Memory Constraints in Adoption of Productive Technologies*

Haseeb Ahmed[a] Erin Giffin[b] Shanthi Manian[c]

April 21, 2025

Abstract

Limited adoption of productive technologies is often identified as a key reason for lagging agricultural productivity in developing countries. We hypothesize that memory limitations play a crucial role in explaining these sub-optimal levels of technology adoption. We test this hypothesis in the context of cattle disease prevention and management among smallholder farmers in east Africa. If farmers under-remember cattle health events, this will reduce their incentive to invest in preventive technologies. We implemented a field experiment in western Kenya to study if relieving memory constraints increases demand for a livestock disease prevention technology. We trained and incentivized study participants to keep simple written records of cattle disease events, health expenditures, and milk production outcomes for a period of three months. We then provided a paper template to help summarize the information in the record books. We find this intervention nearly doubled demand for the preventive technology, and evidence suggests that the record-keeping increased recall of disease events. This paper provides evidence that memory may serve as a barrier to technology adoption and our intervention can serve as a low-cost way of increasing take-up of productive technologies.

Keywords: Memory, technology adoption, field experiment, Kenya

JEL: C93, D91, O12, Q12

*We are grateful for financial support from Colby College and Washington State University. We thank Sam Bird, Thomas Marsh, Jonathan Yoder, and participants at LACDev 2023 for helpful comments. We thank Innovations for Poverty Action, in particular Ben Wekesa, for implementing field activities. This study had IRB approval in Kenya (KEMRI) and the United States (Colby College and Washington State University). This study was pre-registered with the AEA RCT Registry (ID: AEARCTR-0009634).

[a]Asian Infrastructure Investment Bank (AIIB) (Email: haseeb.ahmed@aiib.org)

[b]Department of Economics, Colby College, 5236 Mayflower Hill, Waterville, ME, 04901 (Email: egiffin@colby.edu)

[c]School of Economic Sciences and Paul G. Allen School for Global Health, Washington State University, 255 E Main St, Pullman, WA 99163 (Email: shanthi.manian@wsu.edu)

1 Introduction

Technology adoption plays a critical role in enhancing productivity, growth, and development (Perla et al. 2021; Juhász et al. 2024). However, individuals often fail to adopt technologies that are profitable and welfare-improving in expectation, especially in developing countries (Foster and Rosenzweig 2010). Economists have identified several factors that hinder the uptake of these technologies, including credit constraints and price barriers (Meriggi et al. 2021; Berkouwer and Dean 2022), risk and uncertainty (Foster and Rosenzweig 2010; Barham et al. 2014), incomplete markets (Jones et al. 2022), information frictions (Beaman et al. 2021), and bounded rationality (Karlan et al. 2016; Ferraro et al. 2024).

In this paper, we propose a novel limiting factor – bounded memory – that can lead to low take-up of productive technologies. When individuals are deciding if they should purchase a productive technology, they may rely on their memories of the past: their previous productivity levels, events that affected their productivity, and if they used a similar technology before. If individuals are unable to remember this history accurately, they may not be able to make an accurate cost-benefit assessment of the technology. There is evidence that individuals have overly optimistic memories of past performance (Huffman et al., 2022) and systematically forget negative events (Chew et al., 2020). In relation to our context, if individuals have overly positive memories of past productivity levels and under-remember events that adversely affected their productivity, this will reduce the perceived benefit of productive technologies and subsequently decrease their demand for them. Moreover, the issue of bounded memory may be particularly pronounced in low-income populations, as there is substantial evidence that poverty and the stress of poverty depress cognitive function and memory (Mani et al. 2013; Schofield 2014; Schilbach et al. 2016).

We study the role of memory limitations on take-up of a livestock disease prevention technology in smallholder farmers in Kenya. We focus on acaricides, which are pesticides that kill ticks and mites and are one of the key tick-control strategies used around the world. Tick-borne diseases are a major source of cattle mortality globally; they are estimated to kill over 3 million animals per year in developing countries (Djiman et al. 2024). Acaricides are effective, widely available,[1] inexpensive, and can be applied by the farmer themself. However, evidence suggests that livestock owners use acaricides less frequently than recommended by experts in this region (FAO 2004; Mutavi et al. 2021).

We implemented a field experiment with 300 farm-households involved in cattle production in Busia County, Kenya. Since we cannot randomly assign memories to participants, we instead designed an intervention to relax memory constraints: we trained and incentivized the treatment group to keep daily records of cattle management practices, animal health events and treatments, and milk production for a period of three months. We then provided a paper template allowing participants to summarize the information in the record books. We were successful in incentivizing treatment participants to keep records. Adherence to the randomization was high: while approximately 1 percent of the control group had recent records at endline, over 96 percent of the treatment group had records that had been filled out in the previous month.

We then examine if this intervention affected demand for acaricide. We offered participants an opportunity to purchase acaricide at market price from staff of the county-level veterinary agency, who accompanied enumerators at endline. This allowed participants to credibly reveal their demand. The record-keeping intervention nearly doubled demand for acaricides in our sample of cattle owners: treatment increased acaricide take-up by 16.7 percentage points, relative to a control mean of 17.2 percent take-up.

We further find evidence that record-keeping increased recall of disease events, consistent with a mechanism of record-keeping relieving memory constraints. In the endline survey, participants were asked to report the frequency of cattle illness and milk production. The treatment increased reporting of any sick cattle by 10.3 percentage points. Treatment group participants also reported more frequent symptoms of cattle illness (fever) and reduced and no milk production. This evidence is consistent with our proposed mechanism

[1] In our baseline survey 97 percent of respondents reported that they knew where to purchase acaricide.

of record-keeping increasing adoption by allowing participants to observe more cattle illness and negative impacts on production than they remembered.

The participants kept daily records for three months, generating a large number of individual entries. To relieve the memory constraint, individuals had to not only record, but also process and synthesize the information in the record books. This suggests that the record books may be more effective for individuals with better processing capabilities. We had participants complete a complex span task to generate a measure of their working memory. Consistent with this, we find a higher score on the working memory task is associated with a larger treatment effect. These results suggest that having accurate long-term memories of past events *and* being able to process, manipulate, and summarize this information effectively when faced with a decision are both key components to the role of memory in decision-making.

To further strengthen support for the memory channel, we conduct additional analysis to rule out alternative mechanisms. We provide evidence that the main treatment effect is unlikely to be driven by income effects from the incentives provided for record keeping. We also show that memory constraints are a more convincing mechanism for the results than other information effects potentially induced by record keeping, such as information transmission between household members.

Our paper builds on the literature that documents errors in self-reported agricultural data. Smallholder households are engaged in several on- and off-farm activities to make ends meet, and it becomes difficult to track and recall agricultural outcomes that change sometimes on a daily or weekly basis. Recall discrepancies have been documented in terms of self-reported labor, hunger, and agricultural productivity data (Arthi et al. 2018; De Weerdt et al. 2016; Godlonton et al. 2024). There is also evidence from health surveys that health shocks that are less severe or require little health-related expenses are underreported (Das et al. 2012). This evidence of faulty recall, especially related to smaller health events, has important implications for us given that disease in adult cattle more often results in nuanced symptoms rather than livestock death. For livestock disease specifically, van Andel et al. (2020) find that farmers' verbal reports under-report foot-and-mouth disease incidence in cattle in comparison to actual exposure calculated from blood samples – which suggests memory discrepancies. Our paper provides evidence that these memory errors have important consequences on farmers' choices, in particular demand for technologies that would protect against negative outcomes and improve productivity.

This paper contributes to the relatively new but quickly growing literature on memory and economic decision-making. This literature has demonstrated memory has substantial implications for economic decision-making (see Amelio and Zimmermann (2023) for a recent review),[2] including in developing contexts (Dean et al., 2017). However, the existing literature has not examined the role of memory in technology adoption or proposed it as a potential explanation for low uptake of technology.

We also extend a large literature on reminders, which may suggest a role for memory constraints in decision-making. However, effects of reminders may operate through several channels, and previous interventions largely focus on constraints due to present bias or limited attention. These interventions center around nudging individuals to complete tasks (e.g., contributing to a savings account or completing a medical visit) (Karlan et al. 2016; Ericson 2017). Our study instead focuses on how memory constraints may affect the information that individuals rely on to make decisions. The aim of our intervention is to relieve constraints on information recall. Our record books provide subjects with more information on their past behavior and outcomes than they can remember, improving optimal decision-making.

Our findings also have implications for other risk-reducing investments, including livestock and crop insurance. We consider acaricides a productive technology because tick-borne diseases reduce cattle productivity, in particular milk production (Surve et al. 2023). This is in contrast to other risk-reducing investments, like insurance, that do not prevent the

[2]Recent work examines the role of memory in belief formation (Graeber et al. 2024), forecasting (Afrouzi et al. 2023), financial decisions (Charles 2022; Jiang et al. 2022), market interactions (Enke et al. 2023), and choice of college major (Conlon & Patel 2023).

productivity losses themselves but reimburse the farmer for the income losses associated with cattle death. While livestock insurance has large benefits, including reducing conflict (Gehring and Schaudt 2024), uptake is low (Johnson et al. 2023). As a result, demand for livestock insurance is an active area of research, especially in east Africa. Others have studied willingness to pay for livestock insurance (e.g., Chantarat and Barrett 2009; Aina et al. 2018; Oduniyi et al. 2020) and if providing information about insurance increases uptake (Takahashi et al. 2016). Our findings suggest our intervention has the potential to increase demand for these forms of risk-reducing investments.

Our paper has important policy implications. We make an important contribution to the literature on disease preventive actions in smallholder livestock production systems. The livestock disease management literature has highlighted factors including limited supply of quality vaccines, poor transport infrastructure, income and credit constraints, and information asymmetries (Homewood et al. 2006; Campbell et al. 2018; Railey et al. 2018; Railey and Marsh 2019; Waithanji et al. 2019; Campbell et al. 2019). A few studies have identified psycho-social constructs and relied on different technology adoption models (e.g., Theory of Planned Behavior) to understand and predict farmers' decision-making regarding livestock disease management (Sok et al. 2015; Sok et al. 2021). Our results provide a new explanation for under-utilization of disease-preventive technologies, as we provide evidence that memory constraints prevent accurate recall of disease events and dampen demand for preventive technologies.

More generally, 56 percent of the population of sub-Saharan Africa keeps livestock for income and nutrition (Marsh et al. 2016). Acaricides are an important technology to prevent livestock disease. Given their effectiveness and low cost and the importance of livestock for these households, increasing utilization of acaricides would be welfare-improving. Our intervention can serve as a low-cost way of increasing take-up of acaricides. The technology adoption puzzle is well-established in the literature and is especially pronounced in developing countries. Extending beyond the specific context we study, this intervention has the potential to increase take-up of other critical productive technologies, generating benefits for the poor.

The remainder of the paper is organized as follows: Section 2 provides background on livestock disease and preventive technologies. We present a conceptual framework in Section 3. Section 4 details the experimental design. We outline our empirical strategy in Section 5 and present our results in Section 6. Section 7 concludes.

2 Background

Livestock-dependent households in sub-Saharan Africa often rely on cattle for income and nutrition (McPeak 2006; Rawlins et al. 2014; Hoddinott et al. 2015; Mosites et al. 2015). 75 percent of the population in sub-Saharan Africa is engaged in small-scale farming and 80 percent of these households keep livestock assets (Marsh et al. 2016). For the 50 million pastoralists and agro-pastoralists of sub-Saharan Africa, livestock may play an even greater role in economic and food security (Krätli et al. 2013).

While cattle play a key role as economic, nutritional, and socio-cultural assets within these households, most cattle production systems in east Africa can be characterized as low-input, low-output production systems with substantial opportunity to enhance productivity (Enahoro et al. 2019). Therefore, raising cattle productivity can play an important role in alleviating poverty in livestock-dependent households in east Africa.

Cattle productivity is constrained globally by the burden of tick-borne diseases (Thumbi et al. 2013; Kasaija et al. 2021). These diseases include heartwater, anaplasmosis, babesiosis, and East Coast Fever (ECF). ECF, resulting from the infection of *Theileria parva*, is particularly destructive in the context of western Kenya. It is identified as a main cause of cattle death, killing approximately 1 million cattle per year in east Africa, and accounts for 40% of all mortality in cattle within the first year of their birth (Gachohi et al. 2012; Thumbi et al. 2013). ECF is often not fatal in adult cattle and instead causes more nuanced productivity losses, like fatigue and reduced milk production (e.g., Surve et al. 2023), that are easy to forget once the animal has recovered.

There are two preventive animal health technologies that can be used to protect cattle against the losses that occur from tick-borne diseases. First, an ECF vaccine has been developed and a single course of this vaccine has shown promise in preventing mortality (Morrison and McKeever 2006). Second, acaricides, pesticides used to kill ticks and mites, protect against all tick-borne diseases and can be used at regular intervals to ensure a low tick burden for the animals. However, most livestock owners in Kenya apply acaricides less frequently than recommended by the FAO (FAO 2004; Mutavi et al. 2021). While the vaccine must be administered by a trained veterinary professional, acaricides can be purchased by farmers at their local agrovet store. We choose to focus on acaricide take-up, because acaricides are inexpensive, easily accessible, and can be applied by the farmer themself, so low-take up of this technology is particularly puzzling.

3 Conceptual Framework

We provide a simple conceptual framework to fix ideas. Consider a decision-maker (DM) who is deciding whether to purchase acaricide at market price m. At time 0, the DM decides to purchase acaricide ($a = 1$) or not ($a = 0$).[3] The decision-maker gets utility from their choice over the next T periods (their consumption in time t, c_t, is a function of a), which they discount using function $D(t)$.[4]

There is uncertainty about future animal health, based on different possible illness states of the world, $s_t \in S_t$. The DM forms subjective beliefs about the probabilities of these states, probability distribution π. We denote the DM's subjective probability of state s_t as $P(s_t)$, where $P(s_t) = \pi_{s_t}$.

Assuming the DM maximizes their subjective expected utility, they choose to purchase

[3] Since we are interested in take-up, we make the choice of a binary. The model could be extended to a being continuous, where it instead denotes the quantity of acaricide.

[4] Farm households may choose to consume their cattle's milk output themselves, or they may choose to sell it to increase their consumption of other goods.

acaricide if and only if :

$$\underbrace{u(c_0) - u(c_0 - m)}_{\text{Cost of purchasing today}} \leq \sum_{t=1}^{T} D(t) \underbrace{\sum_{s_t \in S_t} P(s_t)[u(c_t(a=1, s_t)) - u(c_t(a=0, s_t))]}_{\text{Future benefits of purchasing}}$$

Memory influences this decision through the DM's probability formation. When forming π, the DM relies on memories of the past. There are two stages to constructing their probability distribution: *retrieval* and *assessment*.

In the *retrieval* stage, the DM reaches into their long-term memory to recall past animal health events. Denote the set of retrieved memories as M. If the DM has perfect long-term memory, M contains the complete, accurate history of all past animal health events they have experienced. However, the DM could have bounded long-term memory, in which case M contains a strict subset of the full history (i.e., forgetting) or contains different events from what actually occurred (i.e., false memories).[5] M serves as the information set the DM brings to the second stage.

In the *assessment* stage, the DM holds these retrieved memories in working memory and aggregates the information to form their subjective probability distribution.[6] Let $A(M)$ denote the DM's assessment function, which maps the information set M to probability distribution π.

This two-stage process highlights that both components are important when using memory to form subjective probabilities: accurate long-term memories *and* the ability to make use of that information. If individuals have accurate long-term memories but face working memory constraints, they may not be able to organize, aggregate, or synthesize that infor-

[5]Others in economics have modeled errors in probabilistic assessments or subjective expectations based on retrieval errors. Bordalo et al. (2016) model stereotypes as being driven by representative types more easily coming to mind. Mullainathan (2002), Bordalo et al. (2020, 2023, 2024), and Enke et al. (2024) model beliefs based on selective recall where past information that is similar to new information is more likely to be recalled. These models are motivated by the psychological phenomena of the availability heuristic (Kahneman and Tversky 1972), associative memory and memory interference (Kahana 2012).

[6]There is evidence from psychology that working memory is critical in probability formation. For example, Yin et al. (2020) conclude that working memory is a major factor in Bayesian reasoning.

mation into an accurate probability distribution.[7] As a result, accurate long-term memory and effective working memory are complements.[8]

We use this framework to consider how memory constraints would affect a decision-maker's take-up of acaricide. Huffman et al. (2022) find that managers distort memories of feedback to maintain favorable beliefs and Chew et al. (2020) find systematic evidence of individuals creating false memories of positive events and selectively forgetting negative events. Based on this evidence, the DM may have overly positive memories of the past and be less likely to remember adverse animal health events. Relatedly, other research shows that individuals distort memories to rationalize past choices. For example, Gödker et al. (2024) find individuals manipulate memories to justify past investment decisions. Along these lines, if the DM chose not to purchase acaricide in the past, they may be less likely to remember negative health events. In the language of our conceptual framework, memory biased in this way means the DM's set of retrieved memories M, through selective forgetting or memory manipulation, will contain more positive events and fewer negative events than the DM actually experienced.

Consider the scenario where the DM has positively biased memory, denoted M_b, compared to if they had perfect memory, denoted M_p. Using information set M_b will result in the DM's subjective probability distribution π having more probability mass on "good" states and lower probability mass on "bad" states than if they used M_p. Assume the benefit of adoption, $u(c_t(a=1,s_t)) - u(c_t(a=0,s_t)$, is increasing in higher illness states ("worse" s_t's). Then, $\sum_{s_t \in S_t} P(s_t)[u(c_t(a=1,s_t)) - u(c_t(a=0,s_t))$ will be higher under M_p than under M_b. This means that having overly-positive memories depresses the DM's perceived future benefit of purchasing acaricide and decreases their take-up as a result.

[7]Studies in psychology find that larger working memory capacity is associated with more accurate probability judgments and that working memory constraints are often a limiting factor in performing probabilistic reasoning (Brainard 1981; Yin et al. 2020).

[8]The complementary nature of recall/retrieval and working memory in probability judgments is documented in the psychology literature (Dougherty and Hunter 2003).

4 Experimental Design

We enrolled 300 livestock-owning households in several villages in the Nambale and Teso South sub-counties of western Kenya.[9] We selected these areas because it was common for households in these villages to have cattle. Field officers enrolled a convenience sample by walking door-to-door until the required number of households had been enrolled.

To qualify for participation in the study, households had to meet the following criteria: owned at least one milking cow or expected to have a calf born within the next three months; the primary cattle decision-maker was 18 years of age or older; the primary cattle decision-maker was sufficiently literate to keep simple written records in English; at least one household member had a mobile phone.[10]

We describe the study timeline, intervention, and measurement methodologies in detail in the sections below. This study was pre-registered with the AEA-RCT registry (AEARCTR-0009634).

4.1 Experimental Timeline

The study consists of two in-person surveys (baseline and endline), as well as an intervention period of three months. Study enumerators recruited and enrolled households and administered the baseline survey in a single visit. After completion of the baseline survey, households were randomized to treatment or control. If the household was assigned to the treatment group, they also received record-book training during this same visit. After an intervention period lasting three months, study officers returned to the household to administer an

[9]In Namable, we targeted Lwanyange, Malanga, Siekunya, and Khwilare villages. In Teso South, we targeted Amairo, Parater, Kaliwa, Obulibuli, and Machakusi villages.

[10]We also conducted a separate experiment with chicken caretakers, and we recruited at the household level. The following additional eligibility criteria were used for that experiment: owned at least one chicken; the primary person responsible for making decisions about chickens and the primary person responsible for making decisions about cattle were two different people; the primary chicken decision-maker was 18 years of age or older and sufficiently literate to keep simple written records in English. The chicken caretaker experiment involved a similar record-keeping intervention but used a different sample (wives of cattle caretakers) and involved a very different product and valuation elicitation method at endline. In our pre-analysis plan, we pre-specified that the cattle caretaker and chicken caretaker samples would be analyzed separately. Results from the chicken caretaker experiment will be reported in a separate paper.

endline survey.

4.2 Randomization

Participating households were randomized to treatment or control using on-the-spot randomization immediately after completion of their baseline survey, implemented through a random number generator on the tablet used to record participants' survey responses. Households assigned to treatment then immediately received the record-keeping intervention.

4.3 Intervention

The intervention involved training and incentivizing households to maintain record books. Participants in this treatment were given a record book and paid to keep daily records of livestock management practices, animal health events and treatments, and milk production. An image of the record book template is shown in Appendix Figure 1 and an example of a filled out record book is shown in Appendix Figure 2.

Participants in the treatment group were paid 100 kSH every two weeks via mobile phone airtime to keep their record books up to date. With prepaid phone plans, users buy airtime in advance, which can then be used for calls, text, and data. We chose to pay participants in this way because of two important benefits. First, it compensated subjects for their participation while minimizing concerns associated with paying subjects in cash, including directly alleviating liquidity constraints, signaling to subjects that they should be using cash payments for in-study purchases (namely, the acaricide purchase at endline), or making payments salient. Second, it allowed us to pay subjects remotely throughout the intervention period, ensuring timely and consistent payments. Since the intervention period was three months, the total incentive amount was 600 kSH. At baseline, participants reported an average household income of 7870 kSH over the previous three months, meaning the total incentive was approximately 8% of household income over the intervention period.

We ensured treatment compliance in two ways. First, participants in the treatment group were sent a weekly SMS reminder to maintain their record book. Second, treated participants were told that they would receive at least one unannounced visit from a study enumerator on a random day. If the record books were not up to date at the visit, the incentive payments would be stopped unless they could show that they had resumed record-keeping within one week. All participants in the treatment group were visited at least once, and a randomly selected subset were visited two or three times. Because they did not know when or how many times these visits would occur, these participants had an incentive to always keep their record book up to date.

Since we cannot randomly assign different memories to participants, we instead randomized use of a tool that would relax the memory constraint. By keeping records, participants generate a contemporaneous log of daily animal health events. This intervention therefore relaxes the long-term memory constraint. In the language of our conceptual framework, this means participants do not need to rely on their memories of past animal health events during the *retrieval* stage. We then ask participants to review their record books at endline, which completes the *retrieval* stage by bringing these entries (events) into working memory.

4.4 Summarization Exercise

After three months of keeping records, participants received an endline visit where they had the opportunity to purchase acaricide. Prior to the acaricide purchase decision, participants were asked to complete a template summarizing illness and death in their herds for the period in between the baseline and endline surveys (i.e., the record book intervention period). Control group participants were asked to do this from memory, while treatment group participants were encouraged to refer to their records while completing this exercise.

The key purpose of this summarization exercise was to equalize salience across treatment and control, allowing us to isolate the memory effect. A potential concern is that by encouraging treatment participants to review their record books at endline, factors included in the record book, like cattle illness, became more salient and more likely to influence decisions.

However, since all participants completed the summarization, these pieces of information became salient for both the treatment and control groups. This supports our interpretation that record keeping increases information available to individuals by relieving their memory constraint, rather than changing the choice environment.

4.5 Acaricide Demand

Our primary outcome of interest is demand for acaricides, which can be used to prevent tick-borne diseases. After participants completed the summarization exercise, we offered them an opportunity to purchase acaricide at market price.[11] This was a take-it-or-leave-it offer and participants could purchase as many bottles of acaricide as they wished. We partnered with the Busia county veterinary directorate for the acaricide sales. A veterinary directorate staff member accompanied enumerators to endline visits and brought acaricides with them. Partnering with veterinary directorate staff increased confidence in the quality of the acaricides. Normally, households would purchase acaricides by visiting their local agrovet stores.[12]

4.6 Heterogeneity Measure: Working Memory

While the record book relaxes the long-term memory constraint and encouraging treatment participants to review their record books at endline completes the *retrieval* stage, individuals still need to be able to use the information to form a subjective probability distribution (i.e., the *assessment* stage, where they need to hold information in their short-term memory

[11] The price of one bottle was 200 kSH at the time the endline survey was administered.

[12] We considered the alternative of implementing a Becker-DeGroot-Marschak mechanism to elicit participants' willingness to pay for acaricide, but we elected to use take-it-or-leave-it sales because use of acaricides among our participants at baseline was relatively high: 63 percent of participants reported spending a positive amount on acaricides in the last month, and 97 percent of participants reported at baseline that they knew where to purchase acaricides. This means that most of our participants have already revealed that their per-unit willingness to pay is at or above market price. If we were to implement a BDM, participants would have no incentive to state a WTP above market price (since acaricides are so readily available and can be administered by individuals). We would therefore expect pooling at the market price, which is equivalent to the take-it-or-leave-it mechanism but with a much more complicated implementation. As a result, we opted for the much simpler outcome of selling acaricide at the market price.

and manipulate, synthesize, and process that information). As proposed in the conceptual framework, long-term memory and working memory are both important components.

We elicited participants' working memory by having them complete a complex span task. Complex span tasks are designed to measure working memory and are predictive of fluid intelligence (Unsworth et al., 2009), which is why they are preferred over classic measures of short-term memory, like simple digit span (Hale et al., 2011). Complex span tasks have been used in developing contexts (see Nugroho et al. (2023) for a recent review of studies that use different measures of working memory, including complex span on children in four developing countries).

For our complex span task, the participant was shown a sequence of lines of triangles and circles. For each line, they counted the number of triangles in that line and tried to remember that number. After completing this for all lines in the sequence, they were asked to recall the numbers they had generated in order. They repeated this for an increasing number of lines (starting at one line and going up to six).

5 Empirical Strategy

5.1 Intention-to-Treat

We estimate the impact of alleviating memory constraints related to animal health and productivity via a record-keeping intervention on demand for acaricide. We use the following pre-specified linear regression:

$$AcaricidePurchase_i = \beta_0 + \beta_1 T_i + \beta_2 HerdSize_i + X\gamma + \epsilon_i$$

where $AcaricidePurchase_i$ is a binary indicator equal to 1 if the cattle decision-maker purchased any acaricide, $T_i = 1$ if household i is assigned record-keeping and 0 otherwise; $HerdSize$ is the total number of calves, heifers, bullocks, bulls, and cows owned at baseline;

X is a vector of pre-specified baseline control variables; and ϵ_i is the error term. The control variables included in X are age, gender, education level, off-farm income, household assets, number of sick cattle, milk produced in the last week, herd vaccination status, veterinary and livestock health expenditures, record-keeping at baseline, and numeracy. As specified in our pre-analysis plan, we show three specifications: 1) controlling only for herd size, 2) with the pre-specified set of controls, and 3) with control variables chosen through post-double selection lasso (Belloni, Chernozhukov, and Hansen 2014). Our primary outcome of interest is β_1, the intent-to-treat effect of relieving the memory constraint.

5.2 Summary statistics and balance

Table 1 shows summary statistics and randomization balance for the cattle owners in the study. The sample is well balanced on the key variables of interest. The average herd size at baseline is approximately 5 cattle. Cattle illness is common, with 45 percent of participants reporting at least one sick cattle in the past month. Acaricide use is also prevalent. The average expenditure amount of approximately 250 Ksh in the past month is slightly more than the cost of one of the 20ml bottles that we sell at endline. However, the median expenditure at baseline is 150 Ksh, and approximately 30 percent of the sample has no acaricide expenditures at baseline. Record-keeping is rare in the sample at baseline (less than 10 percent of respondents). All these key variables are similar across treatment and control. There is also no significant difference in complex span by treatment group.

With respect to demographics, there is an imbalance on educational attainment, with the treatment group having approximately one more year of education on average. Since the randomization was not stratified and was conducted on the spot by the tablet, this is consistent with chance. We show that results are robust to controlling for baseline education.

Table 1: Cattle Owners: Balance

Variable	N	(1) Total Mean/(SE)	N	(2) Control Mean/(SE)	N	(3) Records Mean/(SE)	N	(2)-(3) Pairwise t-test P-value
Baseline herd size	298	5.037 (0.188)	145	5.028 (0.265)	153	5.046 (0.268)	298	0.962
Any sick cattle	299	0.452 (0.029)	145	0.421 (0.041)	154	0.481 (0.040)	299	0.300
Number sick cattle	299	0.686 (0.060)	145	0.669 (0.084)	154	0.701 (0.085)	299	0.786
Acaricide exp, past month	273	251.355 (29.870)	131	233.511 (23.567)	142	267.817 (53.223)	273	0.556
Baseline record-keeping	299	0.097 (0.017)	145	0.090 (0.024)	154	0.104 (0.025)	299	0.678
Digit span: classic	299	1.953 (0.065)	145	1.876 (0.087)	154	2.026 (0.096)	299	0.249
Age	297	50.448 (0.704)	144	50.611 (0.956)	153	50.294 (1.031)	297	0.822
Female	299	0.090 (0.017)	145	0.090 (0.024)	154	0.091 (0.023)	299	0.970
Education	295	8.841 (0.192)	143	8.210 (0.284)	152	9.434 (0.250)	295	0.001***
Numeracy	299	3.920 (0.059)	145	3.834 (0.085)	154	4.000 (0.083)	299	0.164
Off-farm income	297	7870.047 (1001.970)	144	7698.611 (1677.493)	153	8031.399 (1141.535)	297	0.870
Asset index	299	-0.002 (0.093)	145	-0.035 (0.130)	154	0.028 (0.134)	299	0.735

Table 2: Cattle Owners: Adoption

	(1) Any records	(2) Filled last month
Records	0.957***	0.951***
	(0.0174)	(0.0184)
Observations	282	282
Control Mean	0.0435	0.0145

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors in parentheses.

6 Results

6.1 Adoption of records

We begin by showing that our intervention was successful in encouraging record-keeping. Table 2 shows that control participants report almost no record-keeping in the past month, while adoption among treatment group participants is nearly 100 percent.[13] The bottom row of the table shows mean adoption in the control group, and the coefficient represents the difference in adoption for the treatment group. Column 1 shows that there is a large difference in possession of record books. Moreover, Column 2 shows that there is also a large difference in recent *use* of record books. Enumerators documented that over 96 percent of the treatment group filled out the record books in the last month.

6.2 Acaricide Take-up

We then turn to our main outcome of interest: the impact of the treatment on acaricide take-up. Table 3 shows the intention-to-treat effects of the record-keeping intervention on

[13]Participants were asked in the endline survey if they used any record-keeping system for their cattle in the last three months. If they answered yes, the enumerator asked to see the record books. The enumerator then documented if the record book was one of the study record books as well as the date of the most recent entry. We categorize participants as having "any records" if they responded yes to the first question about having a record-keeping system. We categorize participants as having record books filled in the last month if the date of the last entry was in the month leading up to the endline survey.

Table 3: Main Treatment Effects

Dependent Variable:	Bought acaricide			
	(1)	(2)	(3)	(4)
Records	0.167***	0.129**	0.165***	0.165***
	(0.0497)	(0.0585)	(0.0488)	(0.0495)
Herd size	X	X	X	
All controls		X		
PDS LASSO			X	
Observations	298	257	298	299
Control Mean	0.172			

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors in parentheses. Column 2 controls for: age, gender, education level, off-farm-income, household assets, number of sick cattle, milk produced in the last week, herd vaccination status, veterinary and livestock health expenditures, record-keeping at baseline, and numeracy. The lower number of observations reflects missing data in some of these variables.

a binary indicator of buying acaricides at market price from the study team at endline.[14] Controlling only for herd size, Column 1 shows that the record-keeping intervention increased acaricide take-up by 16.7 percentage points. Relative to a control mean of 17.2 percent take-up, this represents a near doubling of demand. Column 2 shows that the result is robust to controlling for a large pre-specified set of baseline demographics, livestock health measures, and livestock management practices, and Column 3 shows a similar result when an optimal set of baseline controls is selected via post-double selection lasso, a machine learning method (Belloni, Chernozhukov and Hansen, 2014). Column 4 shows that the result is robust to excluding all controls.

We expect acaricide take-up to be driven by cattle owners' expectations of future cattle illness. Thus, record-keeping would increase take-up if it allowed cattle owners to observe more cattle illness than they remembered, in other words, relieved the long-term memory constraint. In the summarization exercise, participants were asked to report their herd size, number of cattle that were sick, and frequency of illness symptoms between baseline and endline. Table 4 presents the differences in these reports across the treatment and

[14]Columns 1, 2, and 3 show pre-specified estimating equations. The estimating equation in Column 4, with no controls, was not pre-specified.

control groups. Column 1 shows there are no differences in reported herd size.[15] However, Column 2 shows the record-keeping intervention increased reporting of any sick cattle by 10.3 percentage points, and this is statistically significant at the 10 percent level. Participants were asked how often their cattle had illness symptoms (fever, swollen lymph nodes, loss of appetite, reduced milk production, and no milk production) during the study period, on a likert scale of 1 to 5, where 5 was most often. As shown in Columns 3-7, record-keeping increased reported frequency of cattle fever, reduced milk production, and no milk production. These results suggest the record books contain more disease events and more negative impacts on cattle productivity than individuals remember.

These results may raise a question of whether the record-keeping intervention caused actual changes in cattle outcomes, instead of just changes in reporting. However, if there were behavioral responses to the intervention prior to endline, we should expect those responses to *decrease* cattle illness. After the acaricide purchase, we asked participants about their livestock health expenditures in the last month. Consistent with the idea that any expenditure changes would have reduced cattle illness, Table 9 in the Appendix shows that treatment group respondents reported higher spending on vaccines during the intervention period, but no other differences in expenditures on their cattle.[16] This suggests that, if anything, the results in Table 4 represent a lower bound on the effect of the intervention on reporting of cattle illness frequency. Overall, the results suggest the record-keeping intervention increased recall of cattle illness events and, in turn, increased take-up of preventive health investment in acaricides.

As seen in Appendix Table 9, the intervention did not increase the likelihood a participant purchased acaricide (Column 5) or expenditures on acaricide (Column 6) in the month leading up to endline. We only observe a difference in acaricide take-up for the purchase

[15]This result is in line with previous findings that changes in herd size are important, salient events and therefore recall of these events is reliable (e.g., Grandin 1983; Assefa 1990; Ensminger 1996; Lybbert et al. 2004).

[16]Participants were asked at endline how much they spent in the last month on veterinary health and medicine consultation services (Column 1), antibiotic treatments (Column 2), vaccines (Column 3), deworming (Column 4), and acaricide (Column 6) for their cattle.

Table 4: Treatment Effects on Reported Illness

	(1) Total cattle	(2) Any sick cattle	(3) Fever	(4) Lymph	(5) Appetite	(6) Reduced mlk	(7) No mlk
Records	-0.298	0.103*	0.376*	-0.150	0.242	0.417**	0.191*
	(0.415)	(0.0587)	(0.198)	(0.152)	(0.220)	(0.196)	(0.105)
Observations	282	282	278	281	282	282	282
Control Mean	5.486	0.529	0.934	0.703	1.362	0.826	0.246

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors in parentheses.

decision offered at endline. While this could be due to costs or behavioral biases that prevent farmers from going to their local agrovet store to purchase acaricide or increased salience of the intervention at endline, this is also consistent with memory constraints. Simply keeping detailed records was insufficient for participants to use this information – they needed prompting from the summarization exercise to generate increased take-up.[17]

6.3 Heterogeneity by Working Memory Capacity

We hypothesized that record-keeping would improve decision-making by giving cattle owners access to information that they could not remember. This means that the record books helped relax the long-term memory constraint. However, the record books contain a large number of individual entries. Therefore, the record books may be more effective for participants who are better able to process and synthesize these entries. In other words, the treatment effect may be more bigger for participants with larger working memory capacities.

We measured working memory using a complex span elicitation task, in which participants generated sequences of increasingly long numbers then recalled them (described in detail in Section 4.6). Table 5 shows heterogeneity in treatment effects based on various measures of complex span, where higher measures indicate better working memory.[18] A

[17]We thank an anonymous referee for suggesting this explanation.

[18]Column 1 shows the classic measurement of complex digit span, which is the highest number of digits that a participant recalled correctly, when they also recalled all shorter numbers correctly. Column 2 shows complex digit span based on the longest number recalled correctly, allowing for errors in shorter numbers. Column 3 shows the total count of numbers recalled correctly in the task. Column 4 is a binary indicator equal to 1 if the participants' complex digit span was above the median in the sample.

higher complex span is associated with a *larger* treatment effect. In other words, the record-keeping intervention was more helpful for participants who exhibited better working memory in our measures. In line with the conceptual framework we propose in Section 3, we propose this result is because participants with better working memory are better able to use the information in their record books when they are reviewing them at endline (i.e., are able to hold more of this information in their short-term memory as well as manipulate, synthesize, and the process the information). These results suggest that having accurate long-term memories of past events *and* being able summarize and synthesize that information effectively when faced with a decision are both key components to the role of memory in decision-making.[19]

6.4 Robustness checks

In this section, we consider several threats to our interpretation of the treatment effect as the effect of alleviating the memory constraint.

6.4.1 Spillover Effects

By relieving the memory constraint, record-keeping is, in effect, an information intervention. Randomization was done at the household level, meaning villages had both treatment and control households. This raises the concern that information may have spilled over to the control group, either by encouraging the control group to keep records themselves, or by changing control group perceptions of disease prevalence or impacts. There is little evidence of spillovers in record-keeping: while approximately 96 percent of treated households kept records and filled them out in the last month, only 4 percent of control households report keeping any records and just 1 percent percent report doing this in the month leading up to

[19]Table 5 also shows that within the control group, a higher complex span is associated with lower acaricide take-up. One hypothesis is that if control group participants have positively-biased long-term memories, individuals with higher complex spans could making more efficient use of those biased memories, thereby decreasing their demand for acaricide. So, one interpretation of this result is that it provides further evidence of the complementarities of accurate long-term memories and effective working memory.

Table 5: Cattle Owners: Heterogeneous Treatment Effects by Memory Capacity

Dependent Variable:	Bought acaricide			
	(1)	(2)	(3)	(4)
Records	0.000723	-0.0874	-0.104	0.0706
	(0.103)	(0.120)	(0.123)	(0.0829)
Digit span: classic	-0.0452			
	(0.0311)			
Records × Digit span: classic	0.0858*			
	(0.0453)			
Digit span: highest correct		-0.0569**		
		(0.0272)		
Records × Digit span: highest correct		0.102**		
		(0.0421)		
Digit span: num. correct			-0.0630*	
			(0.0340)	
Records × Digit span: num. correct			0.122**	
			(0.0495)	
Above median digit span=1				-0.106
				(0.0685)
Records × Above median digit span=1				0.157
				(0.104)
Herd size	X	X	X	X
Observations	298	298	298	298
Control Mean				

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors in parentheses.

Table 6: Spillover Effects

Dependent Variable:	Bought acaricide		
	(1)	(2)	(3)
Records	0.166***	0.166***	0.167***
	(0.0498)	(0.0504)	(0.0503)
Distance to nearest treated	-0.0482		
	(0.0750)		
N. treated within 0.5km		-0.00242	
		(0.0111)	
N. treated wtihin 1km			0.000106
			(0.00563)
Herd size	X	X	X
Observations	298	298	298

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors in parentheses.

endline (Table 3).

We study potential spillover effects in acaricide purchases in Table 6. If there were information spillovers, we might expect control households that are closer to treated households or have more treated household nearby to increase their perception of local disease prevalence. In this case, control households would be more likely to purchase acaricides. We do not find evidence for significant spillover effects. Column 1 shows results for the distance to the nearest treated neighbor. Columns 2 and 3 show results for the number of treated neighbors within 0.5 km and 1 km respectively. There is no statistically significant relationship between the any of these measures and acaricide purchases.

There may be other mechanisms for information spillovers other than distance, such as social networks. However, if there were information spillovers regarding the likelihood of disease, this would bias us *against* finding an effect on acaricide purchases. So if spillovers occurred, our estimate would be a lower bound on the impact of record-keeping.

6.4.2 Income Effects

A key concern in interpreting our results is that they simply represent an income effect, since cattle owners in the treatment group were paid to keep records while the control group was not.[20] An income effect could manifest as a straightforward demand effect, or as an expectation of reciprocity. We present evidence against this interpretation in this section. Treated cattle owners received 581 Ksh in mobile phone airtime over the course of the intervention on average, while the cost of one bottle of acaricide is 200 Ksh. However, it is important to note that since the incentives were delivered as mobile phone airtime, they did not directly relieve a liquidity constraint. In addition, they were delivered over the course of 12 weeks, so the total amount received may not have been particularly salient. To study income effects, we study heterogeneity based on baseline measures of income and wealth. If our results were an income effect, we should expect cattle owners with lower income at baseline to respond more to the treatment. However, Table 7 shows that there is no statistically significant heterogeneity in the treatment effect along herd size, a proxy for wealth (Column 1); asset index quintile (Column 2); or off-farm income quintile (Column 3).[21]

Additionally, if income effects were at play, we would expect treatment and control to have the same beliefs about cattle illness, but see the treatment group have higher take-up of acaricide. As discussed previously, the results in Table 4 demonstrate that the treatment and control groups have different beliefs about cattle illness, with the treatment group reporting beliefs that cattle illness occurs more frequently. Income effects, whether related to demand or reciprocity expectations, cannot explain these different beliefs. Taking together how payments were implemented and the results as a whole, we conclude our results are more consistent with an effect of the records themselves rather than income effects.

[20]We considered the possibility of offering unconditional transfers in randomized amounts to the control group over the course of the experiment, matching the timing of payments to the treatment group, to account for income effects. However, our implementing partner felt that this would not be acceptable to participants due to fairness concerns. Because the incentives were quite small, we instead chose not to provide transfers to control participants. For ethical reasons, they were compensated for study participation after the acaricide purchase.

[21]While we do not see heterogeneity by wealth or income measures, we may be underpowered to detect them given our sample size.

Table 7: Heterogeneous Treatment Effects by Respondent Income

Dependent Variable:	Bought acaricide		
	(1)	(2)	(3)
Records	0.0484	0.0529	0.0655
	(0.1000)	(0.114)	(0.119)
Records × Baseline herd size	0.0236		
	(0.0173)		
Asset quintile		-0.0141	
		(0.0222)	
Records × Asset quintile		0.0382	
		(0.0342)	
Off-farm income quintile			0.00376
			(0.0230)
Records × Off-farm income quintile			0.0340
			(0.0384)
Herd size	X	X	
Observations	298	298	297
Control Mean			

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors in parentheses.

6.4.3 Intrahousehold Information Transmission

Another key concern is that the record-keeping may constitute an intrahousehold information transmission rather than recall. While men are more likely to be cattle owners,[22] if women and children of the household are the primary care-takers of cattle, it may be that in the absence of record books, the men who make decisions about technology adoption are not fully informed about disease events or reduced productivity. By specifically asking about these events, record books could facilitate transmission of this information (e.g., if other household members help the household head in filling in the record-books later in the evening). This would mean the record book facilitates household members communicating information to the cattle owner that he would not have otherwise. Although we cannot test this with our data, we present evidence against this interpretation using data on time spent on livestock husbandry that was collected as part of the Socioeconomic Survey (SES) data collected in

[22]This is true in our sample, as shown in Table 1, and in this region more broadly.

Table 8: Time Spent on Livestock Husbandry and Management

	Mean Hours Per Week/(SE)			
	(1)	(2)	(3)	(2)+(3)
	Men	Women	Children	Women & Children
Grazing	19.00	5.79	3.54	9.44
	(23.16)	(10.21)	(10.10)	(15.49)
Watering	1.52	0.91	0.46	1.38
	(2.11)	(1.53)	(1.61)	(2.41)
Disease Control	1.54	0.24	0.01	0.25
	(3.41)	(0.83)	(0.38)	(1.11)
Milking	1.83	1.24	0.05	1.30
	(3.35)	(2.04)	(0.46)	(2.06)

2017 in Siaya county in western Kenya. Siaya county borders Busia county and the cattle production systems in both counties are similar, so the intrahousehold time spent measures from these data should be a good reflection of how the cattle-related workload is distributed among the household members in our sample.

Table 8 shows the mean hours per week spent on various cattle management activities including grazing, watering, disease control, and milking in this similar sample. There is no activity that women and children spend more time on than men. Grazing takes up most of the livestock management time, and men of the household spend more than twice as much time on grazing as women and children of the household. The time spent on disease control-related activities for men is six times that of other household members. These time-use measures indicate that indeed male members of the household likely spend significant time managing their cattle, which is inconsistent with the hypothesis that record-keeping is merely serving as a means of transmitting information to the cattle owner.

7 Conclusion

Low take-up of productive technologies is a well-established puzzle in the development literature. We demonstrate that memory constraints may serve as an important contributing factor to low adoption of productive and welfare-improving technologies. We study this in the context of cattle disease prevention and management among smallholder farmers in western Kenya. Our intervention of having participants keep simple written records of cattle disease events and milk production outcomes, combined with a paper template allowing them to summarize the information in the records, doubled demand for a livestock disease preventive technology at endline. We find heterogeneous treatment effects by working memory capacity: the effect was larger for participants with better working memory.

This paper provides evidence that both long-term memory and working memory are important constraints, and that accurate long-term memory and effective working memory are complements. While record-keeping alone can relieve the constraint on long-term memory by generating a contemporaneous log of individual events, it does not relieve the constraint on working memory. Thus, our results suggest that both record-keeping and summarizing the information in the records are important in promoting technology adoption.

In considering policy implications, it is important to note that our primary outcome is purchases of a technology at home, without having to travel, which would not generally be available in the market. However, in our experiment, this home delivery was offered to both the treatment and control groups. Thus, our results demonstrate that memory constraints influence technology adoption in this setting.

Our results suggest that memory constraints may serve as an important barrier to technology adoption and highlight the need to consider bounded memory in policymaking related to technology diffusion. While our study focuses on the context of a livestock disease prevention technology, our results provide evidence that supplying individuals with paper-and-pencil record books paired with nudging to summarize the information in the records can increase take-up of other technologies. Given our heterogeneous treatment effects by working memory, a potential policy could build on our simple written records intervention and introduce tools that would provide summary statistics of the records. This would help address both key components of the memory constraint.

References

1. Afrouzi, H., Kwon, S. Y., Landier, A., Ma, Y., & Thesmar, D. (2023). Overreaction in Expectations: Evidence and Theory. *The Quarterly Journal of Economics*, *138*(3), 1713-1764.

2. Aina, I., Ayinde, O. E., Thiam, D., & Miranda, M. (2018). Willingness to pay for index-based livestock insurance: Perspectives from West Africa. *Working Paper.*

3. Amelio, A., & Zimmermann, F. (2023). Motivated memory in economics—a review. *Games*, *14*(1), 15.

4. Arthi, V., Beegle, K., De Weerdt, J., & Palacios-López, A. (2018). Not your average job: Measuring farm labor in Tanzania. *Journal of Development Economics*, *130*, 160-172.

5. Assefa, M. (1990). Borana cattle herds: productivity, constraints and possible interventions.

6. Barham, B. L., Chavas, J. P., Fitz, D., Salas, V. R., & Schechter, L. (2014). The roles of risk and ambiguity in technology adoption. *Journal of Economic Behavior & Organization*, *97*, 204-218.

7. Beaman, L., BenYishay, A., Magruder, J., & Mobarak, A. M. (2021). Can network theory-based targeting increase technology adoption?. *American Economic Review*, *111*(6), 1918-1943.

8. Berkouwer, S. B., & Dean, J. T. (2022). Credit, attention, and externalities in the adoption of energy efficient technologies by low-income households. *American Economic Review*, *112*(10), 3291-3330.

9. Bordalo, P., Burro, G., Coffman, K., Gennaioli, N., & Shleifer, A. (2024). Imagining the future: Memory, simulation, and beliefs. *Review of Economic Studies*, *00*, 1-32.

10. Bordalo, P., Coffman, K., Gennaioli, N., & Shleifer, A. (2016). Stereotypes. *The Quarterly Journal of Economics*, *131*(4), 1753-1794.

11. Bordalo, P., Conlon, J. J., Gennaioli, N., Kwon, S. Y., & Shleifer, A. (2023). Memory and Probability. *The Quarterly Journal of Economics*, *138*(1), 265-311.

12. Bordalo, P., Gennaioli, N., & Shleifer, A. (2020). Memory, attention, and choice. *The Quarterly Journal of Economics*, *135*(3), 1399-1442.

13. Brainerd, C. J. (1981). Working memory and the developmental analysis of probability judgment. *Psychological Review*, *88*(6), 463.

14. Campbell, Z. A., Marsh, T. L., Mpolya, E. A., Thumbi, S. M., & Palmer, G. H. (2018). Newcastle disease vaccine adoption by smallholder households in Tanzania: Identifying determinants and barriers. *PloS One*, *13*(10), e0206058.

15. Campbell, Z. A., Otieno, L., Shirima, G. M., Marsh, T. L., & Palmer, G. H. (2019). Drivers of vaccination preferences to protect a low-value livestock resource: Willingness to pay for Newcastle disease vaccines by smallholder households. *Vaccine*, *37*(1), 11-18.

16. Chantarat, S., Mude, A. G., & Barrett, C. B. (2009). Willingness to pay for index based livestock insurance: results from a field experiment in northern Kenya. *Working Paper.*

17. Charles, C. (2022). Memory and trading. *Available at SSRN 3759444.*

18. Chew, S. H., Huang, W., & Zhao, X. (2020). Motivated false memory. *Journal of Political Economy*, *128*(10), 3913-3939.

19. Conlon, J. J., & Patel, D. (2022). What Jobs Come to Mind? Stereotypes about Fields of Study. *Working paper.*

20. Das, J., Hammer, J., & Sánchez-Paramo, C. (2012). The impact of recall periods on reported morbidity and health seeking behavior. *Journal of Development Economics*, *98*(1), 76-88.

21. De Weerdt, J., Beegle, K., Friedman, J., & Gibson, J. (2016). The challenge of measuring hunger through survey. *Economic Development and Cultural Change*, *64*(4), 727-758.

22. Dean, E. B., Schilbach, F., & Schofield, H. (2017). Poverty and cognitive function. In *The Economics of Poverty Traps* (pp. 57-118). University of Chicago Press.

23. Djiman, T. A., Biguezoton, A. S., & Saegerman, C. (2024). Tick-Borne Diseases in Sub-Saharan Africa: A Systematic Review of Pathogens, Research Focus, and Implications for Public Health. *Pathogens*, *13*(8), 697.

24. Dougherty, M. R., & Hunter, J. (2003). Probability judgment and subadditivity: The role of working memory capacity and constraining retrieval. *Memory & Cognition*, 31(6), 968-982.

25. Enahoro, D., Mason-D'Croz, D., Mul, M., Rich, K. M., Robinson, T. P., Thornton, P., & Staal, S. S. (2019). Supporting sustainable expansion of livestock production in South Asia and Sub-Saharan Africa: Scenario analysis of investment options. *Global Food Security*, *20*, 114-121.

26. Enke, B., Schwerter, F., & Zimmermann, F. (2024). Associative memory, beliefs and market interactions. *Journal of Financial Economics*, *157*, 103853.

27. Ericson, K. M. (2017). On the interaction of memory and procrastination: Implications for reminders, deadlines, and empirical estimation. *Journal of the European Economic Association*, *15*(3), 692-719.

28. Ensminger, J. (1996). Making a market: The institutional transformation of an African society. Cambridge University Press.

29. FAO. (2004). Module 1. Ticks: Acaricide Resistance; Diagnosis Management and Prevention. *Guidelines resistance management and integrated parasite control in ruminants.* Link

30. Ferraro, P. J., Messer, K. D., Shukla, P., & Weigel, C. (2024). Behavioral biases among producers: Experimental evidence of anchoring in procurement auctions. *Review of Economics and Statistics*, *106*(5), 1381-1392.

31. Foster, A. D., & Rosenzweig, M. R. (2010). Microeconomics of technology adoption. *Annual Review of Economics*, *2*(1), 395-424.

32. Gachohi, J., Skilton, R., Hansen, F., Ngumi, P., & Kitala, P. (2012). Epidemiology of East Coast fever (Theileria parva infection) in Kenya: past, present and the future. *Parasites & Vectors*, *5*(1), 1-13.

33. Gehring, K. & Schaudt, P. (2024). Insuring peace: index-based livestock insurance, droughts, and conflict. CESifo Working Paper No. 10423.

34. Gödker, K., Jiao, P., & Smeets, P. (2024). Investor memory. Available at SSRN 3348315. https://dx.doi.org/10.2139/ssrn.3348315

35. Godlonton, S., Hernandez, M. A., & Paz, C. (2024). Can survey design reduce anchoring bias in recall data? Evidence from smallholder farmers in Malawi. *European Review of Agricultural Economics*, *51*(4), 1129-1167.

36. Graeber, T., Roth, C., & Zimmermann, F. (2024). Stories, statistics, and memory. *The Quarterly Journal of Economics*, *139*(4), 2181-2225.

37. Grandin, B. E. (1983). Livestock transactions data collection. In *Pastoral Systems Research in Sub-Saharan Africa* (pp. 277-285). International Livestock Centre for

Africa, Addis Abeba.

38. Hale, S., Rose, N. S., Myerson, J., Strube, M. J., Sommers, M., Tye-Murray, N., & Spehar, B. (2011). The structure of working memory abilities across the adult life span. *Psychology and Aging*, *26*(1), 92.

39. Hoddinott, J., Headey, D., & Dereje, M. (2015). Cows, missing milk markets, and nutrition in rural Ethiopia. *The Journal of Development Studies*, *51*(8), 958-975.

40. Homewood, K., Trench, P., Randall, S., Lynen, G., & Bishop, B. (2006). Livestock health and socio-economic impacts of a veterinary intervention in Maasailand: infection-and-treatment vaccine against East Coast fever. *Agricultural Systems*, *89*(2-3), 248-271.

41. Huffman, D., Raymond, C., & Shvets, J. (2022). Persistent overconfidence and biased memory: Evidence from managers. *American Economic Review*, *112*(10), 3141-3175.

42. Jiang, Z., Liu, H., Peng, C., & Yan, H. (2023). Investor memory and biased beliefs: Evidence from the field. *Available at SSRN.*

43. Johnson, L., Shariff Mohamed, T., Scoones, I., & Taye, M. (2023). Uncertainty in the drylands: Rethinking in/formal insurance from pastoral East Africa. *Environment and Planning A: Economy and Space*, *55*(8), 1928-1950.

44. Jones, M., Kondylis, F., Loeser, J., & Magruder, J. (2022). Factor market failures and the adoption of irrigation in rwanda. *American Economic Review*, *112*(7), 2316-2352.

45. Juhász, R., Squicciarini, M. P., & Voigtländer, N. (2024). Technology adoption and productivity growth: Evidence from industrialization in France. *Journal of Political Economy*, *132*(10), 3215-3259.

46. Kahana, M. J. (2012). *Foundations of Human Memory.* Oxford University Press USA.

47. Kahneman, D., & Tversky, A. (1972). Subjective probability: A judgment of representativeness. *Cognitive Psychology*, *3*(3), 430-454.

48. Karlan, D., McConnell, M., Mullainathan, S., & Zinman, J. (2016). Getting to the top of mind: How reminders increase saving. *Management Science*, *62*(12), 3393-3411.

49. Kasaija, P. D., Estrada-Pena, A., Contreras, M., Kirunda, H., & de la Fuente, J. (2021). Cattle ticks and tick-borne diseases: a review of Uganda's situation. *Ticks and Tick-borne Diseases*, *12*(5), 101756.

50. Krätli, S., Huelsebusch, C., Brooks, S., & Kaufmann, B. (2013). Pastoralism: A critical asset for food security under global climate change. *Animal Frontiers*, *3*(1), 42-50.

51. Lybbert, T. J., Barrett, C. B., Desta, S., & Layne Coppock, D. (2004). Stochastic wealth dynamics and risk management among a poor population. *The Economic Journal*, *114*(498), 750-777.

52. Mani, A., Mullainathan, S., Shafir, E., & Zhao, J. (2013). Poverty impedes cognitive function. *Science*, *341*(6149), 976-980.

53. Marsh, T. L., Yoder, J., Deboch, T., McElwain, T. F., & Palmer, G. H. (2016). Livestock vaccinations translate into increased human capital and school attendance by girls. *Science Advances*, *2*(12), e1601410.

54. McPeak, J. (2006). Confronting the risk of asset loss: What role do livestock transfers in northern Kenya play?. *Journal of Development Economics*, *81*(2), 415-437.

55. Meriggi, N. F., Bulte, E., & Mobarak, A. M. (2021). Subsidies for technology adoption: Experimental evidence from rural Cameroon. *Journal of Development Economics*, *153*, 102710.

56. Mosites, Emily M., Peter M. Rabinowitz, Samuel M. Thumbi, Joel M. Montgomery, Guy H. Palmer, Susanne May, Ali Rowhani-Rahbar, Marian L. Neuhouser, and Judd

L. Walson. (2015). The relationship between livestock ownership and child stunting in three countries in Eastern Africa using national survey data. *PLoS One*, no. 9: e0136686.

57. Morrison, W. I., & McKeever, D. J. (2006). Current status of vaccine development against Theileria parasites. *Parasitology*, *133*(S2), S169-S187.

58. Mullainathan, S. (2002). A memory-based model of bounded rationality. *The Quarterly Journal of Economics*, *117*(3), 735-774.

59. Mutavi, F., Heitkönig, I., Wieland, B., Aarts, N., & Van Paassen, A. (2021). Tick treatment practices in the field: Access to, knowledge about, and on-farm use of acaricides in Laikipia, Kenya. *Ticks and Tick-Borne Diseases*, *12*(5), 101757.

60. Nugroho, H. W., Salimo, H., Hartono, H., Hakim, M. A., & Probandari, A. (2023). Association between poverty and children's working memory abilities in developing countries: a systematic review and meta-analysis. *Frontiers in Nutrition*, *10*, 1067626.

61. Oduniyi, O. S., Antwi, M. A., & Tekana, S. S. (2020). Farmers' willingness to pay for index-based livestock insurance in the North West of South Africa. *Climate*, *8*(3), 47.

62. Perla, J., Tonetti, C., & Waugh, M. E. (2021). Equilibrium technology diffusion, trade, and growth. *American Economic Review*, *111*(1), 73-128.

63. Railey, A. F., Lembo, T., Palmer, G. H., Shirima, G. M., & Marsh, T. L. (2018). Spatial and temporal risk as drivers for adoption of foot and mouth disease vaccination. *Vaccine*, *36*(33), 5077-5083.

64. Railey, A. F., & Marsh, T. L. (2019). A rational explanation of limited FMD vaccine uptake in endemic regions. *Pathogens*, *8*(4), 181.

65. Rawlins, R., Pimkina, S., Barrett, C. B., Pedersen, S., & Wydick, B. (2014). Got milk? The impact of Heifer International's livestock donation programs in Rwanda on

nutritional outcomes. *Food Policy*, *44*, 202-213.

66. Schofield, H. (2014). The economic costs of low caloric intake: Evidence from India. *Working Paper*.

67. Schilbach, F., Schofield, H., & Mullainathan, S. (2016). The psychological lives of the poor. *American Economic Review*, *106*(5), 435-440.

68. Sok, J., Hogeveen, H., Elbers, A. R. W., & Lansink, A. O. (2015). Farmers' beliefs and voluntary vaccination schemes: Bluetongue in Dutch dairy cattle. *Food Policy*, *57*, 40-49.

69. Sok, J., Borges, J. R., Schmidt, P., & Ajzen, I. (2021). Farmer behaviour as reasoned action: a critical review of research with the theory of planned behaviour. *Journal of Agricultural Economics*, *72*(2), 388-412.

70. Surve, A. A., Hwang, J. Y., Manian, S., Onono, J. O., & Yoder, J. (2023). Economics of East Coast fever: a literature review. *Frontiers in Veterinary Science*, *10*.

71. Takahashi, K., Ikegami, M., Sheahan, M., & Barrett, C. B. (2016). Experimental evidence on the drivers of index-based livestock insurance demand in Southern Ethiopia. *World Development*, *78*, 324-340.

72. Thumbi, S.M., Bronsvoort, M.B., Kiara, H., Toye, P.G., Poole, J., Ndila, M., Conradie, I., Jennings, A., Handel, I.G., Coetzer, J.A. and Steyl, J., (2013). Mortality in East African shorthorn zebu cattle under one year: predictors of infectious-disease mortality. *BMC Veterinary Research*, *9*, pp.1-14.

73. Unsworth, N., Redick, T. S., Heitz, R. P., Broadway, J. M., & Engle, R. W. (2009). Complex working memory span tasks and higher-order cognition: A latent-variable analysis of the relationship between processing and storage. *Memory*, *17*(6), 635-654.

74. van Andel, M., Jones, G., Buckle, K., Phiri, B., McFadden, A., Dacre, I., Bingham, P., Heuer, C., Abila, R., Win, H.H. & Lwin, K.O., 2020. Estimating foot-and-mouth disease (FMD) prevalence in central Myanmar: Comparison of village headman and farmer disease reports with serological findings. *Transboundary and Emerging Diseases*, *67*(2), pp.778-791.

75. Waithanji, E., Mtimet, N., & Muindi, P. (2019). Contagious bovine pleuropneumonia vaccine delivery and adoption by women and men in north-eastern Kenya. *The European Journal of Development Research*, *31*(3), 364-387.

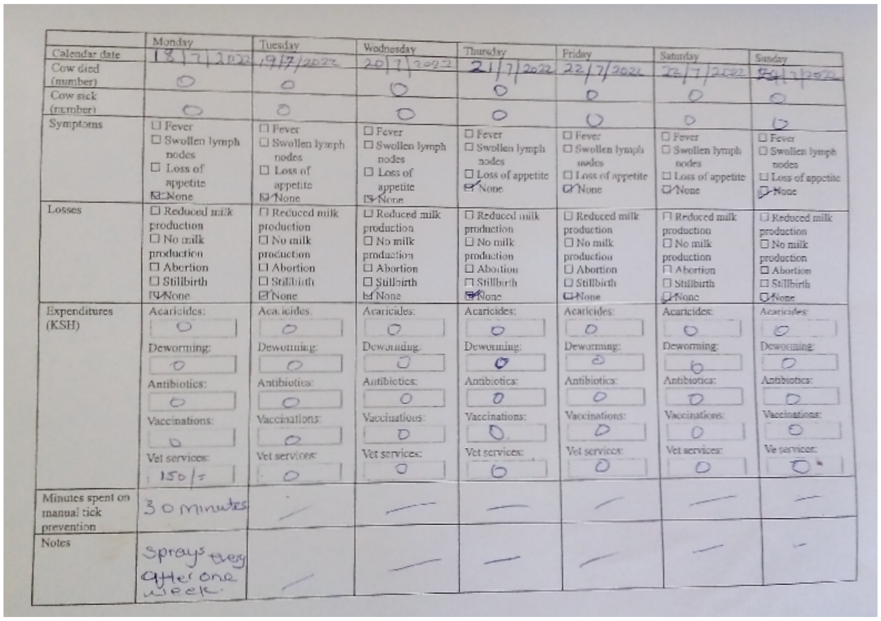
76. Yin, L., Shi, Z., Liao, Z., Tang, T., Xie, Y., & Peng, S. (2020). The Effects of Working Memory and Probability Format on Bayesian Reasoning. *Frontiers in Psychology*, *11*, 863.

Appendix

Figure 1: Record book template

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Calendar date							
Cow died (number)							
Cow sick (number)							
Symptoms	☐ Fever ☐ Swollen lymph nodes ☐ Loss of appetite ☐ None	☐ Fever ☐ Swollen lymph nodes ☐ Loss of appetite ☐ None	☐ Fever ☐ Swollen lymph nodes ☐ Loss of appetite ☐ None	☐ Fever ☐ Swollen lymph nodes ☐ Loss of appetite ☐ None	☐ Fever ☐ Swollen lymph nodes ☐ Loss of appetite ☐ None	☐ Fever ☐ Swollen lymph nodes ☐ Loss of appetite ☐ None	☐ Fever ☐ Swollen lymph nodes ☐ Loss of appetite ☐ None
Losses	☐ Reduced milk production ☐ No milk production ☐ Abortion ☐ Stillbirth ☐ No losses	☐ Reduced milk production ☐ No milk production ☐ Abortion ☐ Stillbirth ☐ No losses	☐ Reduced milk production ☐ No milk production ☐ Abortion ☐ Stillbirth ☐ No losses	☐ Reduced milk production ☐ No milk production ☐ Abortion ☐ Stillbirth ☐ No losses	☐ Reduced milk production ☐ No milk production ☐ Abortion ☐ Stillbirth ☐ No losses	☐ Reduced milk production ☐ No milk production ☐ Abortion ☐ Stillbirth ☐ No losses	☐ Reduced milk production ☐ No milk production ☐ Abortion ☐ Stillbirth ☐ No losses
Expenditures (KSH)	Acaricides: Deworming: Antibiotics: Vaccinations: Vet services:	Acaricides: Deworming: Antibiotics: Vaccinations: Vet services:	Acaricides: Deworming: Antibiotics: Vaccinations: Vet services:	Acaricides: Deworming: Antibiotics: Vaccinations: Vet services:	Acaricides: Deworming: Antibiotics: Vaccinations: Vet services:	Acaricides: Deworming: Antibiotics: Vaccinations: Vet services:	Acaricides: Deworming: Antibiotics: Vaccinations: Ve services:
Minutes spent on manual tick prevention							
Notes							

Figure 2: Example of filled record book



	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Calendar date	18/7/2022	19/7/2022	20/7/2022	21/7/2022	22/7/2022	23/7/2022	24/7/2022
Cow died (number)	0	0	0	0	0	0	0
Cow sick (number)	0	0	0	0	0	0	0
Symptoms	☐ Fever ☐ Swollen lymph nodes ☐ Loss of appetite ☑ None	☐ Fever ☐ Swollen lymph nodes ☐ Loss of appetite ☑ None	☐ Fever ☐ Swollen lymph nodes ☐ Loss of appetite ☑ None	☐ Fever ☐ Swollen lymph nodes ☐ Loss of appetite ☑ None	☐ Fever ☐ Swollen lymph nodes ☐ Loss of appetite ☑ None	☐ Fever ☐ Swollen lymph nodes ☐ Loss of appetite ☑ None	☐ Fever ☐ Swollen lymph nodes ☐ Loss of appetite ☑ None
Losses	☐ Reduced milk production ☐ No milk production ☐ Abortion ☐ Stillbirth ☑ None	☐ Reduced milk production ☐ No milk production ☐ Abortion ☐ Stillbirth ☑ None	☐ Reduced milk production ☐ No milk production ☐ Abortion ☐ Stillbirth ☑ None	☐ Reduced milk production ☐ No milk production ☐ Abortion ☐ Stillbirth ☑ None	☐ Reduced milk production ☐ No milk production ☐ Abortion ☐ Stillbirth ☑ None	☐ Reduced milk production ☐ No milk production ☐ Abortion ☐ Stillbirth ☑ None	☐ Reduced milk production ☐ No milk production ☐ Abortion ☐ Stillbirth ☑ None
Expenditures (KSH)	Acaricides: 0 Deworming: 0 Antibiotics: 0 Vaccinations: 0 Vet services: 150/=	Acaricides: 0 Deworming: 0 Antibiotics: 0 Vaccinations: 0 Vet services: 0	Acaricides: 0 Deworming: 0 Antibiotics: 0 Vaccinations: 0 Vet services: 0	Acaricides: 0 Deworming: 0 Antibiotics: 0 Vaccinations: 0 Vet services: 0	Acaricides: 0 Deworming: 0 Antibiotics: 0 Vaccinations: 0 Vet services: 0	Acaricides: 0 Deworming: 0 Antibiotics: 0 Vaccinations: 0 Vet services: 0	Acaricides: 0 Deworming: 0 Antibiotics: 0 Vaccinations: 0 Vet services: 0
Minutes spent on manual tick prevention	30 minutes	—	—	—	—	—	—
Notes	Sprays them after one week.	—	—	—	—	—	—

Table 9: Cattle Owners: Treatment Effects on Reported Expenditures

	(1) Vet	(2) Antibiotic	(3) Vaccine	(4) Deworm	(5) Ever Acaricide	(6) Acaricide Exp.
Records	20.26	34.02	21.28*	-23.01	-0.00391	-13.36
	(58.86)	(87.81)	(11.94)	(38.56)	(0.0283)	(72.24)
Herd size	X	X	X	X	X	X
Observations	278	264	275	263	281	272
Control Mean	160.9	160.2	2.174	146.5	0.942	290.0

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors in parentheses.