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Poverty, cognition, heuristics, livestock, Kenya

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Abstract

Decision-making in economics is largely framed by notions of risk preferences, consumption smoothing and stochastic changes in discounting. However, more recent empirical evidence indicates that direct measures of cognitive processes provide a more nuanced and predictively robust understanding of economic decision-making. The theoretical link between financial stress, changes in cognitive capacity and economic decision-making has become clearer due to the strong association between cognition and dual-processing theory. A need exists to better understand the potentially dynamic role of cognition on economic decision-making, particularly in low-income settings where poverty and associated financial stress are most prevalent. A short, unbalanced panel is used to estimate the effects of changing financial stress on household livestock expenditure in rural Kenya. Estimated negative changes in heuristic use on changes in livestock and educational expenditure provide further empirical evidence of the effect of changes in cognition on economic decision-making.

Introduction

The standard microeconomic assumptions of completeness and transitivity are supported by an implicit assumption that an individual's cognitive capacity is maximized and constant over time. Notions of bounded-rationality also assume individuals have constant and full capacity information processing ability. As a consequence, decision-making in economics is largely framed by notions of risk preferences, consumption smoothing and stochastic changes in discounting (Arrow, 1971; Duflo et al., 2011; Laibson, 1997; Pratt, 1978). However, more recent empirical evidence indicates that direct measures of cognitive processes provide a more nuanced and predictively robust understanding of economic decision-making. Research interest in the effects of poverty on decision-making has revealed that financial stress affects short-term cognitive capacity (Iles et al., 2019c; Mani et al., 2013). Experimental and non-experimental evidence indicates that cognitive capacity affects risk perceptions, discounting and economic decision-making.

The link between financial stress and changes in cognitive capacity, and economic decision-making has become clearer due to the strong association between cognition and rational or reflective thinking. Experimental data consistently indicates that cognitive capacity and heuristic use are strong predictors of performance on rational thinking tasks. Within a dual-processing framework, the predicted positive performance on the Cognitive Reflective Test, proposed by Kahneman and Frederick, (2002), is causally related to positive cognitive capacity and negative heuristic use (Frederick, 2005; Toplak et al., 2011). The Cognitive Reflective Test measures one's tendency to override incorrect autonomous or immediate responses with extended reflection. The simultaneous channels of cognitive capacity (as measured by fluid intelligence) and mechanisms to simplify choices, which are predictors of reflective thought (System 2 thinking), are also predictors of choices that have uncertain and delayed returns (Iles et al., 2019c). While not tested in the current paper, changes in risk preferences are hypothesised to be related to changes in reflective thought (Shah et al., 2015).

The risk preference framework for Arrow-Pratt remains dominant as a means of analyzing economic decision-making. An important relationship exists between trade-offs in "uncertainty across states of nature and fluctuations over time" (Lybbert and McPeak, 2012). Agrarian enterprises in East Africa are characterised by poverty, uncertainty of future returns and risks to crops and livestock health. The analysis of the behaviour of livestock owners towards managing their portfolio of livestock and their associated returns in Kenya reveals a Preference for Early Resolution of Uncertainty (PERU) (Lybbert and McPeak, 2012). This result indicates that individuals may be “both risk averse and tolerant of high consumption variability over time” (Lybbert and McPeak, 2012). Intertemporal changes in both risk preference and practices of consumption smoothing make the identification of optimal economic decisions problematic. While arguing for the presence of PERU, the possible behavioural effects of anxiety or hope on individuals’ preferences are acknowledged by Lybbert and McPake (2012).

Individuals’ perceptions of their financial status are important factors that mediate the effect of exogenous stressors on cognitive capacity. A growing body of literature attests to this thesis (Haushofer and Fehr, 2014; van Gelder et al., 2009). The model of cognition on economic decision-making, proposed by Iles et al. (2019a) incorporates subjective notions of affect and perception. Multivariate analysis of cross-sectional data demonstrates that the financial experiences of the immediate past, relative to prior expectations, along with future expectations of financial well-being affect fluid intelligence measures (Iles et al., 2019a). This proceeding work frames the model of cognition on economic decision-making by drawing on the Gestalt school of psychology (Koehler, 1947) and the decision-making framework of attribute trade-offs (Gigerenzer and Goldstein, 1996; Lancaster, 1966). These model results, in combination with experimental data concerning cognition and risk preference and discounting, suggest that cognition has a primary role in economic decision-making. While the current research does not test the above assertion, it provides a working hypothesis to consider the effects of short-term changes in cognitive capacity on economic decision-making.

Identifying sufficient levels of financial stress to induce changes in cognition has proved critical in this financial stress literature. The study by Carvalho et al. (2016) indicates that how financial stress and cognitive capacity are measured may play an important role in identifying cognitive capacity change. For example, a drought experienced by agrarian households is believed to be a sufficient source of financial stress that may be used to measure changes in cognitive capacity. Measures of the stress hormone cortisol before, during and after a drought among agrarian and non-agrarian households in Kenya demonstrate the appropriateness of this belief (Chemin et al., 2013). However, before considering the effect of short-term changes in cognitive capacity on economic decision-making, the relationship between exogenous stress, affect and perception and risk preferences requires clarification.

Earlier, related research indicates that changes in cognition confound the relationship between causes of financial stress (e.g. lack of rainfall, reduced vegetation coverage and death of livestock) and individuals' willingness to smooth consumption (Iles et al., 2019c). This work considers the effect of changes in cognition and heuristic use on six household expenditure categories: food, energy, transportation, education, livestock and crops. The current research differs from this proceeding work in several important respects. The focus on livestock vaccine use and expenditure, in the present work, enables a clearer interpretation of results. Vaccine use is consistently optimal with respect to livestock productivity and future household returns (Marsh et al., 2016). As a result, a need exists to better understand the role of potentially dynamic role of cognition on economic decision-making, particularly in low-income settings where poverty and associated financial stress are most prevalent.

Analysis of vaccine expenditure provides a consistent context to assess the effects of changes in cognition on economic decision-making. The contrasting disease profiles and changing perceptions of contagious bovine pleuropneumonia (CBPP) and Rift Valley fever (RVF) and the required frequency of vaccine use allow analysis to control for changes in risk preferences. The contrasting pathology and recommended vaccine regimes of CBPP and RVF provides an important decision-making context to assess the effects of changes in cognition on economic decision-making. CBPP is an air-borne disease, while RVF is a zoonotic disease that is transmitted by mosquitos (Hightower et al., 2012; Nkando et al., 2012). The relative uncertainty of disease transmission at any point in time between these livestock diseases provides a context to further understand the role of uncertainty as a factor mediating the effect of changes in cognition on economic decision-making. The RVF livestock vaccine is 'once-for-life', while the CBPP requires annual boosters. The difference in the recommended frequency of vaccine doses ensures that cognitive demands to assess trade-offs related to livestock expenditure are likely to differ. CBPP and RVF vaccinations cost livestock owners KES 15 and 12, respectively, in Samburu County.

Cognitive capacity also affects one's ability to recall events and experience hyperbolic discounting. The degree to which events are 'available' to recall and accurately date events contribute to 'telescoping' (i.e. over estimation of past events occurring in a given interval) (Rubin and Baddeley, 1989). The proposed role of availability in contributing to recall bias also affects forward looking projections of time. Rubin and Braddeley (1989) argue that there exists a lack of availability of future events. Among the poor, when recalling past human health events, a systematic under-report health events is observed (Das et al., 2012). This finding is in apparent contrast to the expected over-reporting because of telescoping. However, it is possible that the rate of availability decreases at a greater rate among the poor, who may suffer from prolonged exposure to financial stress and anxiety (Al Hazzouri et al., 2017; Moran, 2016).

The current paper demonstrates that changes in short-term cognitive capacity (i.e. fluid intelligence - gf - and working memory capacity - (WMC)) and heuristic use are directly related to economic decisions concerning investment in livestock. The use of two measures of cognition and an attribute trade-off heuristic enables modelling to identify the presence of changes in risk preferences (heuristic use and intelligence) and recall bias (WMC). In line with the experimental evidence, the results here demonstrate that heuristic use is a dominant variable identifying changes in cognitive capacity and in turn, risk preferences. Contrasting parameter estimates between the ultra-poor and non-ultra-poor for the contributions of CBPP and RVF vaccine expenditure to total livestock expenditure demonstrates sub-optimal vaccine use.

The modelling methods are outlined in Section 2. A detailed description of the data is presented in Section 3. This description includes a discussion of the cognitive capacity measures - Raven's Progressive Matrices (RPM) and complex span counting exercise - and a rationale for use the use of changes in cognition over level analysis. Results are presented and discussed in Sections 4 and 5.

The research design and associated tools used in the study were approved by the Washington State University Institutional Review Board (#16207) and the Kenyatta National Hospital - University of Nairobi Ethics and Research Committee (P613-10/2017). The principle investigator also received a research permit from the Kenyan Government (NACOSTI/P/17/91630/19302).

Methods

Several regression estimators are used in this analysis. An evaluation of the use of cross-sectional and panel specifications is conducted on the coefficients for cognitive capacity and heuristic use. A series of binary probit estimators are used, and equations 1 - 3 denote the latent structure of the threshold determining the binary classification. Equation 4 introduces a panel structure with the subscripts *i* (respondent) and *t* (time period). The panel random parameter specification used includes a normal distribution of $\mathbf{v}_i$. The use of the random parameter specification aids the control of heterogeneity in parameter estimates. A first-difference estimator is also used to measure the association between changes in household expenditure with those of cognitive capacity, heuristic use and stress. The first-difference estimator is outlined in equation 5, and uses an ordinary least squares approach.

$$y^* = \mathbf{x}'\boldsymbol{\beta} + u \quad (1)$$

$$y = \begin{cases} 1 & if\ y^* > 0 \\ 0 & if\ y^* \leq 0 \end{cases} \quad (2)$$

$$Prob(y = 1) = Prob(\mathbf{x}'\beta + u > 0) \quad (3)$$

$$Prob(y_{it} = 1) = F(\boldsymbol{\beta}_i'\mathbf{x}_{it}),\ i=1,\ldots N,\ t=2, 3. \quad (4)$$

$$\boldsymbol{\beta}_i |\ i \sim h(\boldsymbol{\beta}|i) \text{ with mean vector } \boldsymbol{\beta} \text{ and covariance matrix } \boldsymbol{\Sigma} = \mathrm{Var}[\boldsymbol{\beta_i}|\mathbf{z_i}]$$

The random parameter model is operationalized by

$$\boldsymbol{\beta}_i = \boldsymbol{\beta} + \Gamma\mathbf{v}_i, \text{ where } \mathbf{v}_i \sim \mathrm{N}[0,1]$$

$\boldsymbol{\beta}$ is fixed constant term, while $\Gamma\mathbf{v}_i$ represents the lower triangular matrix that produces the covariance matrix of the random parameters and $\mathbf{v}_i$, which here takes on a normal distribution for the unobservable Kx1 latent random term in the ith observation.

The first-difference estimator is similar to the fixed-effects specification. Equation 5 demonstrates that the difference in the dependent variable is between the response in time t and their corresponding response in time t-1. When t=2 the first-difference and fixed-effects models correspond.

$$(y_{it} - y_{i,t-1}) = (\mathbf{x}_{it} - \mathbf{x}_{i,t-1})'\beta + (\varepsilon_{it} - \varepsilon_{i,t-1}), \qquad t = 2,3. \tag{5}$$

The estimation equations (6-8) outline the role of livestock vaccine use in predicting: i) the use of other livestock vaccines, ii) livestock expenditure, and iii) education expenditure. Measures of cognitive capacity and heuristic use are also included. The use of equations (7) and (8) in a first-difference model prevents the inclusion of non-varying categorical covariates.

$$\text{Vaccine use} = \beta_0 + \beta_1 \boldsymbol{Cognition}\ (Fluid\ Intelligence) + \beta_2\ \boldsymbol{Heuristic}(ANA) + \beta_3\ \boldsymbol{Stressor}\ (Rainfall_{3months}) + \beta_4\ \boldsymbol{Stressor}\ (NDVI\ ) + \beta_5\ \boldsymbol{Ticktreatment} + \beta_6\ \boldsymbol{Vaccinate_{otherdisease}}(RVF\ or\ CBPP) + \beta_7\ \boldsymbol{Cattle\ number}\ (cattle\ or\ calves) + \beta_8 \boldsymbol{Round1}, \tag{6}$$

$$\text{Livestock expenditure} = \beta_0 + \beta_1 \boldsymbol{CBPP_{vaccineexpenditure}} + \beta_2\ \boldsymbol{RVF_{vaccineexpenditure}} + \beta_3\ \boldsymbol{Ticktreatment} + \beta_4\ \boldsymbol{Cognition}(WMC) + \beta_5\ \boldsymbol{Heuristic}(ANA) + \beta_6\ \boldsymbol{Stressor}(NDVI) + \beta_7\ \boldsymbol{Borrow}, \tag{7}$$

$$\text{Education expenditure} = \beta_0 + \beta_1 \boldsymbol{Livestockexpenditure} + \beta_2 \boldsymbol{Cognition}(WMC) + \beta_3\ \boldsymbol{Heuristic}(ANA) + \beta_4\ \boldsymbol{Stressor}(NDVI) + \beta_5\ \boldsymbol{Borrow}, \tag{8}$$

Four survey tools were administered to each respondent during each round. Either the RPM (Figure A1) or the Counting Span (Figure A2) tasks were completed first. The ordering of these survey tools alternated to prevent any ordering effects. A discrete choice experiment (DCE) focused on a hypothetical choice of whether to vaccinate cattle for CBPP was administered second. This DCE had two unlabeled choice alternatives and a default ‘none’ alternative (Figure A3). The two unlabeled alternatives each had the following four attributes: price, distance to access livestock vaccines, level of information concerning CBPP disease risk, and possible vaccine side-effects. The latter two attributes were designed to capture non-market features of vaccine choice and reflect attributes less available to respondents. Respondents answered six choice tasks. The attribute ordering was fixed in three of the tasks (as listed above), while the ordering changed in the other three tasks. Once each choice task was answered respondents nominated which of the four attributes were ignored, if any. The sum of these ignored attributes over the six choice tasks provides the heuristic measure used in this study - attribute non-attendance (ANA). Respondents indicated which attributes they ignored even when they selected the default 'none' alternative. The none alternative was selected in approximately eight percent of choice tasks. The final survey tool was a survey that included the following components: demographic, mental health, socio-economic, perception of livestock diseases, livestock management, human health, and herd movements.

Data

Samburu County Kenya, was selected as the study site. The principal town in the county is Maralal, which is positioned approximately 350 km north of Nairobi. Five collection points were used around Maralal covering a radius of 20 km. The area sampled is classified as agro-pastoralist in an arid or semi-arid environment. Villages in the south-west corner of the county were selected because of the operation of a child education sponsorship program, supported by Compassion International, Kenya in this area. Participation in the child sponsorship program was not a requirement to participate in the study. The program provided a platform to engage with the local community through community leaders. The sample is representative of relatively poor rural Kenyan households in the selected communities. A majority of respondents had a child currently in the Compassion sponsorship program. The vetting of households wishing to receive child sponsorship based on their respective financial need, by Compassion International, helped identify relatively poor households in each of the communities.

Surveys took on average 45 minutes to complete. Prior to the first survey round respondents were unaware that a gift of food (equivalent of $2.50) would be given, which acknowledged the time commitment required to complete the survey tools. In addition to the 45 minutes required to complete the survey, many respondents waited several hours before starting the survey. It is not believed that the gift was a motivating factor for respondents to complete the survey. All respondents were also offered a basic lunch on the day they completed the survey.

The timing and setting of the research coincided with the end of a severe and protracted drought. Samburu County has two wet-seasons each year - March and April, and October and November. Prior to the commencement of the study in the 4th quarter of 2017 Samburu County received 10 out of 11 quarters of below-average rainfall and seven consecutive quarters of below-average rainfall (Government of Kenya, 2018b). Given respondents' knowledge of average weather patterns, and the realities of the drought, the timing of data collection was aimed to capture natural variance in respondents' perceptions of the immediate future financial well-being of their households.

Four hundred individuals participated in the study. The structure of the data is summarized in Table 1. A majority of respondents completed more than one round (58%). Two responses were given by 156 individuals (39%) and 77 respondents provided three responses (19%). The single responses during the first and second rounds allow for comparison and assess whether learning effects are present in the cognition data.

[Table 1]

Table 2 summarises data collected across the three survey rounds. The summary is organized according to the following categories: cognition, stressors, livestock ownership, diseases and treatments, and respondents' characteristics. The cognitive capacity measures RPM and Counting Span Task (Count) correspond to fluid intelligence and WMC conceptions of cognition. This cognition data are presented in level and difference forms. The level cognition measure exhibits a floor-effect, whereby minimum scores are zero. This feature of the data limits the variance between and within responses. The heuristic ANA scores cover the full range possible between zero and eighteen. Three stressors are captured. The difference between total rainfall over the past 3-months and the long-term average is measured at each of the three rounds. A single value is used across all respondents and exhibits a trend. At each round, the rainfall value becomes increasingly positive. Approximately 90 percent of households owned at least one head of cattle, while approximately 95 percent of households owned some form of livestock. The second stressor is the percentage of livestock lost during the last 3-months relative to the current livestock holdings. These measures vary by household. Vegetation coverage is an important driver of livestock movement. The Samburu frequently move their livestock, particularly cattle, during periods of dryness in search of water and vegetation. The third measure of stress is the normalised difference vegetation index (NDVI), which varies by village. 'FAO units' enable the aggregating of livestock ownership into a single measure.

[Table 2]

Table 2 indicates that 68 percent of the sample indicated that they vaccinated livestock against CBPP during the reference periods, while 29 percent they did so for RVF. Figure 2 presents the distribution of vaccine use for CBPP and RVF during the reference periods. Respondents provided a full ranking of the perceived seriousness of livestock diseases during the second and third survey rounds. An index of disease seriousness shows that East Coast fever (tick borne disease) and RVF (mosquito borne disease) were perceived to be the most serious in rounds two and three. The index scores in round two were: East Coast Fever 2.45, RVF 1.51, CBPP 1.02 and Foot and Mouth Disease 0.41. In round three the scores were: RVF 2.08, East Coast Fever 1.26, Foot and Mouth Disease 0.96 and CBPP 0.59. 'Tick treatment', as presented in Table 2, refers to the dipping or spraying of cattle in acaricide to kill ticks. Ticks are the predominant carrier of East Coast fever. Approximately 80 percent of respondents indicated that they used acaricide treatment on their livestock. The increased importance of RVF in round three aligns with increased rainfall following the drought, while the decreased perceived risk of CBPP corresponds with the likely weakening of the transmission pathway as cattle interact less as more watering sources were available and animals were stronger.

[Figure 1]

More than a third of respondents reported that they would have to borrow money, predominantly from family, in the immediate future. In addition, 17 percent reported having a fever at the time of completing the survey. Figure 1 demonstrates that approximately 80 percent of respondents had household income (per person) below the Kenyan National rural poverty line. The level is slightly higher than the 75 percent measured at the start of the drought (Government of Kenya, 2018a).

[Figure 2]

The association between fluid intelligence and WMC is a frequently studied topic in psychology. At the task level the correlation between individual measures of these WMC and fluid intelligence often ranges between 0.15 and 0.40 among populations in high-income countries (Conway et al., 2002; Unsworth and Engle, 2005). The corresponding association in low-income countries, particularly among illiterate samples, is less studied. The proportion of correctly answered RPM tasks (0.2) corresponds closely with the results from other Kenyan studies (Daley et al., 2003). Correlation measures of cognition for this study provide insight into the relative stability of cognition measures among a population with a high level of illiteracy. Approximately two-thirds of the current sample reported not having attended school. The correlation between RPM and Counting Span task among the Samburu sample was 0.15. Figure 3 presents the correlation over income increments for the same sample. At very low levels of household income, that is, below KES 300 (USD 3.00) per month, the correlation is very low. At income levels above KES 2000 per month (USD 20.00), the correlation stabilizes at above 0.2. The correlations between RPM and Counting Span, RPM and ANA heuristic, and Counting Span and ANA heuristic show that ultra-poor households have contrasting measures. Table 3 presents these correlations by sub-samples of individuals with incomes i) below KES 300 and ii) above KES 299.

[Figure 3]

[Table 3]

Measuring changes in cognitive capacity requires analysis focused on intertemporal changes in cognition measures. The relationship between cognitive capacity and changes in that capacity are predicted to be strongly correlated. While level analysis is used in some macro-oriented considerations of development, the dynamic aspect of economic decision-making is better captured when using differences in cognitive capacity and heuristic use (Hanushek and Woessmann, 2008; Mullainathan and Shafir, 2013). Figure 4 plots changes in ANA (heuristic) and RPM across household income by round. The greatest changes in cognition appear at the lowest levels of income, while near zero changes are observed at the highest levels of income. The corresponding cone shape distribution is consistent across rounds and for each measure of cognition.

[Figure 4]

Results

Estimating the probability of using CBPP and RVF vaccines provide insights into the variables that best predict vaccine use. Table 4 presents the marginal estimates for the binary probit model for each livestock vaccine. The corresponding coefficient estimates are presented in Table A1. The use of tick treatment has a strong and statistically significant positive association with CBPP vaccine use at the one percent level. The same variable in the corresponding RVF model is not significant. The timing of vaccine use appears to differ between the two vaccines. CBPP vaccine use is negatively associated with round 1 observations, while round 1 timing is positively associated with RVF vaccine use. This variable is statistically significant at the five percent level in both vaccine estimates. The use of the heuristic ANA is also significant at the five percent level in both estimates, with a positive association with CBPP vaccine use and negatively associated with RVF vaccine use. The number of calves owned by respondents is a positive predictor of CBPP and RVF vaccine use, at the five percent level. The level estimate of the effect of cognitive capacity, as measured by RPM, is not statistically significant at the 20 percent level. Similarly, the level estimates of the stressors - rainfall and vegetation coverage - are also not statistically significant at the five percent level.

[Table 4]

Using panel specifications, Table 5 summarises marginal effects estimates for a random parameter probit model for each livestock vaccine. The constant and ANA coefficients are estimated using 100 Halton draws from a normal distribution. These estimates are summarised in Table A2. The marginal effects are very similar to those from Table 4 and the marginal effects from the fixed parameter probit estimator. ANA heuristic and round 1 continue to have opposing marginal effect signs at the one percent level. The use of the random draws for the ANA heuristic parameter has increased (absolute case) the negative marginal effects from -0.026 to -0.033, with respect to RVF vaccine use. The marginal effects in the CBPP vaccine case are unchanged at 0.01. The marginal effect of using tick treatment also remains strongly associated with CBPP vaccine use and is statistically significant at the one percent level. By using the random parameter estimator, the marginal effect of using tick treatment is 0.407, compared with 0.543 from the fixed parameter probit estimator. The statistically significance of the fluid intelligence, using RPM scores, is lowered too at 0.07, compared with 0.262 in Table 4.

[Table 5]

A first-difference estimator is used to estimate the association between changes in cognition (capacity and heuristic use), livestock health utilisation, stressors and perceived need/capacity to borrow on expenditure decisions. In addition, the increased use of ANA heuristic is leads to decreased expenditure across all models. These negative parameter estimates are statistically significant at the five percent level in all cases, except for education expenditure. The signs of Count and RPM coefficients alternate across models, as shown in Table 6. The cases of the CBPP and RVF models present coefficients that have opposing signs for these cognition measures. This is not the case in the livestock and education models. The loss of livestock as a percentage of current herd size is consistently negative across each of the livestock-related models. These coefficients for CBPP and RVF are statistically significant at the one percent level. The measure of actual experienced financial well-being, relative to prior expectations, is a positive driver of expenditure. In the RVF and livestock models, the corresponding coefficients are significant at the five and ten percent levels.

[Table 6]

Parameter estimates for according to income level are presented in Table 7 for the same expenditure models. The ANA coefficients for each sub-sample are negative and consistently statistically significant at the ten percent level. The parameter estimates for RPM in the livestock model for each income sub-sample have opposing signs, with each estimate significant at the five percent level. Among households with mean monthly income (per person) of greater than KES 299 (Table 7 - panel A), the RPM coefficient is 15.9 and statistically significant at the five percent level. In contrast, the coefficient for households with mean monthly income (per person) below KES 300 (Table 7 - panel B) is -123.9, significant at the five percent level. The contribution of CBPP and RVF vaccine expenditure to total livestock expenditure among the ultra-poor (less than KES 300 per month) are -5.6 (CBPP) and 4.2 (RVF), each being significant at the one percent level. In contrast, the corresponding parameter estimate for CBPP vaccine expenditure among households with income (per person) above 299 is 1.0 and significant at the ten percent level.

[Table 7]

The role of perceptions of financial well-being, as a mediating mechanism between stress and cognition, is consistent across each sub-sample. Perceiving a household's financial status as being worse than expected consistently induces positive expenditure. In panel B of Table 7, the coefficients in the CBPP and RVF models are both positive at 33.5 and 31.7, respectively, each statistically significant at the one percent level. Among higher income households (panel A), the coefficients for the backward-looking perception of financial well-being relative to expectations and the forward-looking perception of the need to borrow in the livestock expenditure model have contrasting signs. The 'worse_expected' parameter estimate is 234.5, while the 'borrow' parameter is -180.6, each statistically significantly at the one percent level.

The signs of coefficients for respondents' WMC, as a proxy for the availability of recalling expenditure details, alternate across expenditure categories. In panel B of Table 7 (ultra-poor respondents), the Count parameter estimates for livestock and education expenditures are negative and positive. The mean effect of WMC on livestock expenditure is estimated as -78.9 and statistically significant at the ten percent level. In contrast, the 'Count' coefficient for education expenditure is 59.4 and significant at the five percent level. While not statistically significant at the ten percent level, the signs for the Count coefficients are the same across panels A and B (Table 7).

Decreases in cognitive capacity, as measured by increased use of the ANA heuristic, consistently reveal declines in livestock expenditure. Figure 5 depicts the predicted marginal effects of changes in ANA heuristic use on livestock expenditure. The binary variables of perceived need/capacity to borrow money and use tick treatment frame the results. In both borrowing cases and when tick treatment was used, declines in cognitive capacity (as measured by increased use of ANA heuristic) lead to lower levels of livestock expenditure. The opposite relationship is true under either tick treatment scenarios and when expected borrowing is nill.

[Figure 5]

Figure 6 presents the predicted marginal effects of changes in ANA heuristic use on educational expenditure. The positive parameter estimated relationship demonstrates that increases in ANA heuristic use contribute to decreased education expenditure. These changes are statistically significant when household borrowing is not expected. Corresponding increases in expenditure are not evident under conditions of increase cognitive capacity, irrespective of borrowing status. The WMC coefficients are positive but statistically insignificant.

[Figure 6]

Discussion

The contrasting results achieved when analyzing the level of cognitive capacity, as opposed to changes in cognitive capacity, indicates that the distinction is important. The parameter estimates for ANA heuristic were positive for predictions of CBPP vaccine use, while the analysis of the change in ANA heuristic reveals a negative effect. Analysis based on changes in cognition reveal the casual effects on expenditure decisions for CBPP vaccines, livestock generally, and education. In addition, short-term movements around a base level of cognitive capacity and heuristic use is a more appropriate measure in the context of understanding the effects of cognition on economic decision-making. Short-run movements around such trends are better identified by the use of panel data, analyzing changes in relevant variables. However, long-run trends in economic decision-making are hypothesised to be affected by long-run levels of cognitive capacity. Furthermore, the generalisability of results based on level analysis is also more limited than those derived from change analysis. The magnitudes of the changes in cognition are believed to be less context-dependent and more closely related to the magnitude of relevant financial stress.

Integrating risk preferences into a dual-processing framework provides a more generalisable understanding of cognition in economic decision-making. Based on the assumption that movements away from reflective thought (System 2 thinking) represent a proxy for increased risk tolerance, the presented results indicate that decreased use of reflective thought generates decreased expenditure across several income generating channels. The predicted marginal effects of changes in ANA heuristic use on livestock expenditure and education expenditure show a negative relationship. Additionally, the effect of positive and negative changes in the use of the ANA heuristic leads to corresponding negative and positive changes in livestock expenditure. Changes by plus and minus six counts of ANA heuristic use, summed across six tasks, provides a threshold for effects on livestock expenditure. Interpretation of the magnitude of this required change in heuristic use is difficult. The use of ANA heuristic is a function of the perceived difficulty of the set of DCE choice task experienced by respondents. A common response when faced with cognitive demanding tasks is to simplify the choice by ignoring features or attributes of the given choice. The attributes selected defining the choice task included two readily accessible attributes - price and travel distance - and two less accessible attributes - disease transmission risk and the probability of vaccine side-effects. Analysis of the DCE data for round 1 of the survey indicates that respondents likely found evaluating the probability of vaccine side-effects difficult (Iles et al., 2019b). This result is consistent with results concerning cognitive biases related to probabilities (Tversky and Kahneman, 1974). Changes to the perceived difficulty of the trade-off of a decision, a function of intertemporal cognitive capacity, are expected to elicit different levels of ANA heuristic use. With respect to education expenditure, declines in cognitive capacity (i.e. increases in ANA heuristic use) lead to decreased household education expenditure.

The near symmetric relationship between negative and positive changes in ANA heuristic use on livestock expenditure reflects the balanced effects of changes in cognitive capacity on information processing and economic decision-making. This symmetry, evident under conditions of zero perceived need to borrow and when tick treatment was used, is associated with poorer respondents. The magnitude of decreased cognitive capacity effects on livestock expenditure is largest under the condition that respondents perceived the need to borrow or could access credit. A positive change of 6 - 10 ANA heuristic counts was estimated to lead to a decrease in livestock expenditure by at least KES 100. The minimum expected decrease, under the condition of zero access to credit, is approximately KES 20. Having access to credit allows for greater decreases in expenditure due to the increased use of heuristics.

Movements towards increasing reflective thought (System 2 thinking) are also linked to increased fluid intelligence. Reflective thought is then driven by decreased use of heuristics and increased reasoning (e.g. fluid intelligence). Stanovich (2011) extends the binary conception of dual processing by including an intermediary thought mechanism that mediates movements between Systems 1 and 2 - the 'Algorithmic Mind'. Among higher-income households, the modelling of livestock expenditure coefficient shows opposing signs (Table 7 - panel A). However, negative parameter estimates for RPM, coupled with negative ANA estimates, are evident for ultra-poor livestock expenditure (Table 7 - panel B) and CBPP vaccine expenditures (Tables 6 and 7). The negative RPM coefficients reflect mean consumption smoothing decisions. This holds for livestock expenditure among the ultra-poor and general expenditure on CBPP livestock vaccines among both income sub-samples.

The consistency of the Count coefficient signs between ultra-poor and higher-income households is a notable feature of the Table 6 and 7. This consistency contrasts with the thesis that the poor systematically underreport past events/expenditures because of poor memories (Das et al., 2012). This consistency contrasts with the changing RPM coefficient signs in the same estimates. The quantile analysis presented in Tables A3-5 provides further evidence of the expected different cognitive domains captured by fluid intelligence and WMC. As a measure of cognitive capacity to recall information, the opposing coefficient signs between livestock and education expenditure, as well as RVF and CBPP vaccine expenditures, reflect the contrasting availability of the associated expenditure events. The contrasting Count estimates likely reflect the regularity of events and respondents' ability to accurately recall such information. The annual CBPP booster vaccinations and monthly or quarterly education expenditures are regular events. As a result, there is a tendency for reductions in WMC to lead to underreporting. In contrast, the irregular events of once-for-life RVF vaccinations and livestock expenditure at the end of a severe drought, tend to be overestimated during recall.

The relative concern for the tick-borne disease East Coast fever (as captured in the ranking of disease seriousness index) is reflected in the large, positive first-difference coefficient with respect to livestock expenditure, particularly among the ultra-poor. The corresponding negative CBPP coefficient among the ultra-poor suggests that these households also reduced their use of CBPP, relative to total livestock expenditure. Although investment in tick treatment and maintaining herd immunity to CBPP may be considered optimal at all times, ultra-poor households are likely to face important trade-offs between protection against selected diseases at selected times.

The mediating effects of livestock loss, perceived access to credit and perceived financial well-being relative to expectations are important in explaining changes in household expenditure. The loss of livestock due to drought and disease is shown to have a negative effect on livestock-related expenditure. This holds for both income sub-samples. The effect of the perception that household finances are worse than expected is strongly positive across both income groups. Additional expenditure is required in these households to make-up the difference in expected consumption. The perceived need to borrow in order to meet basic household consumption demands is strongly negative among higher-income households when considering livestock expenditure.

Conclusion

The estimated positive and negative changes in ANA heuristic use on changes in livestock and educational expenditure provide further empirical evidence of the effect of changes in cognition on economic decision-making. Contrasting, but consistent, differences in the effects of fluid intelligence and WMC on recalling expenditure decisions provide evidence of the effects of information processing on economic decision-making and its recall. There exists a need to further reconcile notions of risk preferences and consumption smoothing with dual-processing theories. The generalisability of these results to other global poor populations, in differing economic environments is unclear. However, inventions aimed at reducing perceptions of financial stress among the global poor are believed to have likely positive effects on economic decision-making. Related results indicate that future research in this direction will likely yield constructive results.

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Tables

Table 1: Response pattern.

n	%	R1	R2	R3
94	24	1	.	.
74	19	.	1	.
51	13	1	1	.
77	19	.	1	1
28	7	1	.	1
77	19	1	1	1
400	**101**	-	-	-

Table 2: Summary statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
Cognition					
RPM	709	5.67	2.74	0	13
RPM_Diff	308	-0.05	3.35	-10	11
Count	710	7.05	6.90	0	55
Count_Diff	308	-0.37	8.62	-34	34
ANA	708	6.65	3.74	0	18
ANA_Diff	307	0.41	5.42	-13	16
Stressors					
Rainfall_previous 3-months	708	-39.52	25.07	-82	-21.5
% of livestock deaths relative to current livestock holdings	708	70.84	78.16	-900	100
NDVI coverage	708	134.75	13.98	114	164
Livestock Ownership					
FAO units	713	4.81	5.86	0	56.3
Cattle_number	713	3.29	4.85	0	58
Heifer_number	713	0.73	1.85	0	18
Calves_number	713	1.87	2.51	0	28
Disease and Treatment					
CBPP_vaccination	706	0.68	0.47	0	1
RVF_vaccination	713	0.29	0.45	0	1
Tick_treatment	704	0.81	0.40	0	1
Respondent Characteristics					
Illiterate	708	0.67	0.47	0	1
Less than 50% of Poverty Line	708	0.35	0.48	0	1
Borrow	703	0.36	0.48	0	1
Worse_expected	704	0.90	0.29	0	1
Household Expenditure					
CBPP_vaccination	713	39.95	97.17	0	720
RVF_vaccination	713	9.12	22.10	0	108
Livestock	707	664.0	1613.4	0	37500
Education	708	2201.0	2973.5	0	18750

Table 3:

	Level		Difference	
Correlation	<300 (KES)	>299 (KES)	<300 (KES)	>299 (KES)
RPM:Count	0.021	0.181	-0.009	0.066
RPM:ana	-0.011	-0.103	-0.357	-0.067
Count:ana	0.039	-0.035	0.050	-0.004
N	135	570	52	255

Table 4: CBPP & RVF marginal effects - probit

	CBPP_vaccination				RVF_vaccination			
	Partial Effect		Standard Error	p-value	Partial Effect		Standard Error	p-value
Fluid Intelligence	0.007		0.01	0.262	0.001		0.01	0.853
Heuristic	0.010	**	0.00	0.034	-0.026	***	0.00	0.000
Rainfall_3months	0.001		0.00	0.432	0.002	*	0.00	0.067
NDVI	<-0.001		<0.01	0.986	-0.002		0.00	0.454
Tick_treatment	0.543	***	0.04	0.000	-0.002		0.04	0.966
RVF_vac / CBPP_vac	-0.017		0.04	0.650	-0.014		0.04	0.729
Calves_number	0.012	**	0.01	0.049	0.014	**	0.01	0.031
Round 1	-0.102	**	0.04	0.017	0.161	***	0.05	0.000

Table 5: CBPP & RVF marginal effects - probit random parameter

	CBPP_vaccination				RVF_vaccination			
	Partial Effect		Elasticity	p-value	Partial Effect		Elasticity	p-value
Fluid Intelligence	0.006	*	0.038	0.07	0.001		0.015	0.92
Heuristics	0.010	***	0.067	0.00	-0.033	***	-0.870	0.00
Rainfall_3months	0.001		-0.037	0.14	0.003	*	-0.414	0.05
NDVI	0.000		0.023	0.86	-0.002		-1.062	0.40
Tick_treatment	0.407	***	0.338	0.01	-0.004		-0.014	0.94
RVF_vac / CBPP_vac	-0.012		-0.004	0.52	-0.007		-0.020	0.87
Calves_number	0.011	**	0.021	0.05	0.016	***	0.121	0.00
Round 1	-0.092	***	-0.034	0.01	0.170	***	0.244	0.00

Table 6: First-Difference estimates of expenditure - vaccines, livestock and education.

	CBPP		RVF		Livestock		Education	
Count	1.09		-0.19		-14.77	*	13.26	
	(0.73)		(0.34)		(7.90)		(10.61)	
RPM	-4.22	**	0.78		-10.92		32.69	
	(1.68)		(2.18)		(12.81)		(75.55)	
ANA	-2.46	**	-2.31	**	-30.88	***	-45.82	
	(1.22)		(1.01)		(9.98)		(28.29)	
Tick_treatment	19.47		6.00		160.16		-290.22	
	(23.47)		(10.81)		(98.10)		(246.84)	
CBPP_vacc	-		-		0.09		-	
					(0.63)			
RVF_vacc	-		-		0.41		-	
					(0.95)			
Livestock-expen	-		-		-		0.41	***
							(0.08)	
Rain	-0.21		-0.57		0.19		9.76	
	(0.69)		(0.43)		(4.22)		(7.34)	
Stress	-0.31	***	-0.23	***	-0.59		0.16	
	(0.08)		(0.03)		(0.53)		(1.00)	
Borrow	21.97		1.44		-217.68	**	-83.17	
	(14.53)		(6.64)		(91.69)		(452.64)	
Worse_expected	25.16		12.38	**	103.99	*	735.86	
	(15.52)		(6.19)		(62.65)		(615.22)	
Constant	-25.29		-37.33	**	-72.69		194.80	
	(29.04)		(17.53)		(164.26)		(347.22)	
R2	0.14		0.11		0.06		0.08	
n	271		271		270		270	

Table 7: First-Difference estimates of expenditure - vaccines, livestock and education, by income.

Income>299 (A)	CBPP		RVF		Livestock		Education	
Count	1.09		-0.02		-3.83		10.91	
	(0.87)		(0.46)		(5.65)		(13.17)	
RPM	-4.99	**	0.50		15.86	**	14.59	
	(2.36)		(2.94)		(7.48)		(86.93)	
ANA	-1.69	*	-2.04	***	-22.77	***	-48.09	
	(0.96)		(0.73)		(8.35)		(32.66)	
Tick_treatment	12.52		5.66		113.02		-	
	(28.19)		(11.31)		(118.22)			
CBPP_vacc	-		-		0.85	*	-	
					(0.51)			
RVF_vacc	-		-		-0.25		-	
					(0.97)			
Livestock-expen	-		-		-		0.40	***
							(0.09)	
Rain	0.03		-0.37		0.27		3.79	
	(0.66)		(0.36)		(5.13)		(9.46)	
Stress	-0.33	***	-0.24	***	-0.07		-1.63	
	(0.08)		(0.04)		(0.64)		(1.17)	
Borrow	23.95		3.62		-180.63	***	-4.03	
	(17.29)		(6.49)		(42.90)		(529.81)	
Worse_expected	21.38		8.26		234.45	***	920.83	
	(21.79)		(5.46)		(75.40)		(643.45)	
Constant	-14.16		-28.20	**	-62.98		-20.63	
	(27.60)		(13.08)		(206.31)		(424.55)	
R2	0.14		0.11		0.06		0.05	
n	222		222		270		224	

Income<300 (B)	CBPP		RVF		Livestock		Education	
Count	1.91		-1.04		-78.92	*	59.43	**
	(1.35)		(0.72)		(46.63)		(29.71)	
RPM	-3.37		0.72		-123.93	**	-22.36	
	(2.28)		(0.95)		(58.94)		(69.49)	
ANA	-3.91	***	-1.57		-66.49	***	-75.34	*
	(1.28)		(1.43)		(11.33)		(40.63)	
Tick_treatment	52.16	**	2.80		672.13	***	-	
	(25.56)		(17.70)		(208.54)			
CBPP_vacc	-		-		-5.55	***	-	
					(0.92)			
RVF_vacc	-		-		4.16	***	-	
					(1.48)			
Livestock-expen	-		-		-		0.45	**
							(0.18)	
Rain	-1.13		-1.45	**	2.21		28.29	***
	(0.98)		(0.64)		(7.31)		(5.97)	
Stress	-0.16	**	-0.12		-2.14	**	5.45	**
	(0.07)		(0.08)		(1.06)		(2.71)	
Borrow	9.34		-14.17		-463.92		-66.52	
	(19.35)		(13.42)		(447.30)		(581.08)	
Worse_expected	33.50	***	31.69	***	-785.82		8.21	
	(9.69)		(11.40)		(709.91)		(1113.48)	
Constant	-68.37		-76.48		-149.03		734.29	***
	(43.48)		(32.41)		(315.84)		(144.31)	
R2	0.20		0.22		0.38		0.24	
n	49		49		49		50	

Figures

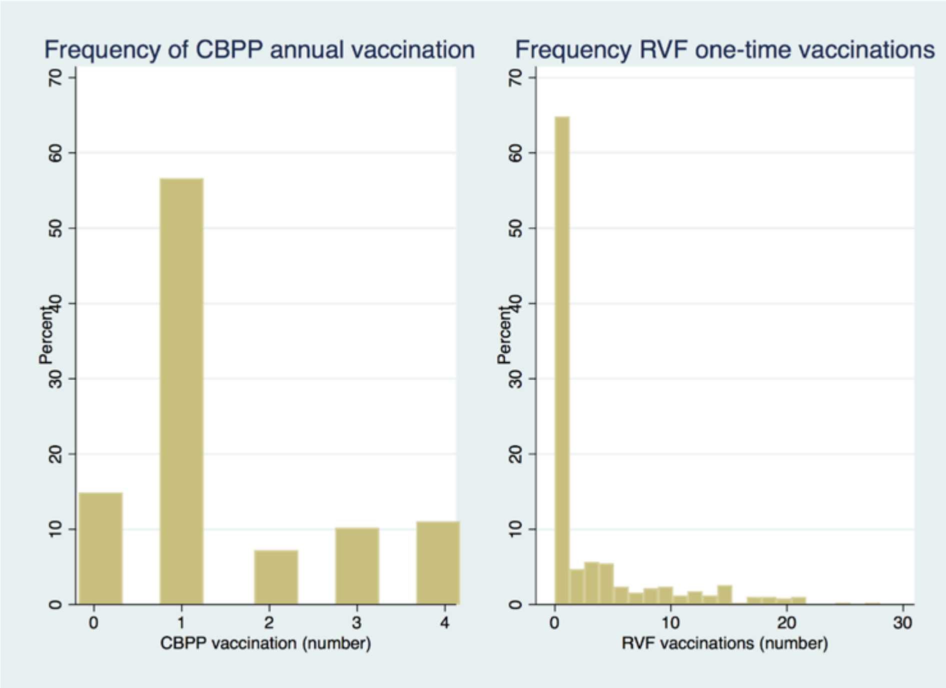

Figure 1: Number of livestock vaccinations (CBPP & RVF) per herd.

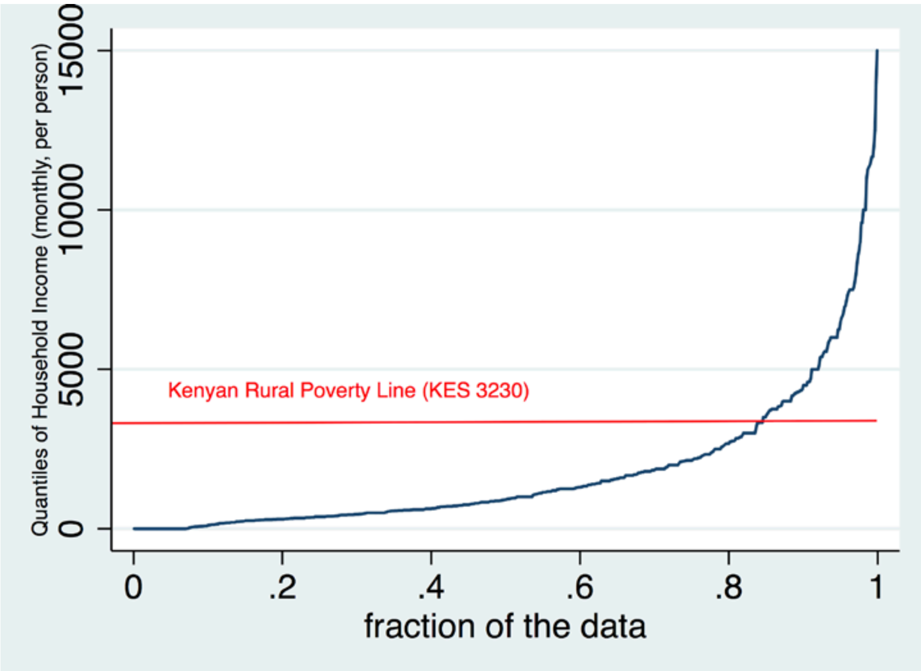

Figure 2: Distribution of Household Income (two major sources).

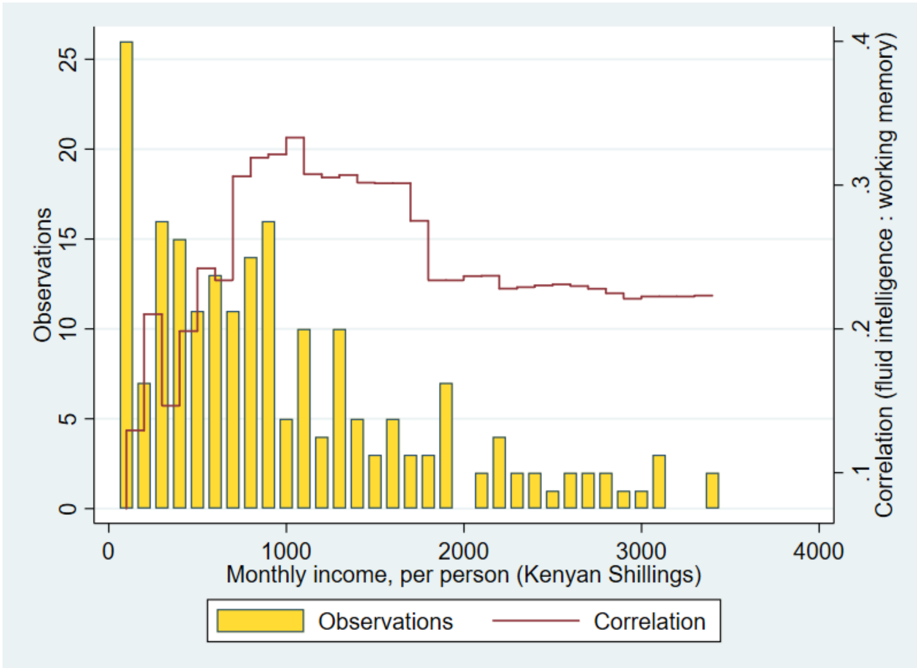

Figure 3: Correlation of cognition measures across income, Round 1.

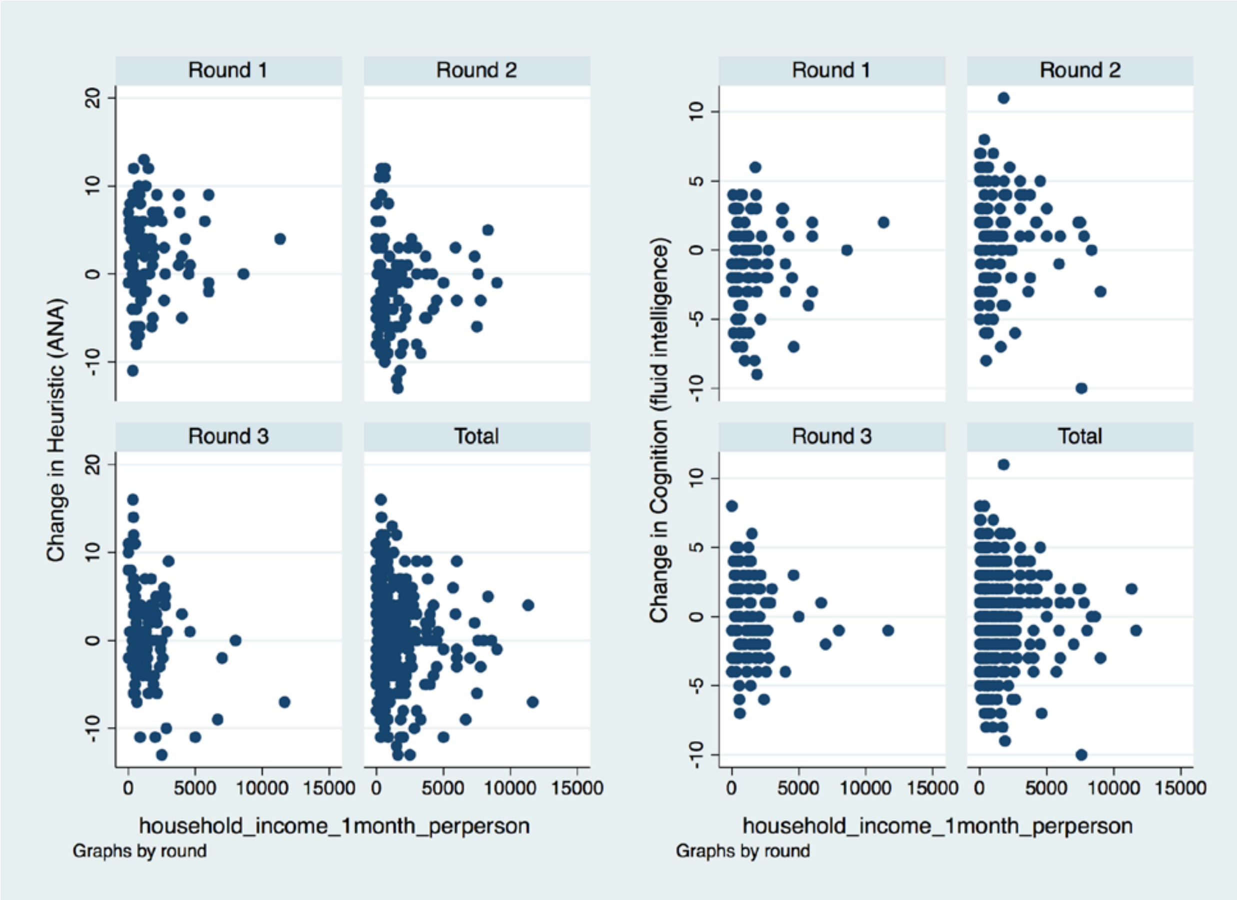

Figure 4: Scatter plot of changes in heuristic use (ANA) and cognition (fluid intelligence) across household income.

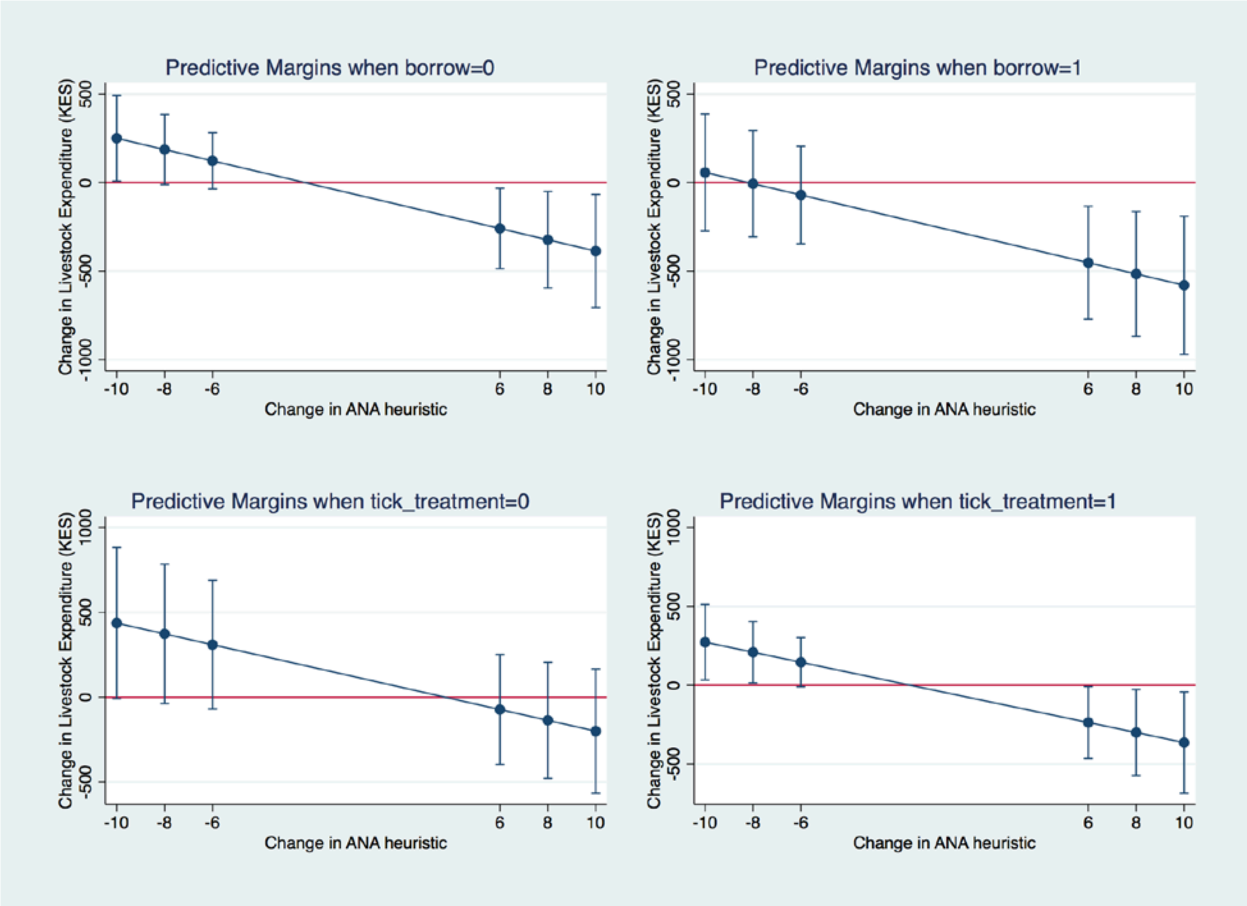

Figure 5: Predicted marginal effects - changes in ANA heuristic on livestock expenditure.

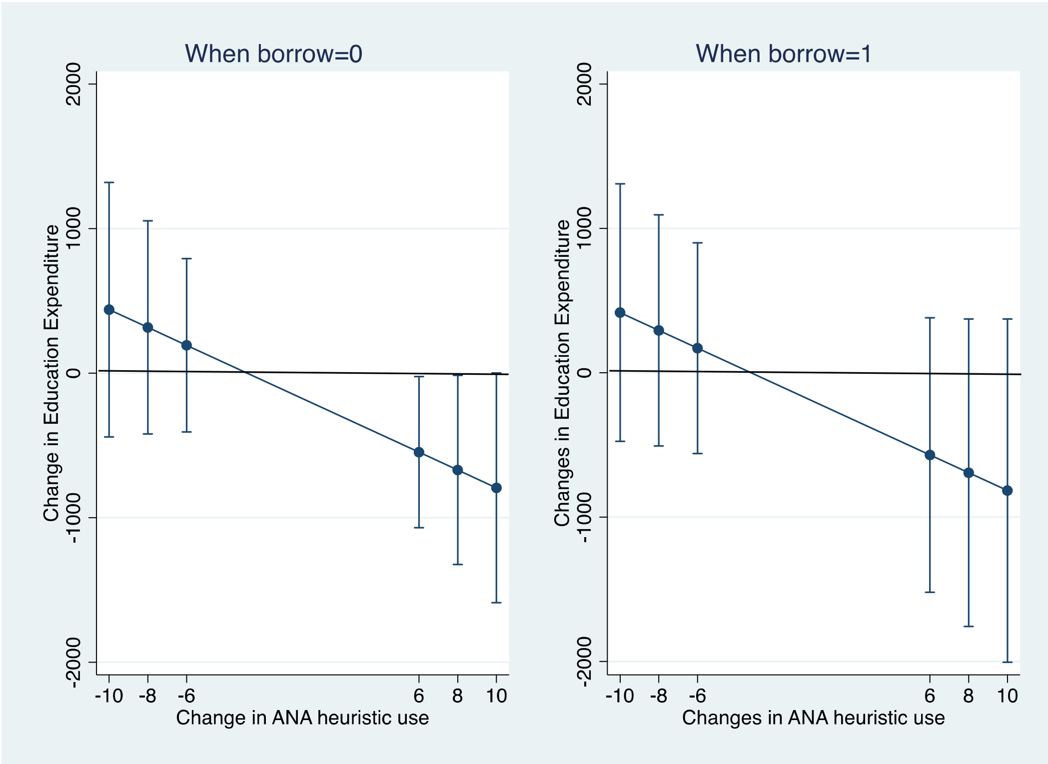

Figure 6: Predicted marginal effects of changes ANA heuristic use on education expenditure.

Supplementary

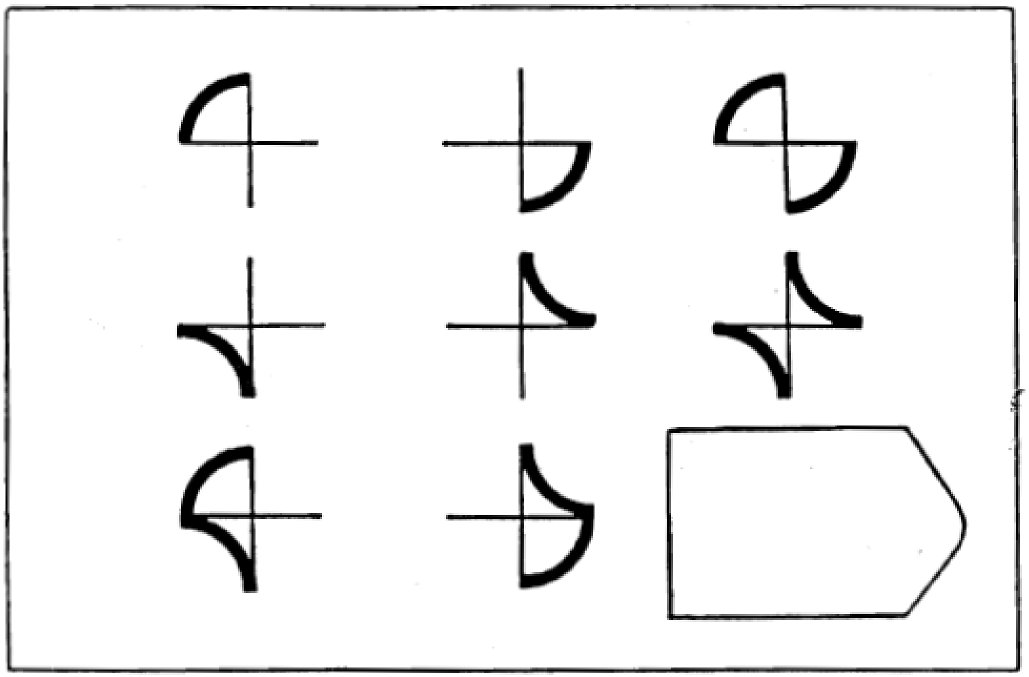

Figure A1: Raven's Progressive Matrix.

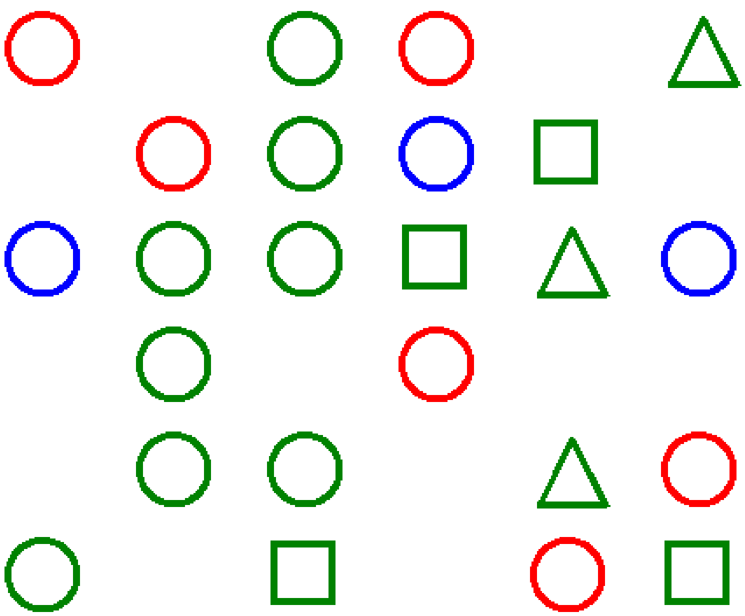

Figure A2: Counting Span Task.

	Option A	Option B	Neither
Price			
Travel Distance			
CBPP-risk information	 (1/4'ly)	Current status	
Side-effect likelihood	 Risk ↓ Risk	 Risk ↓ Risk	

Figure A3: Discrete Choice Experiment Task display.

Table A1: CBPP & RVF probit estimates.

	CBPP_vaccination				RVF_vaccination			
	Coefficient		Clustered Std.Error	p-value	Coefficient		Clustered Std.Error	p-value
Constant	-0.877		0.88	0.317	0.805		0.96	0.401
Fluid Intelligence	0.023		0.02	0.264	0.004		0.02	0.853
Heuristic	0.033	**	0.02	0.034	-0.086	***	0.02	0.000
Rainfall_3months	0.003		0.00	0.433	0.008	*	0.00	0.069
NDVI	0.000		0.01	0.986	-0.006		0.01	0.454
Tick_treatment	1.520	***	0.14	0.000	-0.006		0.15	0.966
RVF_vac / CBPP_vac	-0.057		0.13	0.648	-0.045		0.13	0.728
Calves_number	0.041	**	0.02	0.049	0.045	**	0.02	0.034
Round 1	-0.343	**	0.14	0.015	0.500	***	0.14	0.000
Psedu R2	0.19				0.12			

Table A2: CBPP & RVF probit estimates - random parameter

	CBPP_vaccination				RVF_vaccination			
	Coefficient		Standard Error	p-value	Coefficient		Standard Error	p-value
Fixed_parameters								
Constant			-		0.901		0.91	0.32
Fluid Intelligence	0.089	**	0.04	0.02	0.002		0.02	0.92
Rainfall_3months	0.013	*	0.01	0.09	0.008	**	0.00	0.05
NDVI	0.002		0.01	0.86	-0.006		0.01	0.40
Tick_treatment	5.623	***	0.55	<0.01	-0.013		0.18	0.94
RVF_vac / CBPP_vac	-0.164		0.24	0.49	-0.023		0.14	0.87
Calves_number	0.146	***	0.05	0.01	0.050	***	0.02	0.00
Round 1	-1.279	***	0.30	<0.01	0.536	***	0.15	0.00
Random_parameters								
Constant	-3.662	**	1.66	0.03			-	
Heuristic	0.136	***	0.03	<0.01	-0.103	***	0.02	<0.01
Scale								
Constant	3.376	***	0.32	<0.01			-	
Heuristic	0.069	***	0.02	<0.01	0.051	***	0.01	<0.01

The use of semiparametric quantile regression provides information concerning the association between stress variables and respondent characteristics across selected quantiles of the sample. The standard assumptions of parametric distribution of error terms are relaxed, thereby making quantile regression highly suitable for heteroskedastic data. Tables A3 - A5 present coefficients using the quantiles 0.2, 0.4, 0.6 and 0.8 for each of the absolute cognition measures as the dependent variable. Independent variables include livestock loss, NDVI coverage, literacy and the presence of persistent fever. Table 4 shows that the stressors of livestock loss and NDVI coverage are consistently associated with RPM. The sign of each variable is as predicted: greater livestock loss is associated with reduced cognitive capacity, and increased vegetation coverage is associated with improved capacity. The binary variables of illiteracy and persistent fever consistently have negative coefficients. Again, the negative association is as expected. The same association with the Counting Span Task is not evident. Livestock loss is not associated with Counting Span scores for any quantile. The NDVI measure of vegetation coverage is negatively associated and statistically significant across all quantiles. The coefficients for illiteracy are negative and highly significant. The goodness of fit measures for the RPM estimation is higher for each quantile, compared to the Counting Span score.

Table A3: Quantile regression of RPM (fluid intelligence)

	Livestock Loss		NDVI		Illiterate		Persistent Fever	
Quantile	**Coeff.**	**p-value**	**Coeff.**	**p-value**	**Coeff.**	**p-value**	**Coeff.**	**p-value**
0.2	-0.006	0.012	0.018	0.076	-0.818	<0.001	-0.586	0.085
0.4	-0.007	0.007	0.023	0.020	-1.001	0.019	-0.719	0.078
0.6	-0.008	<0.001	0.024	0.014	-1.751	<0.001	-0.251	0.528
0.8	-0.007	0.001	0.026	0.089	-1.883	<0.001	-0.047	0.938

R^2: Q_{20}= 0.0344, Q_{40}=0.0462, Q_{60}=0.0579, Q_{80}=0.0601.

Table A4: Quantile regression of Counting Span (WMC)

	Livestock Loss		NDVI		Illiterate		Persistent Fever	
Quantile	**Coeff.**	**p-value**	**Coeff.**	**p-value**	**Coeff.**	**p-value**	**Coeff.**	**p-value**
0.2	-0.003	0.232	-0.031	0.020	-1.104	<0.001	-0.165	0.707
0.4	-0.002	0.211	-0.027	0.002	-1.036	0.001	-0.728	0.035
0.6	-0.002	0.772	-0.048	0.001	-5.041	0.001	-0.857	0.067
0.8	-0.004	0.714	-0.133	0.001	-2.284	0.017	-4.339	0.003

R^2: Q_{20}= 0.0202, Q_{40}=0.0160, Q_{60}=0.0367, Q_{80}=0.0314.

Cognitive capacity and livestock loss, as a stressor, are both associated with respondents' use of the ANA heuristic. Table A5 presents marginal effects of RPM, livestock loss and perceived access to credit on heuristic use. Cognitive capacity (RPM) and credit access (borrow) consistently have negative effects across the quantiles 0.2, 0.4, 0.6 and 0.8. As cognitive capacity increases, lower rates of heuristic use are predicted. Likewise, as a household has more access to credit, particularly informal lines of credit, then less stress is experienced and there is a lower use of choice heuristics. The effect of livestock loss on heuristic use is positive at the quantile levels of 0.6 and 0.8.

Table A5: Quantile Poisson regression marginal effects of ANA (heuristic)

	RPM		Livestock Loss		Borrow	
Quantile	**M. E**	**p-value**	**M. E**	**p-value**	**M. E**	**p-value**
0.2	-0.107	0.101	-0.002	0.280	-1.187	0.000
0.4	-0.086	0.088	0.001	0.267	-0.593	0.044
0.6	-0.126	0.032	0.003	0.015	-0.910	0.006
0.8	-0.165	0.220	0.008	0.034	-1.102	0.073