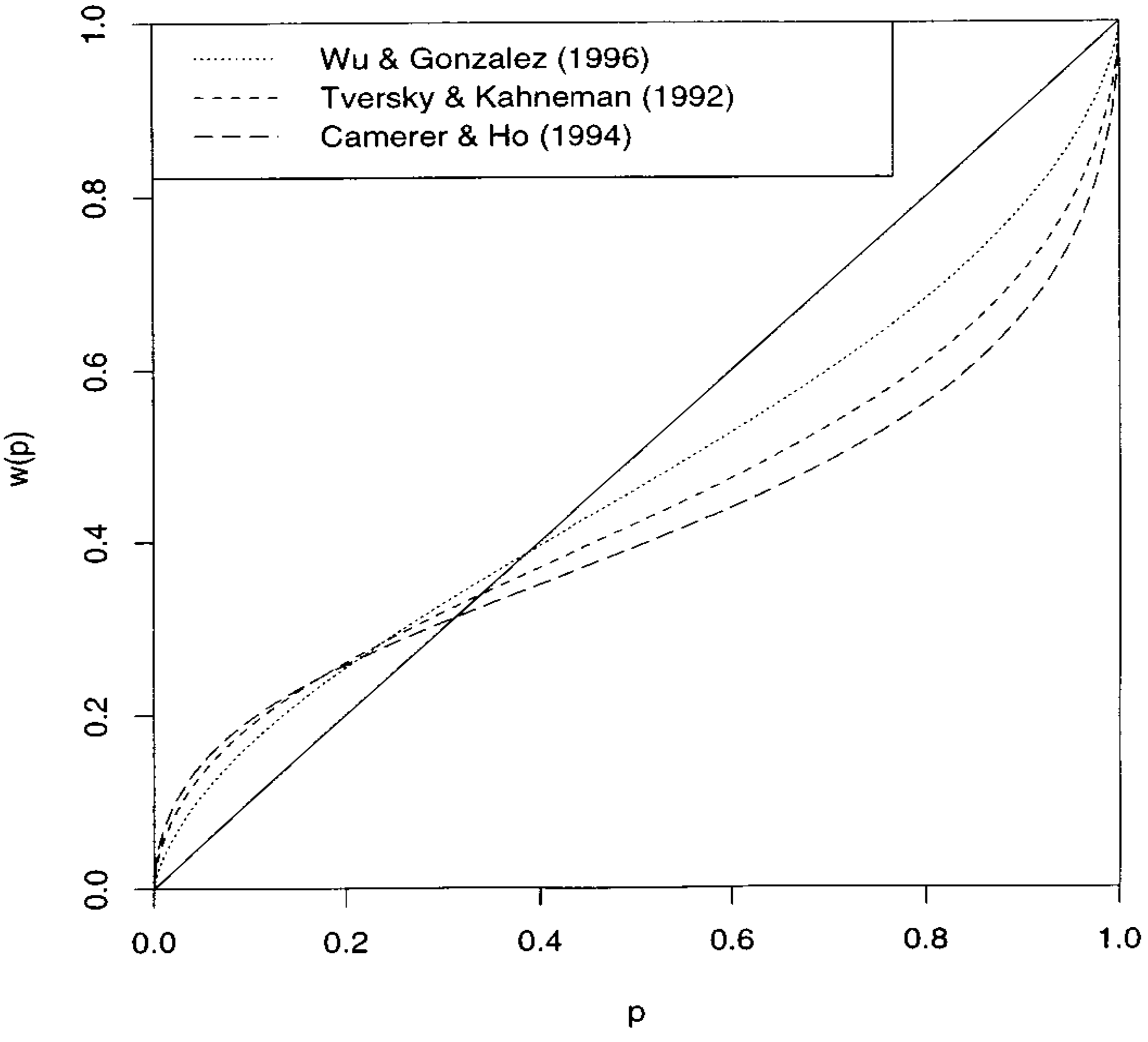
State-contingent framework

- Set of states of nature S
  - The probability of state s in S is π_s
  - A state-contingent output vector *z* in R^S
    - z_s is the realized output if the producer chooses *z* and state *s* is realized
    - Input use is decided before the state of nature is revealed. *x* is the non-stochastic vector of inputs
- Implications: A more risk-averse producer will choose a less risky state-contingent output plan than a less risk-averse producer

State-contingent framework

- Extension to non-EU preferences represented by rank-dependent utility (RDU) or prospect theory (CPT) model:
  - **Subjective probabilities/probability weighting**: Provided this leads to **greater weight on the less likely and less favorable state**:
  - An RDU maximizer will use more risk-substituting and less risk-complementary inputs than an EU maximizer with the same utility function.
    - We call this “probabilistic risk aversion”
- We are not aware of any other studies that have investigated how this type of risk attitude affects fertilizer use intensity and whether it can explain low fertilizer use intensity in Africa

Probability weighting functions



Risk attitude experiments and parameters

- Holt and Laury (2002) approach: Expected Utility Theory
- Relative risk aversion parameter
  - →CRRA-parameter ($U = (1-crra)^{-1}\left(Y^{1-crra}-1\right)$
- Tanaka et al. (2010) Prospect Theory series:
  - 3 series to derive 3 parameters:
    - Subjective probability weighting (**alpha**)

$$w(p) = 1/\exp\left(\ln(1/p)\right)^{\alpha}$$

    - Curvature of value function (sigma)(not used)
    - Loss aversion (lambda):
      - Gains: $v(x) = x^{\sigma}$ Losses: $v(x) = -\lambda(-x)^{\sigma}$

Probability weighting

- The probability weighting parameter determines how much one overweighs small probabilities and underweights large probabilities. The smaller the alpha is, the more one overweights small probabilities and the further away subjective probability departs from the objective linear probability.
- One might overweight the small probability event, such as severe pesticide infestation or event of drought
- This may result in over-use of risk-substituting inputs (e.g. pesticide) and under-use of risk-complementary inputs (e.g. fertilizer) relative to an EU-maximizer

How to measure technology adoption?

- Assess fertilizer adoption for 3 types of maize:
  - **LM** (Local maize)
  - **DT** (Drought Tolerant) maize varieties
  - **OI** (Other improved) maize varieties
- Assess **Intensity of Fertilizer Use** per farm and on each type of maize (measured as kg Fertilizer by maize type)

Setting: Smallholder Farmers in Malawi

- Farm sizes: 0.25 ha – 5 ha
- Rain-fed agriculture
- Rainfall variability: Drought in form of dry spells in the rainy season are common
- Main staple crop: Maize planted on most of the land
- Majority are net buyers of maize (deficit producers)
- Large input subsidy program (FISP) provides subsidized fertilizer and maize seeds
- 2011/12: Drought year (70% of sample affected)
  - Combined hh farm survey and experiments (to elicit risk preferences)

Hypotheses

- H1) Fertilizer use intensity is lower for more risk averse producers.
- H2) Fertilizer use intensity is higher for low-risk DT maize than for high risk OI and local maize
- H3) Subjective overweighting of low probability extreme events is associated with less intensive fertilizer use on maize.
- H4) Subjective overweighting of low probability extreme events ("probabilistic risk aversion") is associated with less intensive fertilizer use on the more risky OI and local maize than the less risky DT maize.

Data and methods

- Household farm panel survey in Malawi
- Framed Field Experiment/Artefactual Field Experiment:
  - 2012 for EUT/PT parameters

- Econometric analysis
  - Censored Tobit (Demand for fertilizer by MZ-technology)
    - Pooled and separate models for each maize type
    - Step-wise addition of controls for robustness assessment

$$F_i^M \,|_{M>0} = F_i^M \left(EP_i^M, EQ_i^M, crra_i, \alpha_i, P_c^F, P_s^F, S_{,}^F, C_i, X_i A_i, \sigma_v \right)$$

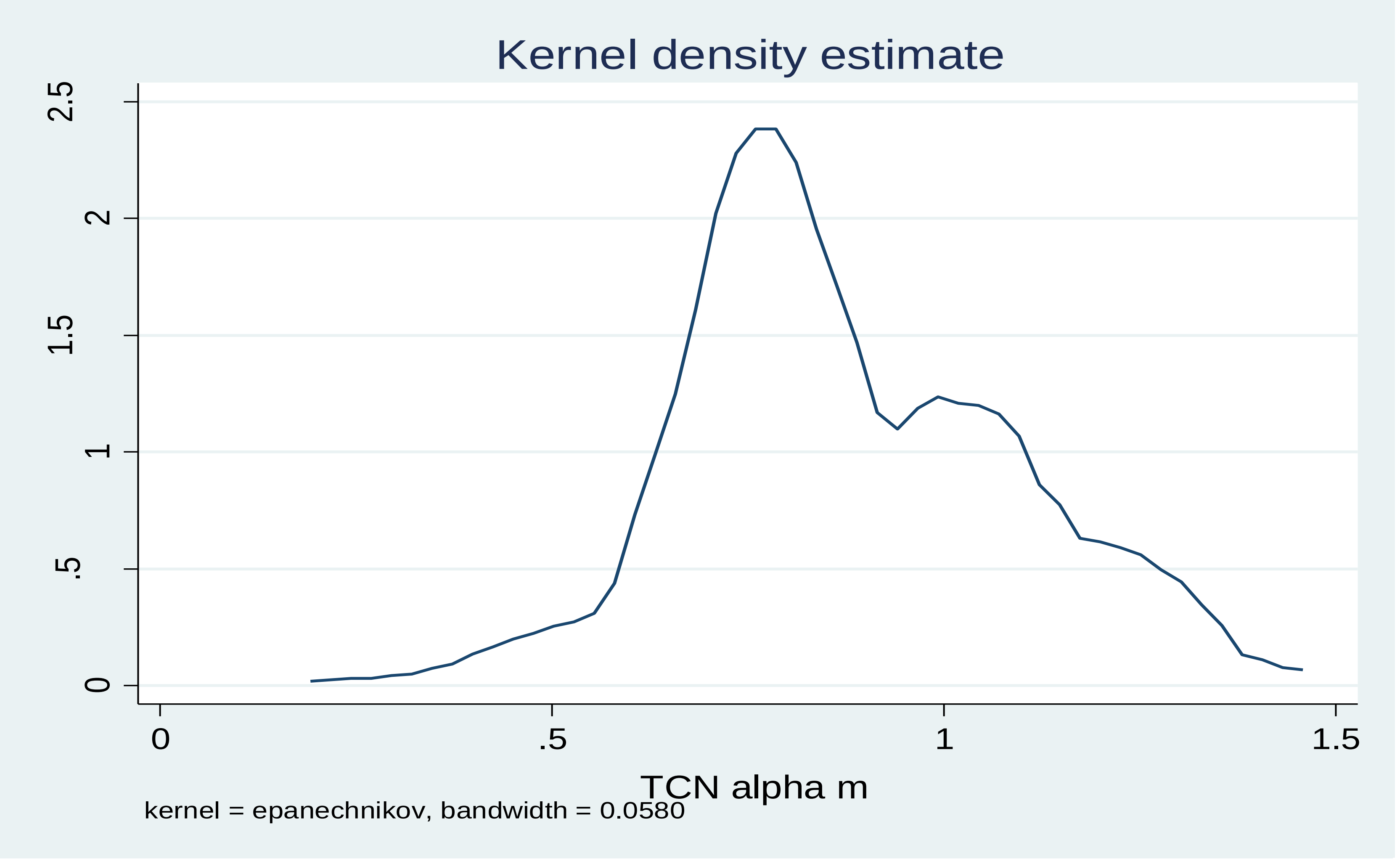
«Lab-in-the-field» experiments in Malawi

- Local schools as field labs
- Incentivized Holt and Laury (2002) and Tanaka et al. (2010) experiments

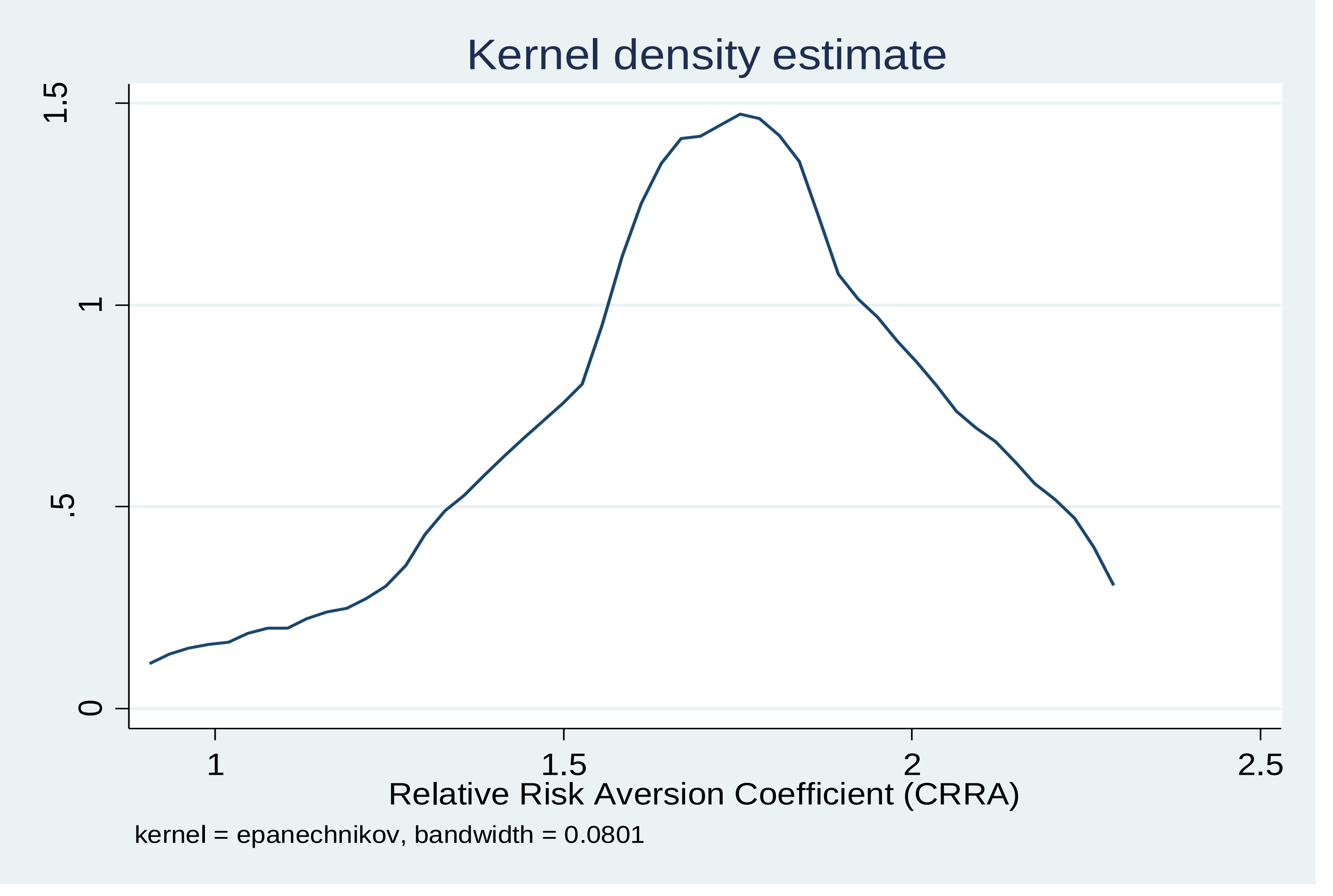
Holden, S. T. and Fischer, M. (2015). Can Adoption of Improved Maize Varieties Help Smallholder Farmers Adapt to Drought? Evidence from Malawi.

Year		Local maize	**DT maize**	OI maize	Total
2006	No of plots	295	**20**	525	840
	% of plots	35.1	**2.4**	62.5	100.0
2009	No of plots	273	**130**	225	628
	% of plots	43.5	**20.7**	35.8	100.0
2012	No of plots	143	**249**	163	555
	% of plots	25.8	**44.9**	29.4	100.0
Total	No of plots	711	**399**	913	2,023
	% of plots	35.2	**19.7**	45.1	100.0

Subjective probability weight (**Alpha**) distribution



Relative risk aversion (CRRA) distributions



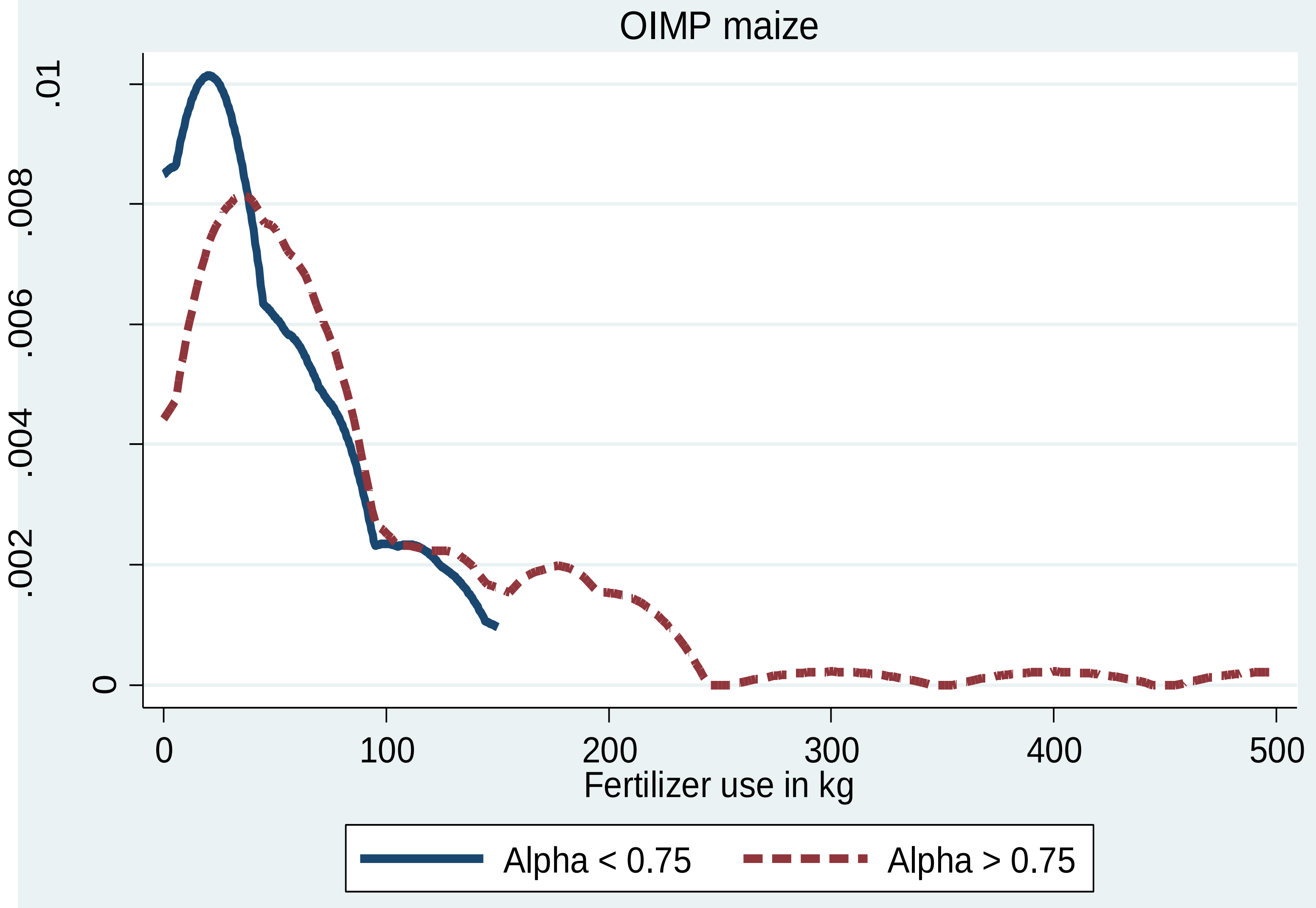
Pooled models

	Base	+Attrition IPW	+village FE	+HH char.	+Endog.var	+Maize area
Relative risk aversion	-28.995	-26.177	-24.953	-27.528	-17.333	-11.500
Subj. Probability weight	**100.753******	**99.800******	**94.833*****	**86.083*****	**81.148*****	**78.472*****
Number of shocks last 3 yrs	-1.535	-3.085	-4.616	-3.126	2.332	1.990
Drought 2012, dummy	-18.118	-15.099	-0.346	-0.182	-7.109	-12.416
Drought 2011, dummy	4.701	6.163	9.925	15.256	14.161	9.308
Drought 2010, dummy	-19.928*	-16.634	-18.205	-16.397	-11.235	-3.729
DT maize, dummy	**21.176***	**21.137**	**34.938****	**38.307*****	**28.442****	**17.688**
Local maize, dummy	**-21.485****	**-21.196****	**-16.206**	**-11.608**	**-17.539***	**-24.788****
Farm size, GPS meas., ha	15.150****	17.138****	18.576****	17.591****	17.787****	9.264
Sex of respondent, male=1	-7.907	-8.875	-10.227	-3.388	3.226	5.314
Livestock, TLU/ha				-1.175	-0.857	-0.929
Consumer/worker ratio				-2.829	-1.038	-1.359
Education, years				3.073**	3.431**	3.200**
Male labour/ha				-1.443	-1.565	-2.110
Female labour/ha				-4.267*	-1.936	-0.329
Subsid. Fertilizer, dummy					57.968****	56.053****
Savings for fertilizer, MK					0.001****	0.001***
Non-agric. Business,dummy					1.313	-2.607
Formal employ., dummy					10.006	12.224
Maize area						46.914***
Village FE	No	No	Yes	Yes	Yes	Yes

Fertilizer use by maize type

	DT1	OI1	LM1	DT2	OI2	LM2
Relative risk aversion	-34.949	-70.932	-2.418	-41.624	-36.401	4.786
Subj. probability weight	128.759***	173.369***	79.473**	172.194****	183.748****	59.207
No. of shocks last 3 yrs	-4.081	-8.987	-14.238*	7.641	-3.544	-9.982
Drought 2012, dummy	-30.030	-21.841	3.752	-51.527*	-38.227	1.319
Drought 2011, dummy	-12.401	21.618	10.192	-5.000	18.608	20.384
Drought 2010, dummy	-7.665	-51.418*	-46.976**	-17.335	-21.821	-40.813
Farm size, GPS meas., ha	25.199*	5.129	14.809****	21.185*	-0.048	14.798****
Sex of respondent, male=1	-16.516	40.122*	-15.897	2.899	62.081***	-6.676
Livestock, TLU/ha				16.706**	-0.316	1.178
Consumer/worker ratio				-2.074	5.515	-5.106
Education, years				0.700	1.963	2.441
Male labour/ha				-5.673*	-0.777	0.442
Female labour/ha				5.203	-4.842	-4.264
Subsid. fertilizer, dummy				71.183****	45.342**	52.835***
Savings for fertilizer, MK				0.003****	0.001**	0.001****
Non-ag. business, dummy				-18.444	51.331**	-20.621
Formal employ., dummy				17.757	-55.647*	-3.470
Village FE	Yes	Yes	Yes	Yes	Yes	Yes

Subjective Probability Weights (alpha) and Fertilizer Use



Sensitivity analysis: alpha parameter coefficients

	Attri-tion IPW	Village FE	Extra HH char	Endog. Var.	Mz area	DT	OI	LM
Yes	No	No	No	No	No	125.266***	139.111***	76.465**
Yes	Yes	No	No	No	No	125.531***	170.183***	82.860**
Yes	Yes	Yes	No	No	No	128.759***	173.369***	79.473**
Yes	Yes	Yes	Yes	No	No	132.622***	163.703***	73.758*
Yes	Yes	Yes	Yes	Yes	No	172.194****	183.748****	59.207
Yes	Yes	Yes	Yes	Yes	Yes	148.679****	149.428***	61.186*

Summary of findings

- **Perceptions and preferences matter!**
- Subjective probability weighting (**over-weighting of low probabilities is associated with lower intensity of fertilizer use**)
- The reduction is higher for the more risky technology
- The implication is **under-use of the productivity enhancing and risk complementary input**
- Could this be an extra argument for fertilizer subsidies to stimulate fertilizer use? Debatable

Implications for policy

- Input subsidies have promoted more rapid adoption of Drought-Tolerant maize in Malawi compared to neighbouring countries with similar agroclimatic conditions
- This has also reduced the risk involved in using the risk complementary fertilizer input and thus stimulated its use
  - The costs of doing so have been high and fertilizer use efficiency low