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Value Chains, ICT and the Transformation of Food Systems: Evidence from East Africa

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> "It's a dangerous business, Frodo, going out your door. You step onto the road, and if you don't keep your feet, there's no knowing where you might be swept off to."
>
> ~ JRR Tolkien, The Lord of the Rings

There are some who claim a PhD is above all an individual journey. While this is true in many ways, I can honestly say there has not been one moment where I felt alone or unsupported. This is all thanks to the extraordinary people I met along the way, many of which I am proud to call friends today.

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Table of Contents

General introduction **9**

References 14

1 Agricultural Extension Messages Using Video on Portable Devices Increased Knowledge about Seed Selection, Storage and Handling among Smallholder Potato Farmers in Southwestern Uganda **16**

1.1 Introduction 17

1.2 Materials and Methods 20

1.2.1 Experimental Units 20

1.2.2 Experimental Design 21

1.2.3 Inference 24

1.2.4 Treatments 25

1.2.5 Outcomes 27

1.3 Results 28

1.4 Discussion 33

References 40

Appendix A 44

Appendix A1: Supporting Information 44

2 Spoiler alert! Accounting for Spillovers in Assessing the Effectiveness of ICT-mediated Agricultural Interventions **45**

2.1 Introduction 46

2.2 Setting and Treatments 49

2.3 Data and Methodology 53

2.3.1 Experimental design 53

2.3.2 Data 54

2.3.3 Modeling spillovers 58

2.4 Results 64

2.4.1 Appreciation of video treatments 64

2.4.2 Main results 65

2.4.3 Varying the spillover radius 73

2.5 Discussion and conclusion 76

References . . . 79
Appendix B . . . 83
Appendix B1: Multiple-choice questions . . . 83
Appendix B2: PSS and PSSH practices . . . 84
Appendix B3: Orthogonality after attrition . . . 85
Appendix B4: Orthogonality of spillover conditions . . . 86
Appendix B5: Varying the spillover radius - Tables . . . 87

3 Fasting, Food and Farming: Value chains and food taboos in Ethiopia 91

3.1 Introduction . . . 92
3.2 Background . . . 95
3.3 Conceptual framework . . . 98
3.4 Data and empirical strategy . . . 100
3.5 Fasting participation and beliefs . . . 105
3.6 Fasting, adaptation strategies, and dairy prices . . . 108
3.6.1 Fasting and producer adaptation strategies . . . 108
3.6.2 Fasting and dairy prices . . . 111
3.7 Fasting and consumption . . . 113
3.8 Discussion and conclusion . . . 117
References . . . 120
Appendix C . . . 124
Appendix C1: Sampling strategy . . . 124
Appendix C2: Comparison with LSMS data . . . 126
Appendix C3: Control variables . . . 129
Appendix C4: Seasonal milk production . . . 130
Appendix C5: Market participation and supply . . . 133

General introduction

Agricultural value chains, the full collection of actors (farmers, input providers, traders, processors, retailers and consumers) and activities directly or indirectly adding value in ensuring the world's food supply (Kaplinsky and Morris, 2001), have been changing rapidly in recent decades. First of all, there has been a drastic shift from local to global food production, with especially developed country retailers increasingly sourcing their produce from developing country producers (Dolan and Humphrey, 2000). One factor which has allowed and intensified this shift is the increasing concentration of retailing, the so-called 'supermarket revolution' (Reardon et al., 2003), first in developed country markets, but increasingly across the world. Second, productivity in agricultural production has been increasing massively but unevenly across the developing world (Barrett et al., 2010). While East Asia in particular has seen exponential growth in agricultural yield for the past 50 years due to a combination of improved inputs (better seeds, fertilizer and land management), intensification of production and diversification of diets (Pingali, 2007), other regions like Africa have been lagging behind (Christiaensen and Vandercasteelen, 2019). Finally, the mid-stream of agricultural value chains, consisting of processors, traders, storage, wholesalers, has been gaining in importance and changing in structure in recent decades, characterized by a proliferation of small companies as well as increased investment by foreign actors (Reardon, 2015). While this dissertation only studies certain aspects of agricultural value chains, mostly pertaining to the lives of farmers, it is important to frame these aspects in the broader context of the value chain. After all, as will be demonstrated throughout this dissertation, one distinguishing feature of value chains compared to simpler models of production is that the actions of actors and companies within it are intimately interlinked.

In recent decades, East Africa has been characterized by fast economic growth and rapid urbanization, leading to drastic increases in overall demand for agricultural produce. This dissertation examines different aspects of two distinct agricultural value chains in East Africa:

the potato value chain in Southwestern Uganda and the dairy value chain in the suburban and rural areas surrounding Addis Ababa, Ethiopia's capital city. The two value chains offer an interesting perspective on broader agricultural development in the region, primarily because they are both characterized by a discrepancy between, on the one hand, growing demand for their products (potatoes and milk), and, on the other hand, stagnating production and productivity (see Makoni et al., 2014 for milk in Ethiopia and FAO, 2015 for potatoes in Uganda). This dissertation empirically explores reasons for this low agricultural productivity.

Information and Communication Technology (ICT) is increasingly seen as a way to boost agricultural productivity by improving agricultural extension. Defined as the "delivery of information to farmers" (Anderson and Feder, 2007), agricultural extension has been introduced in the 1960s across the developing world to meet farmers' evolving information needs with respect to new technologies and to overcome information asymmetries related to factors such as market access. However, in its traditional forms (through so-called Training and Visit and Farmer Field Schools), agricultural extension has been suffering from long-standing issues: interventions are only scalable to a limited extent, there is little evidence on their impact and it has proven difficult to provide extension staff (usually public servants) with the appropriate incentives (Aker, 2011). ICT, and particularly the spread of mobile phone coverage, offers possibilities to overcome these issues, for instance through two-way communication at scale and increased accountability (Aker and Mbiti, 2010). Increasing smartphone penetration (predicted to reach 67% by 2025 in Sub-Saharan Africa) and internet connectivity in rural areas are further adding to that potential, facilitating the distribution of content which requires improved infrastructure, such as video. While audiovisual messages have become common as an additional tool in traditional agricultural extension (as used by organizations such as Digital Green), evidence on their potential as a stand-alone tool is limited (Fabregas et al., 2019). By setting up an experiment mimicking the conditions of farmers watching agricultural extension videos privately in their home, this dissertation aims to contribute to this growing body of literature.

Chapters 1 and 2 of this dissertation start from the observation that agricultural productivity in the most important potato-producing areas in Uganda (around Kabale and Kisoro in the South-West) remains far below its potential given the agro-ecological conditions. The lack of availability of good quality seeding material is widely regarded as one of the main contributing factors to this low productivity. It is estimated that using potato seeds from certified seed suppliers could double potato yields in the region. Unfortunately, Uganda is currently only producing 34 percent of the amount of high-quality potato seed needed to satisfy the growing demand in the country (Mbowa and Mwesigye, 2016). In that context, farmers are left with little choice but to engage in seed recycling, that is, using part of last season's harvest as seeding material for the next. While seed recycling for potatoes has been used for centuries across the world, it is particularly prone to exacerbate poor productivity if not performed adequately. For instance, if farmers consistently select potatoes that are diseased or too small or if potatoes are stored in sub-optimal conditions, the following season's harvest will see bad attributes perpetuated and enhanced. Conversely, if done right, seed recycling can be a cost-effective way to increase yield and quality season after season. Due to an ineffective agricultural extension service in Uganda (Turyahikayo and Edson, 2016), farmers had not been receiving up-to-date information about seed recycling. For that reason, we set up an individually-randomized experiment with ex-ante matching in a factorial design to test whether two simple agricultural extension video messages (shown to farmers on tablets), related to the selection and handling of seed potatoes respectively, would increase farmers' knowledge and adoption of recommended practices.

Chapter 1 shows that the agricultural extension videos indeed significantly increase farmers' knowledge, even beyond the agricultural practices shown in the videos. It is hypothesized that the video messages may have triggered a process of abstraction, whereby farmers apply insights gained in one context to a different context. At the same time, it may be possible that farmers already possessed some of the information, but that the videos served as a reminder and triggered the farmer to start applying this information. This last point in particular has

potentially interesting implications for the role of ICT in agricultural extension. First, it suggests that videos will be most effective in contexts where farmers already have some notion about the techniques explained, for instance in the case of traditional crops. Second, videos might be less suited to deal with existing, but unprofitable or even harmful traditional beliefs and superstitions. Previous studies have shown that providing people with information that contradicts their beliefs might do more harm than good. Finally, for methods such as videos to work, the message should be clear, concise and, perhaps most importantly, applicable to a heterogeneous audience of farmers. When the information or the technique requires a far-reaching degree of customization, standardized methods will not suffice.

Chapter 2 confirms the findings in Chapter 1 by demonstrating that the observed increases in knowledge about seed recycling have translated into beneficial agricultural and welfare outcomes. To show this, Chapter 2 takes into account spillovers, the fact that the information captured in the videos has spread between treatment and control farmers, making simple comparisons between the two groups inadequate. More specifically, we use a randomization-based framework for estimating causal effects under interference between units developed by Aronow and Samii (2017), which uses re-randomization to estimate probability weight corrections for spillovers of arbitrary but known form. Using farmers' locations to estimate how information travels, Chapter 2 shows both videos had important positive effects. The video on seed selection leads to increased awareness and subsequent adoption of practices shown, as well as a higher probability of using improved inputs. While the video on seed storage and handling did not result in improved adoption of agricultural practices, it did generate higher yield, commercialization and consumption. The relative success of the two videos (at least in terms of adoption of practices) can be attributed to differences in the cost of implementation of some of the practices, demonstrating informational constraints should never be considered in isolation.

Chapter 3, finally, investigates the impact of religious food taboos on the dairy value chain. Fasting by Orthodox Christians in Ethiopia, which dictates abstinence from animal-

sourced foods during designated fasting periods, is widely considered to have a pervasive impact on both the production and consumption of dairy products (such as milk, butter, cheese and yogurt). The demand swings caused by fasting affect all actors along the dairy value chain. Processors cut down their capacity during fasting periods, limit the supply of milk using quota systems, require a higher milk quality from their suppliers or build up stocks of processed milk products (Land O'Lakes, 2010; Zijlstra et al., 2015). Likewise, retailers limit the quantity of milk they purchase. Because of the prevalence of these practices throughout the value chain, dairy farmers are necessarily also affected. They indicate a reduced or even a complete lack of market access, lower sales and reduced dairy prices during fasting periods (Makoni et al., 2014; Gizaw et al., 2016). Analysis of unique data collected among dairy farmers in and around Addis Ababa indeed shows that fasting reduces annual dairy consumption by approximately 12 percent nationally. However, Chapter 3 also shows that dairy farmers have found ways to cope with these drops in demand including by increasing the processing of milk into storable products during fasting periods and by giving more milk to children in their households. The importance of each of these strategies varies significantly with the degree of access to the major market of Addis Ababa. Remote households reduce their milk production significantly during longer fasting periods, process some of it into cheese or other dairy products, or feed some of their excess milk production to their children. Non-remote households, on the other hand, have been able to establish better arrangements with milk buyers so that they do not need to stop producing milk during fasting periods. On the whole, the findings in Chapter 3 suggest that other issues such as availability and affordability – instead of fasting – are the main impediments to increased dairy production and consumption in Ethiopia. Further investments to stimulate the dairy sector (in milk chilling centers and improved transportation facilities for instance) are therefore needed to increase availability of dairy products at lower prices.

The studies in this dissertation thus demonstrate, in two different contexts, how agricultural practices (such as poor seed recycling) and societal habits (such as fasting) are

contributing factors to low agricultural productivity and thus inhibit the full development of agricultural value chains. While cost-effective ICT solutions like agricultural extension videos can help solve part of this problem, only increased investment in processing, storage and infrastructure can truly and sustainably transform agricultural value chains.

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Chapter 1

Agricultural Extension Messages Using Video on Portable Devices Increased Knowledge about Seed Selection, Storage and Handling among Smallholder Potato Farmers in Southwestern Uganda

Abstract*: To feed a growing population, agricultural productivity needs to increase dramatically. Agricultural extension information, with its public, non-rival nature, is generally undersupplied, and public provision remains challenging. In this study, simple agricultural extension video messages, delivered through Android tablets, were tested in the field to determine if they increased farmers' knowledge of recommended practices on (i) potato seed selection and (ii) seed storage and handling among a sample of potato farmers in southwestern Uganda. Using a field experiment with ex ante matching in a factorial design, it was established that showing agricultural extension videos significantly increased farmers' knowledge. However, results suggested impact pathways that went beyond simply replicating what was shown in the video. Video messages may have triggered a process of abstraction, whereby farmers applied insights gained in one context to a different context.

Keywords: Video, extension, potato, Uganda, seed quality

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1.1 Introduction

To feed a growing population, agricultural production needs to increase dramatically. The global population is projected to increase to more than 9 billion by 2050. In order to meet the demand for increasingly calorie-intense and complex diets, overall food production would need to increase by some 70 percent between 2005 and 2050 (FAO, 2009). However, this increase needs to be accomplished against a background of greater competition for land, water, and energy, and in the context of a changing climate. Therefore, sustainable intensification, whereby modern inputs and improved technologies and practices allow farmers to grow more food from the same area of land while reducing environmental impacts, is imperative (Tilman et al., 2011; Garnett et al., 2013). Indeed, in Asia, the use of modern inputs and techniques on a large scale (e.g, inorganic fertilizer and hybrid seeds) and improved technologies (e.g., irrigation and row planting) led to a substantial increase in yields in a relatively short period of time (Mueller et al., 2012). Conversely, yield gaps, expressed as the difference between actual yields and attainable yields when modern inputs and proper practices are used, remain large in many parts of the world, and especially in Africa south of the Sahara. Reducing these gaps in underyielding locations through the use of modern inputs and improved technologies is expected to boost production, increase food security, and reduce poverty (Godfray et al., 2010).

Use of modern inputs and adoption of recommended farming practices is generally low in developing countries. There are different reasons why smallholder farmers shun agricultural intensification investments. It may be that the agricultural technology is simply not profitable, so non-adoption is a rational response on the part of the farmer. However, more careful investigation suggests substantial heterogeneity, with some farmers adopting certain practices while others do not. Such selective adoption is indicative of various market imperfections (de Janvry et al., 1991). For example, new technologies may affect the type and amount of labor needed, and poorly functioning labor markets may interfere with adoption decisions

(Jack, 2013). Land market imperfections, characterized by insecure property rights, may also prevent some farmers from investing in, for instance, soil conservation measures (Ali et al., 2014). New, unfamiliar technologies may carry small downside risk, potentially affecting adoption when insurance markets are incomplete (Dercon and Christiaensen, 2011). Other market inefficiencies that have been found to affect technology adoption include input and output market inefficiencies (Croppenstedt et al., 2003; Zeller et al., 1998), missing credit markets (Giné and Yang, 2009), and information market inefficiencies (Cole and Fernando, 2016).

In poor, remote communities, information market inefficiencies in particular are thought to be important in explaining underadoption: if an individual does not know that a technology exists, does not know about its benefits, or does not know how to use it effectively, then he or she will not adopt the technology. Since information is a public, non-rival good, governments across the developing world have started providing extension services on a large scale to address these information gaps. However, they have done so with mixed success. While most studies have reported positive impacts of extension services, these effects are far from general (Taye, 2013), with cost-effectiveness, limited scaleability and accountability frequently cited as issues (Anderson and Feder, 2007). Information and Communication Technologies (ICTs) have been advanced as a promising way to improve agricultural extension services (Aker, 2011). However, to date, most use of ICTs in development has been in the provision of financial services through mobile phones (Duncombe and Boateng, 2009), while the potential for agricultural extension has been studied less.

This research contributes to the literature on innovations in agricultural extension services by testing whether showing simple and short videos is a viable alternative to more elaborate, and hence more costly, extension practices. More specifically, this paper investigates whether simple informational interventions would succeed at increasing knowledge among smallholder farmers. To do so, an experiment was set up among potato (*solanum tuberosum*) farmers in the Kigezi subregion in southwestern Uganda, where poor seed quality is an important reason

for low yields. For instance, by using quality seed from a certified source instead of reusing seed from the previous harvest, agronomic data suggested tuber yields could be doubled. While providing access to clean planting material derived from basic foundation seed should remain a key policy priority, current seed systems are too weak to have a significant impact in the short to medium term. Therefore, in a context where farmers rely heavily on saved seed as planting material for the next season, the selection, storage and handling of seeds are important pathways to improve quality. The interventions therefore focused on Positive Seed Selection (PSS), the practice of keeping the best potatoes as seed material (Schulte-Geldermann et al., 2012), and on Proper Seed Storage and Handling (PSSH), involving best practices to preserve seed potatoes between harvesting and planting them in the next season.

The interventions relied on two basic information treatments. Simply providing information has been found to be very effective in changing behavior in a range of applications. For example, Jensen (2010) observed that returns on education were perceived much lower than they actually were, and found that students who were told about the higher measured returns complete on average 0.20–0.35 more years of schooling over the next four years than those who were not given this information. Dupas (2011) found that providing teenagers with information about the risk of HIV infection relative to one's partner's age significantly impacted sexual behavior. In the context of agricultural extension, Cole and Fernando (2016) demonstrated that delivering timely, relevant, and actionable information and advice to farmers reduced knowledge gaps and increases productivity.

The information treatments took the form of video messages shown to individual farmers on Android tablets. Video, combining both visual and verbal communication methods, has been found promising in providing low-literacy populations with skills, information, and knowledge on complex technical topics (David and Asamoah, 2011; Zossou et al., 2009; Van Mele et al., 2010). Steady progress in mobile video display equipment and increasing mobile phone penetration and internet connectivity in rural areas have made it easier and cheaper to distribute video content. In addition to increasing knowledge directly, video has

also been found to induce behavioral changes in poor countries. While some of this behavioral change may be a consequence of the newly acquired knowledge, research by Bernard et al. (2015) suggested that videos featuring role models can induce behavioral change by affecting the motivation and aspirations of farmers.

The objective of this study was to investigate if short agricultural extension information messages, delivered to individual farmers through Android tablet computers, increased farmers' knowledge. The method used was a field experiment where farmers were randomly allocated to different treatment groups. One treatment consisted of farmers being shown a video on how to select the best potatoes as seed materials to be used for the next planting season. Another treatment consisted of farmers being shown a video on how to store potatoes to be used as seed materials for the next season. We also included a control group in our experiment. After the treatments were administered, knowledge about seed selection and seed storage, obtained through a short quiz, was compared between treatment and control groups to find out if the videos increased farmers' knowledge.

1.2 Materials and Methods

1.2.1 Experimental Units

Baseline data was collected from potato farmers in three districts (Kisoro, Kanungu, and Kabale) in southwestern Uganda for the 2013/2014 agricultural season. The three districts together accounted for about 47 percent of total potato production in Uganda (UBOS, 2010). With the assistance of the Uganda Bureau of Statistics, 35 enumeration areas were randomly selected. Within each enumeration area, all households were listed and it was determined whether they were growing potatoes. From these lists, potato farmers were randomly selected to be interviewed on a range of socio-economic variables. These variables included household composition, land holdings and use, assets, crop production, and consumption expenditure. In addition, detailed baseline information was collected related to potato farming, including

experience, extension received, knowledge of recommended practices, and inputs and methods used. For the actual experiment, 248 farmers were selected from this baseline (see next section).

Ethics approval for this research was obtained from the International Food Policy Research Institute's Institutional Review Board (IRB #00007490 FWA #00005121). Consent of each selected farmer was obtained orally. After the enumerator introduced him or herself, the aim of the study and procedures were explained and it was made explicit participation was voluntary. The farmer was then asked to agree to participate and this was recorded on the questionnaire form by the enumerator. All this was done in the local language of the farmer by a trained enumerator. The decision to obtain oral instead of written consent was motivated by the fact that many of the farmers in the study were illiterate. It was felt that insisting on written consent might lead to a feeling of shame or frustration on the part of the illiterate farmer. This procedure was approved by the IRB on February 2nd, 2016 (IRB Approval Number 2016-12-DSGD-M).

1.2.2 Experimental Design

The 248 selected farmers were randomly allocated to different treatment conditions within a 2 x 2 full factorial design. In particular, 124 farmers received the first treatment (Positive Seed Selection, or PSS see "Treatments" subsection below) and 124 farmers received the second treatment (Positive Seed Storage and Handling or PSSH). However, half of this last subset overlapped with half of the farmers that were treated with PSS. As such, 62 farmers received both PSS and PSSH treatments, and 62 farmers received no treatment at all. The full factorial experiment was designed to test two main effects (PSS and PSSH) and consisted of four different treatment conditions (Control, PSS, PSSH, PSS + PSSH). Such designs are very efficient, as it allows one to use the entire sample to test main effects. That is, to test if the PSS treatment worked, 124 farmers that received the PSS treatment can be compared to 124 farmers that did not receive the PSS treatment. Similarly, to test if the PSSH treatment

worked, 124 farmers that received the PSSH treatment can be compared to 124 farmers that did not receive the PSSH treatment. Apart from testing main effects, factorial designs also allow estimation of interaction effects, comparing for instance the subgroup of farmers that received only PSS to the subgroup of farmers that received both PSS and PSSH. However, when testing interactions, sample size reduces as there are now only 62 farmers in each experimental condition. As the sample size of this study was determined on the basis of testing main effects only, testing interactions is likely to suffer from a lack of statistical power and so interactions were not considered in this study.

Instead of simple randomization, an ex ante matching procedure was used, where farmers that were similar along a range of characteristics were matched into blocks prior to randomization. In particular, a farmer was selected randomly and matched to another farmer that was most similar to this first farmer on the basis of a set of characteristics (see below for the list of characteristics). To find the most similar farmer, the square root of the sum of squared standardized differences of the measures for these characteristics was minimized. This was repeated three times and the resulting group of four farmers was given a unique block number and removed from the sample. This procedure was then repeated until all farmers were matched in groups of four farmers. Finally, the four different treatment conditions from the factorial design (Control, PSS, PSSH, PSS + PSSH) were randomly allocated to the four farmers within each block. As the sample size was 248 observations, this resulted in 62 blocks of four farmers randomly distributed over the four treatment conditions.

This matched procedure guaranteed that farmers that are similar in some characteristics, for instance income, were allocated to different treatment groups. For instance, it reduced the chance that a disproportionate number of high income farmers were allocated to a particular treatment, which would make it difficult to differentiate between the treatment effect and a potential income effect. It is argued that, especially in small samples, such randomization procedures based on matching and stratification can significantly improve on statistical power (Bruhn and McKenzie, 2009). The procedure was also described in detail in the pre-analysis

plan, which is available at the American Economic Association's registry for randomized controlled trials.

Matching was performed on ten characteristics. All characteristics received an equal weight in the objective function. Three variables related to household demographics that are standard in empirical specifications of agricultural household models were included (Singh et al., 1986). Household size is an important measure of human capital, particularly in the smallholder agricultural settings with imperfect labor markets (Benjamin, 1992). The age of the household head was included to capture experience and life-cycle effects. Observations were also matched on gender of the household head, as previous knowledge about modern agricultural techniques and inputs may differ by sex (Doss and Morris, 2000). The area of potatoes grown, as well as a variable that indicated whether the household received extension on potatoes in the past, the logarithm of potato yields, and the logarithm of welfare per capita were also all included in the matching procedure. Other variables included travel distance to the closest farm input dealer or farm supply store and access to credit.

This research adhered to the highest standards in terms of transparency. For instance, a pre-analysis plan, developed before the interventions, detailed what sampling methods would be used, what specifications would be run, and what outcome variables would be analyzed. The pre-analysis plan also included orthogonality tests for a range of relevant baseline characteristics and demonstrated there are no ex ante systematic differences between treatment and control groups. The experiment was also registered at the American Economic Association's registry for randomized controlled trials (https://www.socialscienceregistry.org/trials/1014). Finally, the entire project, including all data which is also accessible in Appendix A1, computer code, and documents, was under revision control using Git (https://git-scm.com/), a free and open source distributed version control system, and mirrored on an online repository (https://bitbucket.org/bjvca/potseedrct). This means all material can be downloaded to rerun the analysis and track changes to the project over time, resulting in a level of transparency that is exceptional in the social sciences.

1.2.3 Inference

The matched randomization procedure was likely to introduce dependence among outcome variables within blocks, so it was necessary to account for clustering during inference (Bruhn and McKenzie, 2009). The typical approach to deal with this, using cluster-robust standard errors, is known to be biased in small samples. In addition, to facilitate comparison between simple means and to allow more complicated models that control for additional variables such as previous knowledge, linear probability models were used. Standard inference becomes invalid when Ordinary Least Squares (OLS) is used with binary outcome variables. To address these two issues, randomization inference (RI) was used, as RI remains exact regardless of the regression specification (Young, 2015). Instead of relying on a theoretical distribution, RI involves comparing the test statistic with the distribution of the test statistic under each possible allocation of treatments. In this study, only the main effects in the factorial design were tested. In particular, outcomes of 128 farmers that received PSS were compared to outcomes of 128 farmers that had not received PSS. Similarly, outcomes of 128 farmers that received PSSH were compared to farmers that had not received PSSH. RI thus involved computing outcomes within each block of four farmers for all 6 possible permutations of treatment (T) and control (C): {(T,T,C,C),(T,C,T,C),(T,C,C,T),(C,C,T,T),(C,T,T,C),(C,T,C,T)}. For 62 blocks, this led to a total of 6^62 permutations, so instead of actually computing all combinations, inference was based on a random subset of 10,000 permutations.

Not accounting for the method of randomization might have resulted in overly conservative standard errors and a significant reduction in power (Bruhn and McKenzie, 2009). Therefore, in addition to accounting for clustering through the use of RI, regression models including fixed effects at the block level were also run. Recall that in each block $b = \{b_1, ..., b_{62}\}$, four experimental conditions (Control, PSS, PSSH, PSS + PSSH) were randomly assigned. As such, to test a main treatment effect in our study, each block always had two control (C) and two treated (T) observations $t = \{C_1, C_2, T_1, T_2\}$. For example, to test the main treatment effect of the PSS treatment, within each block, one farmer that received the PSS

treatment and one farmer that received both the PSS treatment and the PSSH treatment were compared to a farmer that received only the PSSH treatment and a farmer that received no treatment at all. Similarly, to test the main treatment effect of the PSSH treatment, within each block, one farmer that received the PSSH treatment and one farmer that received both the PSSH treatment and the PSS treatment were compared to a farmer that received only the PSS treatment and a farmer that received no treatment at all. Average treatment effects (β) were estimated by regressing the outcome variable (y) on the treatment indicator I where $I = 1$ if $t = \{T_1, T_2\}$ and 0 otherwise, and on fixed effects for the blocks (δ_b):

$$y_{t,b} = \alpha + \delta_b + \beta I_{t,b} + \varepsilon_{t,b} \tag{1.1}$$

where α was a constant and $\varepsilon_{t,b}$ was an error term. Since an overall constant was included in the model, only 61 fixed effects were included.

1.2.4 Treatments

The first treatment consisted of a video on Positive Seed Selection (PSS), see Appendix A1. In this video, a potato farmer from the area introduces himself and explains that his experiments over the years have taught him that good-quality planting material is key to becoming a successful farmer (0:00-1:25 minutes into the video). He illustrates the benefits of good quality seed by contrasting healthy fields, plants, and tubers to diseased ones (1:25-2:35 minutes). The farmer also explains how he used to do it wrong, pulling out the strongest plants first to eat or sell, and hence was left with small and malformed tubers for planting. He explains how this quickly leads to seed degeneration (2:35-3:19 minutes). Next, the concept of Positive Seed Selection is introduced (3:19-4:26 minutes). In particular, the farmer explains that, at time of flowering, the tallest plants with at least four stems should be marked and pegged for follow-up. Pegs (in the form of wooden sticks in the video) should be removed when plants get diseased or when they grow slowly (4:26-5:05 minutes). At the time of harvest, pegged plants should be harvested first (5:05-5:16 minutes). Only egg sized tubers

should be retained for planting material (5:16-5:27 minutes). Tubers should look healthy, without cuts or bruises, and it is advised to only keep tubers with at least four eyes (5:27-5:43 minutes). The video ends by recapitulating the most important components of Positive Seed Selection. (5:43-7:02 minutes). This video was produced in both Rufumbira and Rukiga, the two languages spoken in the study area.

The second treatment consisted of a video on Proper Seed Storage and Handling (PSSH), see Appendix A1. The first part, in which a farmer introduces himself as a successful potato grower from the region and illustrates the benefits of good-quality seeding material by contrasting healthy fields, plants and tubers to diseased ones, is similar to the first part in the video used in the PSS treatment (0:00-2:08 minutes into the video). The farmer also explains that he used to store and handle seeds incorrectly, storing potatoes in sacks or together with other crops in places that were too dark and inadequately ventilated (2:08-3:24 minutes). The farmer then introduces PSSH. He first underscores potatoes should be spread out on wooden racks, or on dried grass on the floor (3:24-4:03 minutes). Second, seed potatoes should be stored in a separate room, away from animals and humans (4:03-4:11 minutes). Third, seed potatoes should be stored in a well ventilated place in diffuse lighting conditions and checked regularly for rotten tubers (4:11-5:07 minutes). Finally, the farmer advises the use of a cheap organophosphate insecticide for seed preservation and underscores the importance of cleaning all tools used during seed production to avoid contamination (5:07-5:45 minutes). Like the PSS video, this one ends by summarizing the most important aspects of PSSH (5:45-7:05 minutes). This video was also produced in both Rufumbira and Rukiga languages. The choice of which techniques and information to highlight in both treatments was based on extensive interviews with potato-growing experts (seed producers, extension officials, agronomists) in the area and on analysis of data previously collected among potato farmers.

The treatments were administered at the individual level. Enumerators were trained to create a discreet environment. They were instructed to find a quiet place where they were

unlikely to be disturbed. Spouses and other family members (apart from children) were politely asked to leave for the duration of the interview and the screening of the videos to maintain optimal concentration. Most of the treatments were administered in the home of the farmer or in the field.

Individual treatments are uncommon in agricultural extension. This is because it is often too costly to send agricultural extension workers to each individual farmer. Working with groups may also be more effective, as farmers may engage in discussion with each other and ask clarification. However, it may also result in group dynamics that are difficult to control by the experimenter. At a more practical level, it is very difficult to exclude people from group screenings at community centers, greatly complicating the randomization. Showing videos on Android tablets has a much lower marginal cost, making it a potentially important technology to reach remote farmers.

1.2.5 Outcomes

To test whether the videos reduced farmers' knowledge gaps, farmers were asked to take a short quiz. In particular, farmers were subjected to six multiple choice questions. All participants, including control farmers, were presented with all six questions. The questions were asked after the video was shown, unless for control subjects, who were given the six questions without any additional information. Each question had three possible answers, which were read out to the farmer, and only one answer was correct. The farmer was then instructed to indicate what he or she thought was the correct answer. The answer of the farmer was then indicated by the enumerator on the questionnaire. Two of the six questions were related to topics that were discussed in the PSS treatment. As such, it was expected that farmers who received the PSS treatment would do better in answering these questions correctly. Another two questions were related to topics covered in the PSSH treatment, and it was expected that farmers who were provided information in the PSSH treatment would answer these questions correctly. A final set of two questions, one on a topic related to PSS

and one on a topic related to PSSH but not explicitly covered in the treatment videos was also included. It was expected that the incidence of correct answers to these two "control" questions would not differ between the treatment and control farmers.

All multiple choice questions and the correct answers are summarized in Table 1.1. The two questions that test knowledge provided by the PSS treatment related to which plants to peg and the size of the tuber to select as planting material. The answers will be referred to in the analysis below by variable names *sel1* and *sel2* respectively. To test the effectiveness of the PSSH treatment, the first question related to which lighting conditions seed potatoes should be stored in. The second question asked how seed potatoes should be stored. The answers to these questions were recorded in variables called *store1* and *store2* respectively.

Of the questions on topics not explicitly covered in either the PSS or the PSSH videos, the first asked respondents to indicate which of three statements was correct. All three alternatives related to how potato seed should be treated immediately after harvest and before putting them in a store. While this knowledge was not explicitly covered in the PSSH video, it was related to Proper Seed Storage and Handling. The answers to this question were recorded as variable *gen1*. The second question asked if farmers knew where fields for seed potato production should ideally be located. While this knowledge was not explicitly covered in the PSS video, it could be categorized under Positive Seed Selection knowledge. The answers to this question were recorded as variable *gen2*.

1.3 Results

Showing extension videos on Positive Seed Selection (PSS) to farmers increased their knowledge related to seed selection practices covered in the video. The first bar chart in Figure 1.1-(a), shows the proportion of farmers that knew the largest healthy-looking plants need to be pegged for follow-up for seed selection (*sel1*). The figure revealed that about 77 percent of farmers who were not shown the PSS video were able to indicate the correct option in the

Table 1.1: Multiple choice questions used test effect of treatments on knowledge

Code	Question	Answer (correct one underlined)		
sel1	Which plants should you peg for seed selection?	The largest plants in the field that look healthy	The smallest plant in the field that look healthy	Average sized plants that look healthy
sel2	What size should a potato seed tuber be?	The larger the better	Size of an egg	The smallest ones you find
store1	Where do you store your seed potatoes?	In direct sunlight	In a dark place	In indirect light (diffuse light)
store2	How should you store your seed potatoes?	In bags that have been thoroughly cleaned with JIK	Spread out on racks or on dried grass on the floor	In airtight containers or buckets with a closing lid
gen1	Which of the following statements is correct?	Immediately after harvest, you should thoroughly wash potato seeds before putting them in storage using JIK	Immediately after harvest, you should thoroughly wash potato seeds before putting in storage using clean water	You should never wash potato seeds before putting them in storage
gen2	When picking a field for positive seed selection...	Pick a garden that is in highlands and in isolated areas	Pick lowlands with plenty of water	Pick a garden close to your house or in densely populated area

multiple-choice question. Among farmers who were shown the PSS video, this proportion increased to 86 percent. The increase was statistically significant (one-sided RI, p=.041). Similarly, the second bar chart in Figure 1.1-(b), shows that the proportion of farmers who knew that egg-sized tubers are the best seeding material was 89 percent among those who had not received the PSS treatment and 96 percent among those who were shown the video. Again, the increase in knowledge was statistically significant (one-sided RI, p=.042).

Likewise, showing videos on Proper Seed Storage and Handling (PSSH) increased knowledge about recommended storage and handling practices covered in the video. As indicated by the third bar chart in Figure 1.1-(c), only about 60 percent of participants who were not shown the PSSH video knew that seed potatoes needed to be stored in diffuse light (*store1*). This proportion increased to 88 percent among farmers who had seen the video on PSSH.

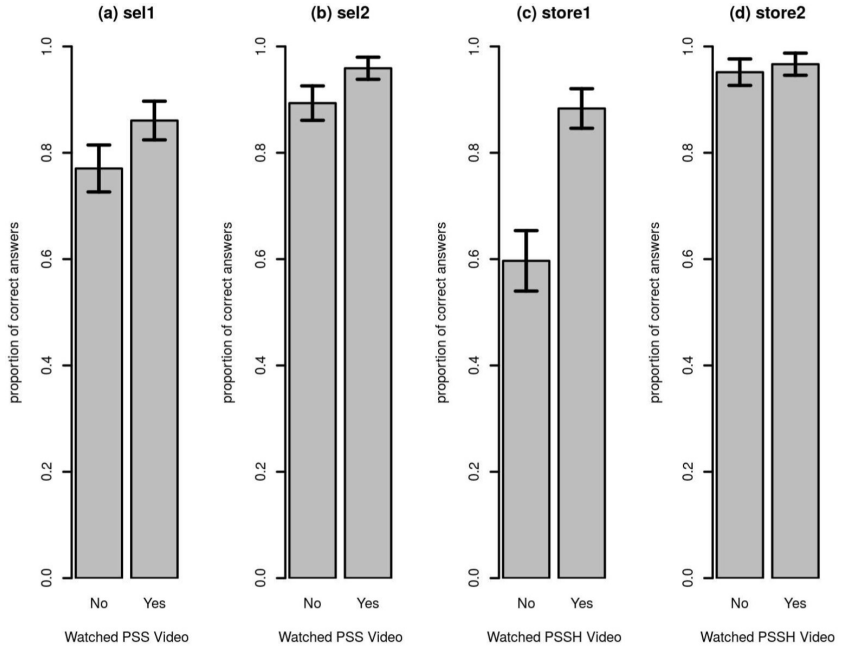


Figure 1.1: Effect of PSS and PSSH treatment on knowledge covered in videos
Figure notes: 10 percent error bars are included.

The increase in the proportion was statistically significant (one-sided RI, p<.001). Finally, as shown in Figure 1.1-(d), 95 percent of farmers who were not shown the PSSH video knew that seed potatoes should be spread out on racks (*store2*). This percentage increased to 97 percent among farmers who had seen the PSSH video, but the increase was not significant (one-sided RI, p=.372). However, to reduce the influence of outcomes with limited variation, it was specified in the pre-analysis plan that variables for which 95 percent of observations were the same value would be discarded.

Being shown any video had the potential to increase knowledge beyond what was explicitly covered in the video. For example, the first bar chart in Figure 1.2-(a) shows that farmers who received the PSS treatment were also significantly more likely to know that seed potatoes should not be washed before being stored (one-sided RI, p<.001). The second bar chart, Figure 1.2-(b), shows that the same treatment also significantly increased the likelihood of a farmer knowing that fields for planting materials should ideally be located in highlands, away from human settlements (one-sided RI, p=.006). The third bar chart, Figure 1.2-(c), shows that farmers exposed to the PSSH treatment were also more likely to know that seed potatoes

should not be washed before being stored (one-sided RI, p=.032), and the fourth, Figure 1.2-(d), shows they also knew fields for planting materials should ideally be located in highlands (one-sided RI, p<.001). This effect was also present when outcomes on knowledge related to one treatment were compared between groups based on the other treatment: farmers who received the PSS treatment score significantly better on *store1* and *store2* than those who had not, and farmers who received the PSSH treatment score significantly better on *sel1* and *sel2*.

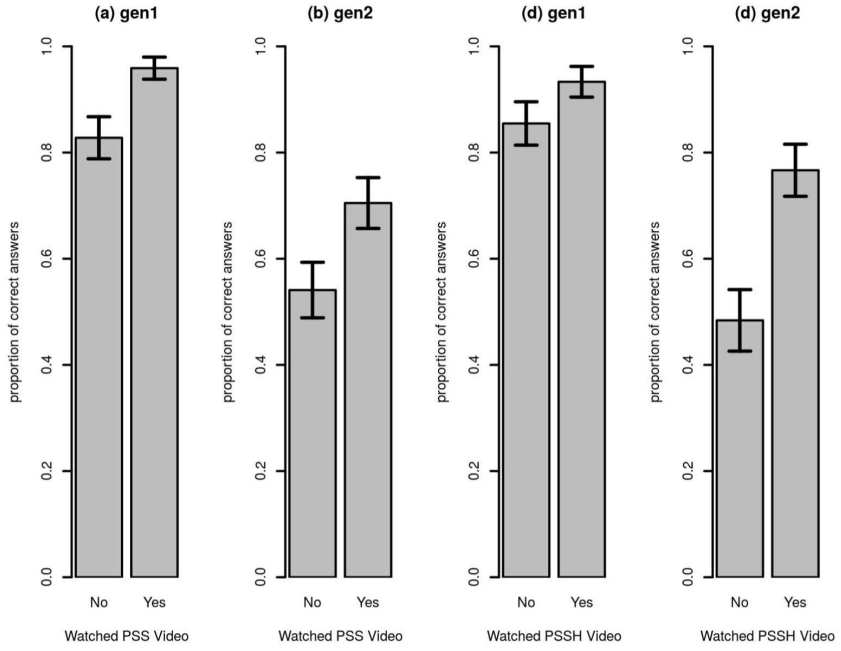


Figure 1.2: Effect of PSS and PSSH treatment on knowledge not explicitly covered in videos
Figure notes: 10 percent error bars are included.

To account for the clustering due to the block matching procedure, regressions using a within-block specification were also run (see equation 1.1). The estimates of the average treatment effects can be found in Table 1.2 and were consistent with the findings in Figures 1.1 and 1.2. For instance, the PSS treatment induced an increase of 9 percentage points in the proportion of farmers who answered correctly on the first seed selection knowledge question. This was exactly what was found in the simple means comparisons above, but the standard error was slightly higher, leading to a p-value of .05. The effect of PSS on the second question related to seed selection was also estimated at 7 percentage points, and this

time the inclusion of block fixed effects reduced the standard error. Also consistent with the means tests, the PSSH treatment had a large and significant effect on knowledge related to storage as measured by the first question, while the effect on the second question was not significant (probably due to limited variation in the outcome variable).

Table 1.2: Effect of PSS and PSSH treatments on knowledge

	sel1	sel2	store1	store2	gen1	gen2
PSS	0.09	0.07	0.28	0.02	0.13	0.17
	[0.050]	[0.012]	[0.000]	[0.165]	[0.000]	[0.002]
PSSH	0.07	0.08	0.29	0.02	0.08	0.28
	[0.091]	[0.003]	[0.000]	[0.163]	[0.010]	[0.000]

Table notes: one-sided p-values are in square brackets and were based on randomization inference, with a random sample of 10,000 permutations used. All regressions included 61 block fixed effects and a constant. PSS = positive seed selection; PSSH = proper seed storage and handling.

Again consistent with Figures 1.1 and 1.2, it was found that showing a video not only increased knowledge related to what was featured in the video, but there seemed to be a more general knowledge effect. For example, as a result of being shown either of the videos, an increase was registered in the proportion of farmers who answer correctly on the questions that were not explicitly covered in the video (*gen1* and *gen2*). Also, farmers who were shown the PSS video scored higher on *store1*, a question about PSSH practices. Similarly, the likelihood of a farmer correctly answering *sel1* and *sel2*, questions on PSS, increased by 7 and 8 percentage points, respectively, as a consequence of having been shown the PSSH video.

The results in Table 1.2 may mask heterogeneity in the average treatment effect. In particular, it may be that farmers with little prior knowledge about PSS, PSSH, or both were more likely to benefit from the information that was contained in the videos. To test this hypothesis, information collected during the baseline was used. In particular, information on farmers' reported awareness of the importance of using clean and disease-free planting materials was added in a regression to control for previous knowledge related to PSS. In

addition, information on farmers' awareness that seeds should be stored on dried grass in the shade was used to control for previous knowledge related to PSSH. This was done in the regression framework of equation (1.1) by interacting both of these variables with the treatment indicators. Results are summarized in Table 1.3. Because the study was not designed to identify heterogeneous treatment effects, and thus sample size is likely to be too small, attention is confined to the variables that display the most variation (*sel1*, *store1* and *gen2*).

The first column in Table 1.3 shows that controlling for prior knowledge substantially increased the treatment effect for the PSS treatment on *sel1*. Among farmers who were not previously aware of the importance of using clean planting materials and who did not know that seed potatoes need to be stored on dried grass in the shade, the coefficient estimate was higher than for those who did have prior knowledge as reported in Table 1.2 (0.31 compared to 0.09). The second column shows a similar response of storage-related knowledge to the PSSH video. Here, the treatment effect increased from 0.29 (see effect of PSSH on *store1* in Table 1.2) to 0.36 among farmers who reported having no prior knowledge pertaining to potato seed quality. Contrary to what was found in Table 1.2, showing the PSS video did not seem to affect knowledge on seed selection not explicitly covered in the video among farmers who had no prior knowledge on the importance of seed quality. However, columns 4 to 6 suggest that even after controlling for previous knowledge, a particular treatment may still increase knowledge about a subject not explicitly covered in the video.

1.4 Discussion

In this study, it was found that showing simple agricultural extension videos to individual potato farmers on portable devices significantly increased knowledge related to seed selection and seed storage and handling among potato farmers. In particular, showing a video that explained Positive Seed Selection (PSS) increased the likelihood that farmers knew about

Table 1.3: Effect of PSS and PSSH treatments on knowledge, controlling for previous knowledge

	sel1	store1	gen2	gen2	sel1	store1
PSS	0.31		0.13			0.36
	[0.017]		[0.203]			[0.011]
PSSH		0.36		0.32	0.24	
		[0.011]		[0.022]	[0.055]	
knowPSS	0.09	-0.04	0.05	-0.10	0.08	0.06
	[0.217]	[0.778]	[0.120]	[0.773]	[0.288]	[0.249]
knowPSSH	0.12	0.00	-0.23	-0.08	0.09	-0.07
	[0.055]	[0.138]	[0.743]	[0.141]	[0.104]	[0.376]
knowPSS*PSS	-0.12		-0.14			-0.07
	[0.832]		[0.831]			[0.689]
knowPSSH*PSS	-0.17		0.17			-0.05
	[0.862]		[0.176]			[0.622]
knowPSS*PSSH		0.05		0.05	-0.11	
		[0.358]		[0.377]	[0.808]	
knowPSSH*PSSH		-0.15		-0.08	-0.13	
		[0.821]		[0.671]	[0.800]	

Table notes: one-sided p-values are in square brackets and were based on randomization inference, with a random sample of 10,000 permutations used. All regressions included 61 block fixed effects and a constant. PSS = positive seed selection; PSSH = proper seed storage and handling.

the methods explained in the video. Similarly, showing a video that demonstrated Proper Seed Storage and Handling (PSSH) increased the likelihood that farmers knew about the information explained in the video. This finding suggests that agricultural extension videos are an effective tool for accurate transmission of homogeneous information from a technical source to a low-literacy population, for instance when a technical expert or high-quality trainer is not available or too expensive.

In addition to a direct effect, it was also found that showing a video displaying methods related to a particular aspect of potato growing increased knowledge in general. For instance, showing a video about PSS methods increased knowledge related to seed selection that was not explicitly shown in the video, such as the ideal location for the seed production field. Similarly, showing a video about PSSH increased knowledge related to storage and handling not covered in the video, such as the importance of keeping potatoes dry. Even more, showing

a video on one topic, for instance on Seed Selection, increased knowledge in another topic, such as Seed Storage and Handling.

There may be different reasons for such indirect effects. First, they might have been be due to poor design of the treatments. One treatment might have inadvertently contained information that gave the farmer clues about knowledge explicitly shown in the other treatment (and thus associated with the other treatment). For example, when the PSS video explained that tubers should look healthy and one should keep only tubers with at least four eyes (5:27-5:43 minutes into the PSS video), the farmer in the video was shown to be selecting from potatoes that were stored on racks in diffuse light. This might have given viewers clues about proper storage and handling, increasing their likelihood of picking the correct option for the question that was intended to measure the information given on PSSH (*store2*).

Second, the above may suggest that farmers went beyond simply repeating what was shown in videos, and engaged, to some degree, in a process of abstraction (learning concepts from examples) whereby they applied insights gained in one context in a different context. For example, recommending that potato seeds be stored away from other crops, animals, and humans, as was done in the PSSH treatment (4:03-4:11 minutes into the PSSH video), may have raised farmers' awareness about abstract concepts of hygiene and separation in the context of seed potatoes. This in turn might have prompted farmers to pick the answer from *gen2* most in line with those concepts, namely that the potato seed field should ideally be in a remote place high in the mountains. In cognitive psychology, this type of learning is known as schema abstraction, which posits that knowledge is an abstraction of different memory traces, each representing a specific experience in our lives (Hintzman, 1986). In this sense, the videos can be interpreted as experiences that teach farmers something about relevant concepts in their profession.

Third, and perhaps most interestingly, it may be possible that farmers already possessed some of the information needed to identify the correct alternative in the multiple-choice questions, but that a video was needed to trigger the farmer to actually use this information

when confronted with the multiple choice questions. For instance, it might have been that a farmer was aware of the recommended practice (through having received extension services in the past for instance), but based his or her actual response on what the customary practice was. Being shown a video in which a fellow farmer talked about the virtues of a range of modern techniques may have served as a visual and auditory cue for the information the farmer already possessed. This finding is consistent with knowledge about the cognitive capacities of human beings (Tulving, 1972). In particular, it suggests the usefulness of video messages to trigger associative recognition and cued recall, which involves retrieval of memory or recognition of previously encountered events, objects, or people with the help of cues and associations (Tulving and Pearlstone, 1966; Mandler, 1980). Alternatively, being shown a video might have confirmed the knowledge the farmer had, making him or her more confident to use it. In this way, a simple reminder might both validate information a farmer had but had not applied, or might have served to make it more salient. This is consistent with the finding that receiving information from a trusted source positively affected take-up of rainfall insurance among smallholders in India (Cole et al., 2013) .

This last explanation, the apparent activation of latent agricultural knowledge by showing short videos to farmers, is undoubtedly the most interesting outcome of this study and deserves to be explored more in detail. It seems to suggest that, while videos can be of value in itself (and especially in contexts where it is difficult or prohibitively costly to implement full-scale extension services), they work best when complementing previously acquired extension information. This could potentially have considerable implications for the way in which extension services are organized in the developing world today. In addition, the insights emanating from this paper represent an important addition to the agricultural technology adoption literature.

First, since the results indicated the importance of latent knowledge, it could be argued that videos will be most effective in contexts where farmers already have some notion about the techniques explained. They could have acquired this information through extension ser-

vices, through interaction with experts or simply through word-of-mouth. This suggests that videos will work best when they deal with traditional crops for which the information base is unavoidably larger, rather than for newly introduced crops or varieties. Since it has been argued that extension efforts should especially be focused on new techniques and crops (Glennerster and Suri, 2015), there has been a tendency to overemphasize those in practice. However, the results in this paper highlight the importance of not neglecting profitable existing, traditional or simple techniques that simply require further reminders and encouragement. In that sense, this is consistent with the findings in Hanna et al. (2014), who showed that farmers "fail to notice" some important elements in the information they already possess. As has been shown here, videos may be the perfect tool to bring out that knowledge and make farmers more confident in applying it.

Second, the results in this paper demonstrated that videos could be effective in reinforcing previously acquired knowledge or beliefs, but that they might be less suited to deal with existing, but unprofitable or even harmful traditional beliefs and superstitions. Previous studies have shown that providing people with information that contradicts their beliefs might actually do more harm than good. For instance, in the context of health care, Rogers (2003) described the failed diffusion of boiling drinking water in a village in Peru simply because of the negative association between hot water and illness. So, in designing an intervention, one should always be considerate of the type of knowledge already present at the local level. If it is in line with the recommended practices, videos (or other simple methods) might represent a viable alternative to more costly extension services. However, if beliefs have to be changed, more extensive methods are probably required.

Third, social networks matter. This study had the benefit of being able to target farmers directly and individually, thus allowing the pure knowledge effect of the video to be captured. However, when such an intervention would be scaled up, this would not be feasible nor desirable. In most instances, groups of farmers would be shown the video at the same time, unleashing social interactions which might reinforce or reduce the impact of the video.

As such, it is crucial to consider the social context in which the intervention will take place. For instance, when a certain community is organized along strict hierarchical lines, it is instrumental to get the leaders on board. If their beliefs or agenda do not coincide with the information provided, videos will not be effective (see also previous paragraph). The importance of social networks in agricultural knowledge adoption is illustrated by the expanding experimental literature on the subject (Beaman et al., 2014; Cai et al., 2015; Emerick, 2014).

Finally, this study focused on the use of videos to transmit agricultural knowledge, but in principle, there exist many more means to achieve the same objective. One can think of radio messages, text messages (Casaburi et al., 2014) or even educational posters. For these methods to work, the message should be clear, concise, easily understood and, perhaps most importantly, applicable to a heterogeneous audience of farmers. When the information or the technique requires a far-reaching degree of customization (as has been found to be the case for many new innovations, see de Janvry et al., 2017), standardized methods will not suffice. Again, a consideration of the social context is crucial to decide upon the form of the intervention. There should be sufficient openness towards the presented technique in the community, otherwise, the intervention will fail to achieve its objective.

The findings from this study suggest that videos are likely to become an indispensable part of the agricultural extension tool kit, sometimes replacing, but in most cases complementing traditional extension services. They also suggest that specific videos aimed at transferring narrow technical information are effective. In addition, video messages that show more general information, such as the importance of nutrient management or general hygiene to combat pests and diseases, may even be more important. Such videos may provide visual and auditory stimuli that lead to cognitive processes of schema abstraction and cued recall, which, in contrast with classic studying, has the potential to create new and longer-lasting connections between concepts (Carrier and Pashler, 1992). In addition, this research suggests that videos should be crop and context specific, featuring model farmers to maximize the potential of videos to leverage knowledge farmers already possess but may not be confident

enough to use. As such, every intervention should be preceded by an agronomic analysis as well as a study of the existing hierarchies and social networks in the communities in which the intervention will take place.

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Appendix A

Appendix A1: Supporting Information

Data

This file provides the data that was used in this study. The first column provides the treatment that the farmer received (Sel+Store, Store, Sel or Ctrl). The next six columns show if the participants to the study answered correct (TRUE) or not (FALSE) on the respective multiple choice question. The next column indicated the block number. The final two questions indicate if subjects had previous knowledge related to seed selection, and storage and handling. The data can be found here:

https://www.dropbox.com/s/2dtuz8e9fl2m4ba/data_PlosOne_VanCampenhout2016.csv?dl=0

Video: PSS treatment:

The Rufumbira version of the video that was used for the first treatment can be found here:

https://www.dropbox.com/s/7o5zcrlr1hvw3m7/moviePSS.mp4?dl=0

A version of the same video was also produced in the Rukiga language. This video can be found here:

https://www.dropbox.com/s/xt5uahqa02m3vmq/moviePSSRukiga.mp4?dl=0

Video: PSSH treatment:

The video that was used for the second treatment in the Rufumbira language can be found here:

https://www.dropbox.com/s/bg0ks15uomr70m9/moviePSSH.mp4?dl=0

The version in Rukinga is available here:

https://www.dropbox.com/s/nqnm6s03gyw43iw/moviePSSHRukiga.mp4?dl=0

Chapter 2

Spoiler alert! Accounting for Spillovers in Assessing the Effectiveness of ICT-mediated Agricultural Interventions

Abstract[*]: Pervasive use of poor quality seed remains an important reason for low yields throughout the developing world. We explore ways to increase the quality of the local stock of seed tubers among a sample of Ugandan potato farmers. We do this by providing agricultural extension information on (i) how to select the best seed tubers and (ii) how to properly handle and store seed tubers until the next planting season. The information is conveyed in the form of engaging videos, shown to individual farmers on mobile devices. The relative effectiveness of the information interventions is tested using an individually randomized controlled trial with a 2x2 factorial design. However, such interventions are prone to spillovers, and there are indications that control farmers might have learned about seed selection, storage and handling through their proximity to, or contacts with farmers in the treatment group. Therefore, we model spillovers using a randomization-based framework for estimating causal effects under interference between units. Doing so, we find evidence that especially the video containing information on seed selection translated into increased awareness and adoption of recommended practices, increased probability of using improved inputs, as well as higher consumption.

Keywords: Video, extension, potato, Uganda, spillovers, seed quality

[*]This chapter is co-authored with Bjorn Van Campenhout (International Food Policy Research Institute and KU Leuven) and Wilberforce Walukano (International Institute of Tropical Agriculture).

2.1 Introduction

Throughout the developing world, the majority of smallholder farmers rely on informal seed systems (McGuire and Sperling, 2016). Seed recycling, where part of the previous harvest is used as seeding material for the next season, is often the norm. Over time, successive cycles of vegetative propagation is likely to reduce seed quality, resulting in lower yields. The effect of recycling on quality and yield varies by crop. For example, seed degeneration due to the accumulation of pathogens and pests in planting material has been a long-standing production challenge for Irish potato (*solanum tuberosum*) growers around the world (Thomas-Sharma et al., 2016). In developed countries, the frequent use of clean planting material derived from foundation seed safeguards quality. While guaranteeing access to quality seed should remain a key policy priority in developing countries, institutional constraints often prevent formal seed systems from having a significant impact in the short to medium term. For instance, in Uganda, a report established that only 34 percent of the amount of high-quality potato seed needed is being produced (Mbowa and Mwesigye, 2016). The time and effort it takes to produce high-quality foundation seed also depends on the crop, which is particularly salient in the case of potato as a single potato plant only produces a limited number of tubers.

We argue that in this context, policies and programs aimed at maintaining the quality of the seed stock may be an important second best solution. Hence, in this study, we investigate the effectiveness of an information campaign to improve the quality of seed tubers among potato growers in Uganda through two farm level interventions: one aimed at improving seed selection and another at improving seed storage and handling. The causal effect of both interventions is then established through a field experiment implemented in southwestern Uganda.

Our study also explores the potential for ICT-mediated video in agricultural extension information campaigns targeted at individuals, rather than groups. Audiovisual messages have become common in agricultural extension as a tool to demonstrate improved farming

practices to potentially illiterate farmers. One popular application of videos are so-called Video Viewing Clubs (VVCs) where farmers are brought together to watch instructional videos and participate in facilitator-led discussions afterwards (David and Asamoah, 2011). In recent years, for instance, a non-governmental organization called Digital Green facilitated the production and dissemination of more than 5,000 locally relevant agricultural extension videos in more than 50 languages (Bernard et al., 2015; Gandhi et al., 2009; Van Mele et al., 2010; Zossou et al., 2009). However, in general, video plays only an ancillary role and extension advisory services are still heavily skewed to the traditional teacher-student model. With smartphones and other viewing devices becoming more widespread (penetration of smartphones is predicted to reach 67% by 2025 in Sub-Saharan Africa), the potential for videos to be used as a stand-alone tool in agricultural extension is increasing rapidly (Fabregas et al., 2019; Van Campenhout et al., 2020). In this paper, we mimic the conditions in which farmers would watch a video privately in their home on their smartphone, tablet or computer (as if they would watch a video on YouTube, for example) contributing to building the evidence base on the use of independent video messages targeting individuals.

Our paper also fits within the growing literature on interference in agricultural experiments and experimental design more broadly. Randomized controlled trials (RCTs) are ubiquitous, especially in development and agricultural economics. A common problem in many experimental settings is interference (or spillovers): the fact that a given subject's outcomes are not only influenced by its own treatment but also by the treatment in its social or geographical surroundings (Cox, 1958). If there is interference, the stable unit treatment value assumption (SUTVA) is violated and simple comparisons between treatment and control will be biased (Rubin, 1990). Understanding how treatment administration influences untreated subjects is important in the evaluation of many different programs such as the provision of cash transfers (Barrera-Osorio et al., 2011), learning about a new technology (Conley and Udry, 2010) and public health programs (Miguel and Kremer, 2004). The issue of interference and social networks is particularly salient in information campaigns aimed at

stimulating technology adoption, as the inherent intangible nature of the provided treatment makes it hard to track the flow and the direction of spillovers (Bandiera and Rasul, 2006; Conley and Udry, 2010).

As can be expected in an information experiment targeting individuals in close-knit communities, looking at the information flows between farmers in our sample, we find important indications of interference between treatment and control. While some experiments try to account for possible interference in the design phase of the experiment using partial population experiments (Duflo and Saez, 2003) or randomization saturation designs (Hudgens and Halloran, 2008 and, more recently, Baird et al., 2018), we incorporate spillovers ex-post. More specifically, we use a randomization-based framework for estimating causal effects under interference between units developed by Aronow and Samii (2017), which uses re-randomization to estimate probability weight corrections for spillovers of arbitrary but known form. When spillovers are taken into account in this way, using farmers' locations to determine how information travels, we find that the seed selection video in particular leads to the adoption of recommended practices, a higher use of improved inputs, and higher welfare. The lack of positive results emanating from the seed storage video may be explained by the precedence of cash and credit constraints.

The remainder of the paper is organized as follows: in Section 2.2, the experiment is motivated and the context is described. We also focus on the content and the implementation of the two video treatments. Section 2.3 then outlines the design of the experiment, the data collection process and the considered outcomes. It also presents the methodology used to model spillovers. Section 2.4 focuses on the results. We first look at farmers' appreciation of the videos after which we show the results taking spillovers into account. After a broad overview of the results, we unpack the different possible channels through which these might have materialized. We further provide evidence on the accuracy of our spillover specification and the robustness of our results. Section 2.5 provides a summary of the main results and what they could mean for agricultural research and decision-making in developing countries.

2.2 Setting and Treatments

We test the effectiveness of audiovisual information campaigns aimed at improving seed quality among a sample of potato farmers in Uganda. In Uganda, Irish potatoes (*solanum tuberosum*) are important both as a cash crop and for home consumption (FAO, 2015). Crucially, however, potato seed is particularly vulnerable to seed degeneration (Thomas-Sharma et al., 2016).[1] At the same time, seed potato breeding is a slow process, and the government organization responsible for the production and distribution of foundation seed to private seed multipliers, the Kachwekano Zonal Research and Development Institute (KAZARDI), is struggling with severe capacity limitations.

Our study population consists of potato farmers in the southwestern Kigezi region in Uganda, which accounts for about 47 percent of total potato production in the country (UBOS, 2010). Baseline data collected from 500 potato farmers in 2013/14 reveals that the majority of farmers in the area are smallholders with an average area allocated to potatoes of about 0.2 hectares.[2] They are not trading exclusively in potato: in terms of value sold, the crop accounts for an average of 51 percent of total gross agricultural revenue. Many farmers use fertilizer (40%) and hire in labor (35%). Median yields in the area amount to about 3 metric tonnes (MT) per hectare, considerably less than what can be achieved in these agro-ecological conditions (25 MT per hectare according to Fermont and Benson, 2011). Seed recycling as a practice is widespread in the area: on average (across two agricultural seasons) 60 percent of farmers report using part of their own harvest as seeding material for the next season. Further, Figure 2.1 shows that seed quality is indeed an important constraint in the context of our study. The farmers with the highest yields in the sample are also those that use high quality propagation (seeding) material. The benefits of applying fertilizer seem

[1] It should also be noted that potato seed management in Uganda is severely hampered by the presence of bacterial wilt, which can be soil-borne or seed-borne and further complicates farmers' efforts to improve seed quality.

[2] This sample was obtained using a two-stage sampling procedure. In the first stage, Enumeration Areas (EAs) were selected proportional to the size of the population in different villages. In the second stage, potato farming households were selected randomly within the selected EAs.

smaller in the study context.

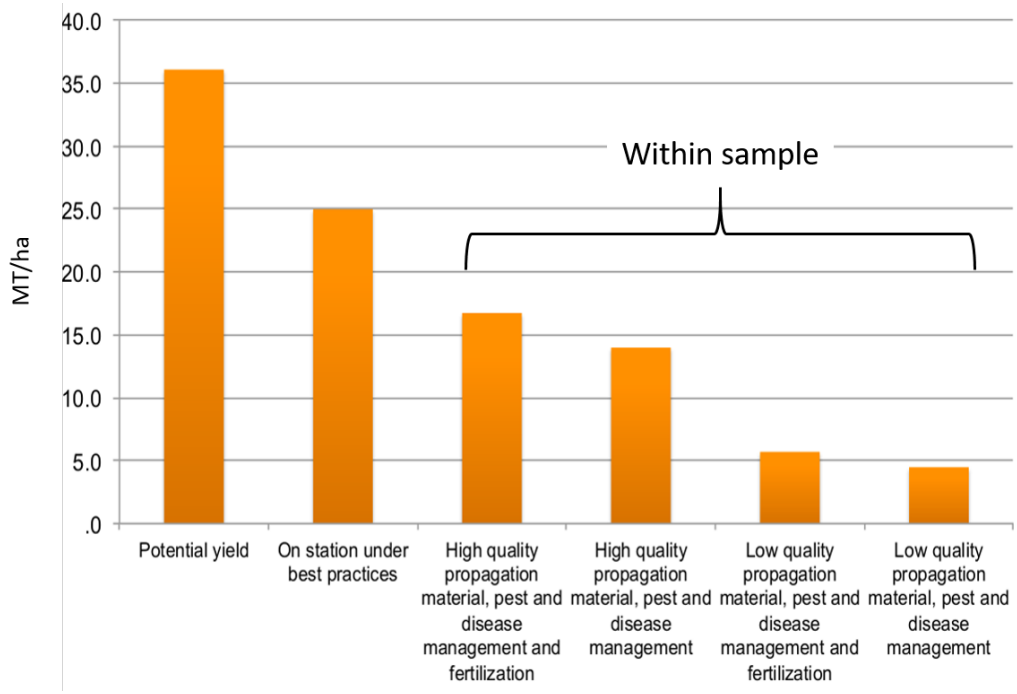


Figure 2.1: Yields (in MT/hectare) obtained under different conditions (source: Van Campenhout et al., 2016)

After extensive consultations with local farmers, extension agents, potato experts and local officials, it was decided to focus on simple, low-cost, but potentially effective messages that could be conveyed using video and that could be implemented by even the most cash- or credit-constrained farmers. Two videos were produced, corresponding to two important, but clearly separate issues that each have an impact on the quality of recycled seed. Both videos are aimed at providing farmers with more information on the trade-off they face between welfare now (consuming or selling the best potatoes now) and potentially higher welfare later (foregoing consumption and sales now by saving some of the good potatoes as planting material for the next season). Of course, in addition to a lack of information, there may be many other reasons why farmers decide to not implement certain changes (such as cost or potatoes only representing a limited share of income), but these are considered beyond the scope of this paper.

A first video promotes Positive Seed Selection (henceforth referred to as the PSS treat-

ment) as a response to the observed practice where farmers consume or sell the best tubers first and as a consequence are left with inferior seeding material for the next planting season. PSS denotes careful selection of only the best potatoes as seed for the subsequent season. This process of PSS already starts during the growing stage of the seed potato in the preceding season. At this stage, the most vigorous plants should be earmarked for the production of seed tubers. Therefore, a first key message in the PSS video is that, during the growing season, potato plants that show the least evidence of disease (i.e., the tallest plants that do not have curled, yellow, or deformed leaves) should be pegged (with a wooden stick for example), and farmers are encouraged to keep checking these plants thoroughly for signs of disease up until the moment of harvest. A second key message is related to the actual selection of the tubers: at the time of harvest, farmers are advised to harvest the pegged plants first and keep only potatoes that have roughly the size of an egg, exhibit no signs of disease, and have at least four eyes (which offers an indication of the number of stems that will sprout from it).

Several (agronomic) studies have already demonstrated the effectiveness of PSS. For example, Kakuhenzire et al. (2012) find large and positive effects of PSS among potato farmers in both Uganda and Kenya, citing yield increases of 19 and 52 percent respectively compared to farmer selected seed. They further argue that the reported increases in productivity translate almost entirely into higher profitability given the limited variable costs involved in implementing PSS (the wooden sticks and the time required to do the selection). Gildemacher et al. (2011) show that in on-farm trials in Kenya, PSS increases yields by 34 percent. In follow-up research, Schulte-Geldermann et al. (2012) find that positive selection reduces the incidence of several viruses that affect potato seeds. However, most of these studies are largely agronomic in nature. In this study, we want to go beyond the boundaries of the trial field and also focus on the adoption of the methodology in a more realistic setting.

The second treatment video promotes Proper Seed Storage and Handling (henceforth referred to as the PSSH treatment), focusing on what happens with seed potatoes between

the moment of harvesting and planting. Key informant interviews show that farmers tend to store seed in bags in a dark corner inside the house without proper ventilation, increasing the likelihood of tuber rot and dormancy. The second video thus contains several key messages to improve storage and handling of seed tubers. First, seed potatoes should be spread out on racks or on dried grass on the floor. Second, potatoes should be kept in a separate store or room, away from other crops and animals. Third, potatoes should be stored in well ventilated and diffuse lighting conditions. And finally, clean materials should be used when handling seed potatoes to reduce contamination.

Less is known about the impact of Proper Seed Storage and Handling on potato yields and farmer well-being, probably because it is less well defined and delineated than PSS. There is some evidence that storage time and temperature are important attributes for yields (Loon, 1987). Gachango et al. (2008) recommend storing seed potatoes in diffuse light in order to get short and strong sprouts, but their study stops short of investigating yield differences related to differing light intensity exposure. As a result, and also given the higher costs involved in altering some storage practices, the profitability implications of PSSH are less clear-cut than in the case of PSS.

The video messages feature successful model farmers. In the videos, they refer to their own experiences and talk about how using PSS or PSSH has allowed them to become successful potato farmers. The use of a role model in conveying information has been shown to be effective in many different contexts (Bernard et al., 2015; Riley, 2017; Porter and Serra, 2019; Beaman et al., 2009). Videos are produced in two local languages (Rukiga and Rufumbira) and are subtitled in English. Both videos are about 7 minutes long.[3] They were shown to individual farmers once by an enumerator using Android tablets at the beginning of May 2016, but no information was given apart from asking for their consent.[4] The experiment

[3]The PSS video can be viewed here: https://www.youtube.com/watch?v=JcacGR0EU94, while the PSSH video can be viewed here: https://www.youtube.com/watch?v=Je8qLqH5vLY.

[4]Consent was obtained orally and marked digitally on the tablet by the enumerator in order to avoid stigmatization on the part of illiterate farmers. This procedure was approved by IFPRI's Institutional Review Board (IRB) on February 2nd, 2016 (IRB Approval Number 2016-12-DSGD-M).

tried to mimic the conditions of the farmer privately watching the video. After having seen the video, the farmer was asked to answer six multiple-choice questions (two on PSS, two on PSSH and two general questions on potato farming). These were used to gauge potential immediate increases in awareness as a result of the video. Chapter 1 of this dissertation (Van Campenhout et al., 2017) reports that this is indeed the case.

2.3 Data and Methodology

2.3.1 Experimental design

Of the 500 farmers for which baseline data was collected in 2013/14, 248 potato farmers are randomly selected to take part in this study. The 248 farmers are allocated randomly to one of four treatment conditions in a randomized controlled trial with a 2x2 full factorial design: 62 farmers only watched the PSS video, 62 farmers only saw the PSSH video, 62 farmers watched both videos while another 62 farmers did not see any video.[5] The experiment is designed to only have power for testing main effects.[6] In other words, in what follows, comparisons are made between half of the sample (or 124 farmers) that have watched one of the two videos (either the PSS video or the PSSH video) and the other half of the sample that has not watched that particular video. This means that those who have watched both videos are always in the group considered as treatment farmers.

Prior to random assignment to the four treatment cells of the 2x2 design, farmers were stratified (across all villages) into groups of four through an ex-ante matching procedure (Greevy et al., 2004). Matching was performed by minimizing the euclidean distance between a set of ten baseline characteristics, including household size, age and gender of the household head, area of potatoes grown, the logarithm of potato yields and logarithm of welfare per capita. We thus end up with 62 groups of 4 matched farmers. Within each group, each

[5]There is no placebo video for control farmers, which means that some of the results in this paper could be due to the mere fact of watching a video rather than the content in those videos.
[6]In particular, the experiment is 80 percent powered to detect yield effect sizes of 2.4 MT/ha.

farmer is then randomly assigned to one of the four treatment cells (control, PSS, PSSH and PSS+PSSH). Such a procedure has the benefit of increasing statistical power, especially in small samples (Bruhn and McKenzie, 2009).[7]

2.3.2 Data

To measure the relative effectiveness of the PSS and the PSSH video treatments, all 248 farmers in the sample were re-visited one year (and two agricultural seasons) after having been shown the videos (around the end of April 2017). This paper focuses on outcomes as measured during that survey. Attrition is an issue in our sample, but not because respondents could not be located or had moved. In the year between the video treatment and the survey, 35 farmers (or about 15 percent of the sample) did not plant potatoes, generally due to poor rains. This means that for these farmers, we do not have data on outcomes related to potato farming, but only on information awareness, consumption and appreciation of the video.

One concern related to attrition is that the lost farmers would in some way be different from the remaining farmers, which could potentially mean we lose orthogonality, otherwise guaranteed by our group-wise matching strategy. To test whether there is differential attrition between treatment and control and whether attrition is independent from potential outcomes, attrition (in this case, a dummy indicating whether potatoes were planted) is regressed on treatment (one regression for PSS and one for PSSH), a set of baseline covariates and the interaction of those covariates with treatment.[8] Reassuringly, none of the baseline covariates turn out to be significantly predictive (at the 5% level) of whether or not farmers planted potatoes at endline. Likewise, an F-test of the joint hypothesis that all coefficients are equal to zero can not be rejected (p-values of 0.29 and 0.87 for the PSS and PSSH treatment

[7] More information on the sampling, matching procedure, balancing tests and the variables used in the analysis can be found in this study's pre-analysis plan which is registered at the American Economic Association's registry for randomized controlled trials (https://www.socialscienceregistry.org/trials/1014).

[8] The included baseline covariates are household size, age, literacy and years of farming experience of the household head, household welfare, whether or not the household engaged in seed recycling, used fertilizer, received training or credit, distance to the closest input provider, market, the time it takes to reach the main parcel, share of the harvest that is kept as seed and sold as ware, potato production and, finally, the share of potato sales in total agricultural revenues.

respectively). For this reason, even though it is best practice in matched designs to drop entire groups as soon as one member drops out, we can confidently keep using the entirety of the non-attrited sample.[9]

The goal of this study is to establish whether the information effects (as reported in Van Campenhout et al., 2017 and the Chapter 1 in this dissertation) persist one year after farmers have seen the video(s) and whether they translate into increased welfare for the farmer's household. The pathways through which such a change in welfare might materialize are numerous and difficult to predict ex-ante. Nevertheless, here, it is hypothesized that watching a video could directly trigger a cognitive effect emanating from an increases in knowledge due the new information that was obtained through the video. This effect might in turn engender a set of intermediate outcomes, such as the adoption of improved farming practices, the adoption of improved inputs or the intensification of available farm land. Finally, those intermediate outcomes could then lead to improvements in final outcomes such as yield, sales or consumption (as a proxy for farmer welfare). This theory of change is summarized using Figure 2.2.

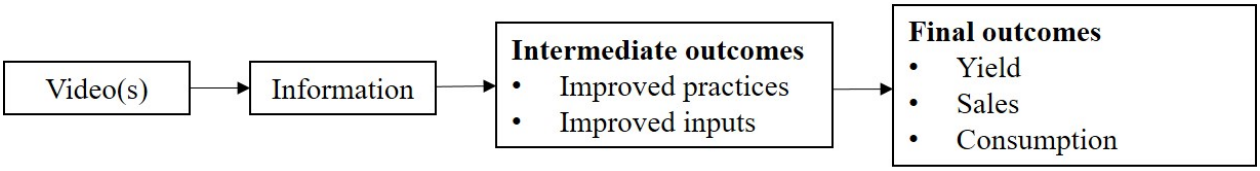


Figure 2.2: Theory of Change

To measure the transmission of information, the same six multiple-choice questions that were asked immediately after the videos were shown (or without having seen the video in the case of control farmers) are submitted again to the farmer during the endline survey. Three extra questions are added to the six existing ones (one on PSS, one on PSSH and one general question related to potato farming) to be able to distinguish between farmers learning from the video and from the quiz questions they received one year prior to the endline survey.

[9] Additionally, a (re-)balancing test of the different treatments taking attrition into account is conducted (also showing means for the different baseline covariates), the results of which can be found in Appendix B3.

Additionally, the order of the questions is randomized to prevent survey priming. The full list of questions, together with their multiple-choice answer possibilities can be found in Appendix B1.

The next set of outcomes that are considered in this study are intermediate outcomes which might be a result of increases in awareness about farming practices. A first logical consequence of increases in awareness about farming practices is the actual adoption of those practices. In line with the two treatments, farmers are asked to report which techniques they use with regards to 1) seed selection and 2) seed storage (we focus on six predetermined techniques for each treatment, see Appendix B2). To try to minimize different types of response bias, two steps are taken. First, the order in which respondents are asked all plot-related questions[10] (including those related to the different practices) and the information questions, is randomized. That way, we avoid that responses to questions in either category are primed by questions in the other category in the same way for all farmers in the sample. Second, questions about practices are first asked in the form of unaided questioning and then, for the remaining practices, in the form of aided questioning.[11] Since we find that the increase in the number of practices mentioned during aided compared to unaided questioning does not significantly depend on treatment, we use the results from aided questioning in the analysis.

Other intermediate results of exposure to the videos could be the adoption of better inputs or crowding-in of other investments. To measure this, farmers are asked to report both the use of chemicals, fertilizer, seed and hired labor as well as how it was acquired. For instance,

[10] All data related to inputs, yields, adoption of improved practices are collected at the plot level for the second season of 2016 (which is the season ending around November/December). More specifically, farmers are asked to list all plots on which potatoes were grown during that season. One plot is randomly picked from that list (generated by the survey program itself). As a result, all reported results relate to one random plot per farmer which on average should generate unbiased results.

[11] In the unaided part, the exact questions were: "Can you please talk a bit about how you selected the seed potatoes that were planted in the second season of 2016 for the <selected plot name> field?" for the PSS treatment and "Can you please talk a bit about how you stored seed potatoes between the first and the second season of 2016 for the <selected plot name> field?" for the PSSH treatment. Any of the six treatments not mentioned during unaided questioning were submitted to the farmer in the form of aided questioning in the following way: "Did you implement practice X during ...?"

the videos might make farmers more aware of the importance of good quality seed which might induce them to buy their seed potatoes from a recognized seed seller. Similarly, the information in the video could lead to the farmers applying more labor (their own or hired) on their plots.

Finally, these intermediate outcomes might in turn engender outcomes which have a direct impact on farmers' (and their households') welfare. First, improved practices, the use of improved inputs or the intensification of existing methods could lead to higher yields, calculated using the farmer's self-reported production and plot size. A second final outcome that is considered in this paper is commercialization, approximated here by the proportion of harvested potatoes sold on the market. This could be a result of increased yields, but also more directly of the techniques displayed in the video (like improved storage allowing sales to be spread over a longer time period). Finally, the ultimate question this paper is trying to answer is whether agricultural extension videos have the potential to increase farmers' welfare. Welfare in this study is measured by adding up the value of a household's consumption (including from own production) over the week prior to the day of interview. This is in accordance with common practice in agricultural and household economics (see, among others, Deaton, 2003). The consumption basket considered consists of the most common food items in the context (vegetables, grains, fruits, potatoes, etc.) and some more general consumption items such as airtime, personal hygiene items and cooking oil.

In order to account for the issue of multiple hypothesis testing (the probability that a false rejection of the null hypothesis increases as outcomes are added), the different questions for each category of outcomes (information, practices, input use and final outcomes) are grouped together in one index, as outlined in the pre-analysis plan. This approach, which has its origins in the biostatistics literature (O'Brien, 1984), has the added benefit of being able to show whether or not our treatments have a general effect on a set of broad categories. Following Anderson (2008), the following steps are undertaken to construct indices for each category. First, each single outcome is standardized by demeaning its value and dividing

by the standard deviation of the control group. Second, weights for each outcome are obtained using the inverted variance-covariance matrix of the standardized outcomes. Finally, indices are constructed as weighted averages of the standardized individual outcomes in each category.

2.3.3 Modeling spillovers

While treatments at the individual level yield highest statistical power, such designs are prone to spillover effects. A control farmer in the PSS experiment may live close to a farmer that received the PSS treatment, and learn from observing his or her behavior. A farmer that did not receive the PSSH treatment may have social ties with a farmer that did get to see the PSSH video, and learn from it through discussion. In both cases, spillover effects are likely to be positive: As the farmer in the control group also benefits from the treatment, his or her outcome variables are likely to change in the same direction as the outcomes of the treated farmer. This would result in a downward bias in the estimated average treatment effect.

To be able to assess how information from the videos would spread in the different villages, a separate, specific module on farmers' networks was included in the endline survey. More specifically, farmers were asked two questions for each other farmer in their village that was also part of the study: whether or not they knew the other person and if so, whether or not a video was discussed with that person.[12] A first look at this data offers an indication that spillovers might indeed be an issue in the sample. Each farmer reports knowing on average six other farmers in the sample (which amounts to about 80 percent of the within-village sample) while 58 percent of respondents have discussed one of the videos with someone else (in the village). More importantly for the purposes of our analysis, about a third of treatment farmers report having discussed the video with at least one control farmer, showing it is necessary to take spillovers into account.

[12]Reference to the video was kept deliberately vague to not overly confuse the control farmers who of course had not seen any video.

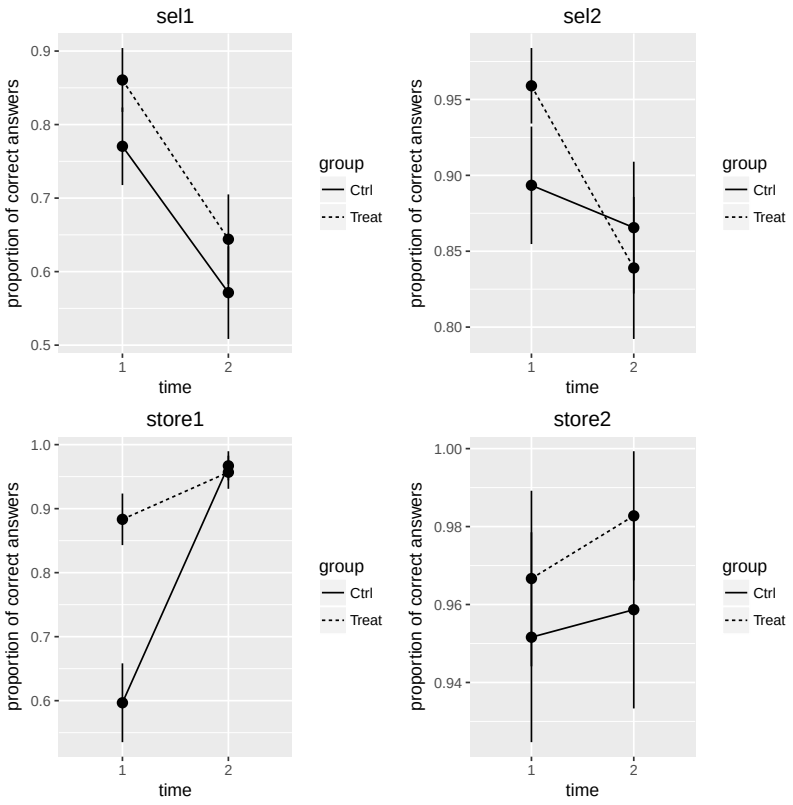


Figure 2.3: Evolution of information awareness over time

The evolution of the information effect over time also supports the assumption of substantial spillovers. In Figure 2.3, the proportion of correct answers for four questions in the survey (two related to seed selection and two related to seed storage) is shown both at the time when farmers saw the video (time 1) as well as at the time of the endline survey (time 2). Particularly for questions where there is a significant difference in knowledge immediately after having been shown the video (sel2 and store1), the difference between treatment and control reduces over time.[13] Especially information on lighting conditions (store1) seems to have spread within the communities: while immediately after showing the video, only about 60 percent of farmers in the control group knew potatoes should be stored in indirect light, this group has caught up with the control group by the time of the follow-up survey (one year later). In a similar study where rice farmers are provided agricultural extension information using video, control farmers also catch up over time in terms of awareness of information

[13]Questions and answering possibilities can be found in Appendix B1.

about what is shown in the videos (Van Campenhout, 2019).

To assess which farmers are affected by spillovers, the data provides us with two options: we could either use farmers' locations (using Global Positioning System (GPS) coordinates) or the social network questions from the survey. Together, these sources of data provide us with village-specific spillover information on two levels: geographic and social. It is difficult to establish which of the two specifications represents the best approximation of actual spillovers. On the one hand, it could be argued farmers are most likely to learn from the farmers in their social network (i.e., social learning), which would lend the most credence to the specification using survey data. On the other hand, one could also claim farmers do not need to know fellow farmers in order to be able to copy their methods (i.e., observational learning), which would validate the GPS specification.[14] Most likely, in reality, both are occurring, with some farmers learning techniques from their social network and others from observing nearby farmers. However, given that social networks are likely to be endogenous (having a wide social circle might be related to agricultural outcomes beyond the impact of the videos), we opt to use only farmers' locations to define spillovers.

To incorporate spillovers in our analysis, we divide the sample in four mutually exclusive treatment-spillover conditions (for both the PSS and the PSSH treatment) that are a function of both farmers' own treatment assignments and the treatment assignments of farmers around them. This is captured using d_{xy}, where x refers to a farmer's own treatment assignment (0 or 1) and y to whether that farmer is subject to spillovers (again, 0 or 1). A farmer is in a spillover condition (y gets a value of 1) as soon as there is one treatment farmer in his or her neighborhood. The first group consists of control farmers with no treatment farmers around them. We call this group the pure control group (d_{00}). Second, in the direct treatment group (d_{10}), farmers have been assigned to the treatment while all others in their neighborhood are assigned to the control. Both the pure control group and the direct treatment group are

[14] While geographic proximity is not necessarily a good proxy for the transmission of information (Chandrasekhar and Lewis, 2016), it is more likely to apply in the adoption of easily observable agricultural techniques (like pegging plants for instance).

thus unaffected by spillovers. Third, the contaminated control group (d_{01}) consists of control farmers that are subject to spillovers because there is at least one treatment farmer within their vicinity. Finally, there are farmers that are assigned to the treatment with at least one other treatment farmer close to them (d_{11}), called the contaminated treatment group. Consequently, the farmers in the latter two groups are said to be in a spillover condition.

To define the spillover radius (the area within which spillovers are assumed to occur), we use farmers' locations (GPS coordinates recorded at the time of the intervention). We construct a euclidean distance matrix and define a geographical spillover radius based on a (somewhat arbitrary) distance threshold that gives us sufficient variation in terms of farmers in different conditions.[15] The resulting number of observations in each group is $\{d_{00}, d_{10}, d_{01}, d_{11}\} = \{53, 69, 50, 72\}$ for the PSS treatment and $\{d_{00}, d_{10}, d_{01}, d_{11}\} = \{49, 75, 56, 64\}$ for the PSSH treatment. As shown in Appendix B4, balance on baseline variables across these newly defined groups (for both treatments) is largely maintained. One notable exception is the fact that farmers in the direct treatment and the contaminated treatment groups for the PSSH treatment appear to have already had a higher potato production at baseline.

This approach is underpinned by three assumptions. First, it assumes that the treatment assignment of farmers outside of a farmer's specific spillover radius have no effect on the latter's outcomes. Only control farmers who live within the spillover radius of a treatment farmer can have learned about the techniques in the videos. Second, by considering farmers to be in a spillover condition as soon as there is one treatment farmer in their spillover radius, we cannot assess how effect sizes might vary with the number of treatment farmers in the vicinity. Finally, we are assuming that the spillover radius that gives us a good variation in terms of farmers in different conditions is also the distance within which information has traveled in the experiment. The extent to which these three assumptions are met will be examined in Section 2.4.3. As an illustration of our approach, Figure 2.4 demonstrates the spillover specification visually for one of the villages in our sample, which is not necessarily

[15] It is fixed at around 290 meters by first calculating the median distance between farmers within each village, taking the average and dividing by 2.

representative for the other villages in the experiment. When farmers are in each other's circle, they are said to be in a spillover relation with one another. Based on the social network data in the survey, a line between two farmers indicates that they discussed the video with each other. Figure 2.4 thus also shows there is a degree of overlap between farmers' locations and social networks and that using locations in the analysis to an extent also serves as a proxy for social networks.



Figure 2.4: Treatment (dark and light dots refer to pure control and any treatment farmers respectively) and spillover conditions (circles and lines refer to the GPS and the network data respectively) of farmers in one sample village

After defining these four groups, one could simply compare differences in outcomes between the direct treatment group (d_{10}) and the pure control group (d_{00}) to estimate the video treatment effect as if there were no spillovers, and compare the contaminated control (d_{01}) to the pure control group (d_{00}) to get an idea of the spillover effect. However, we have to take into account that, even though the treatment was assigned randomly, the likelihood of being in a particular spillover condition also depends on the location of the farmer within the village. For example, as half of the farmers in our sample were exposed to the PSS treatment, the probability of a farmer being in the control condition is 50 per-

cent. However, the probability that this control farmer has been exposed to the treatment through spillovers increases with the presence of other treated units in its proximity. Therefore, when estimating treatment effects in the presence of possible interference, one needs to account for these differential probabilities of exposure to the treatment. To do so, we use a general, randomization-based framework for estimating causal effects under interference between units, as proposed by Aronow and Samii (2017). To map treatment assignments into treatment exposure, an adjacency matrix is constructed whereby the relationship between each of the different experimental units under consideration is defined. In our case, as outlined above, this matrix is based on geographical distance between the units. The adjacency matrix, in combination with the treatment assignment, is then used to define an exposure mapping where each unit is assigned to the different exposure conditions $(d_{00}, d_{10}, d_{01}, d_{11})$ with a certain probability (based on the number and the treatment assignment of units in their proximity). Finally, averages of outcomes in different exposure conditions can then be compared taking into account these probabilities, using, for instance, inverse probability weighting (IPW).[16]

For each unit, probabilities of being in a certain spillover condition are estimated using re-randomization. Using (a sample of) all possible random treatment assignments (within groups to take into consideration the matched group design), for each treatment assignment, farmers are categorized into one of the four exposure categories defined above (d_{00}, d_{01}, d_{10}, d_{11}). The probability that a particular farmer gets assigned to a particular group can then be calculated by simply counting the number of occurrences in each group and dividing by total number of possible random treatment assignment (or the size of a random sample thereof). These probabilities are then used for inverse probability weighting (IPW) in regression models of pairwise comparisons between outcomes of the different exposure conditions. For instance, one can compare outcomes of the pure control (d_{00}) with the direct treatment group (d_{10}) to

[16] As such, this methodology can be considered a more specific version of propensity score matching whereby outcomes of treatment and control farmers with a similar numbers of farmers in their spillover radius would be compared.

see what the impact without interference would look like, but one can also compare the pure control (d_{00}) to the contaminated controls (d_{01}) to estimate the size of the spillover effect.

2.4 Results

2.4.1 Appreciation of video treatments

Before delving into the actual results of this study, it is worth considering farmers' level of appreciation for the videos, summarized in Table 2.1. Results are reported for the whole sample (first column), as well as for the PSS and PSSH video separately (second and third column respectively).[17]

Overall, farmers' experiences with the two videos are positive. Almost all farmers find the videos useful, while rating the quality of the video at about 4.5 out of a possible score of 5. Most farmers report having learned new things (47%) or feeling more motivated (42%) through the videos, which validates the theory of change outlined above. When asked what they remember about the video, a vast majority (almost 80%) refer to the general content of the video (i.e., that it was related to potato farming) while many (between 62% and 67%) also recall the specific topic of the video (PSS or PSSH). The use of a model farmer in the video seems to have increased the credibility of the information provided: more than 90% of farmers indicate they trust the person in the video. A couple of questions about the contact of treatment farmers with other farmers are also included, complementing the village-specific network data (see Section 2.3.3). A majority (about 70%) have talked to other locals (family members, neighbors or fellow farmers) about the video. Those that have talked to others, have talked to about 6 people, discussing mostly general content (rather than specific details). Interestingly, the willingness to pay for such videos is quite high (about 80% of farmers). As a comparison, only 16 percent of farmers report being willing to pay for extension services

[17]Since these questions were not asked to control farmers, they can only be used for descriptive analysis. As there is overlap between those who saw the PSS and those who saw the PSSH video, it is possible to have a lower mean for the total sample than for either video separately.

in general at baseline. Finally, about a quarter of farmers would be able to access the video independently, a number which is likely to increase drastically in the coming years.

Table 2.1: Video experience descriptive statistics

Statistic	Total	PSS video	PSSH video
Remember topic (%)	88.11	88.62	89.34
Remember specifics (%)	63.24	62.70	67.21
Video useful (%)	92.43	93.50	92.62
Why useful?			
Learned something new	47.37	45.22	50.44
Motivated me	42.11	37.39	44.25
Confirmed what I knew	30.99	32.17	31.86
Rating (0-5)	4.46	4.49	4.46
Trust person in video (%)	92.97	94.31	94.26
Contact with others			
Yes/No	68.65	70.73	70.49
How many?	5.95	6.09	6.69
Willing to pay (%)	81.08	77.24	85.25
Possible to watch (%)	23.78	24.39	22.95

Notes: PSS=Positive Seed Selection, PSSH=Proper Seed Storage and Handling. Descriptive statistics are based on 185 observations.

2.4.2 Main results

To first account for spillovers in a simple way, Table 2.2 shows pairwise comparisons (including group fixed effects) of the pure control group (d_{00}) with each of the other exposure conditions: the contaminated control group (d_{01}), the direct treatment group (d_{10}) and the contaminated treatment group (d_{11}) for the different outcome indices (information awareness, adoption of practices, input use and final outcomes), as described in Section 2.3.2. It is clear that, generally speaking, the effect sizes of both video treatments are larger as subjects have interacted more with the video. That is, comparison coefficients are larger for farmers who have seen the video directly than for control farmers who live close to a treatment farmer but have not seen the video themselves. Likewise, farmers who have both seen the video and live close to another treatment farmer fare better than those who saw the video but did not get a chance to discuss with other treatment farmers. Table 2.2 also shows a significant effect of

the seed selection video on the adoption of improved practices.

Table 2.2: Main results (outcome indices) with spillovers - simple pairwise comparisons between groups

	PSS				*PSSH*			
	d_{00}(mean)	d_{01}	d_{10}	d_{11}	d_{00}(mean)	d_{01}	d_{10}	d_{11}
Information awareness	-0.022	-0.221	0.203	0.069	-0.145	0.223	0.079	0.244
(3 questions per treatment)		(0.209)	(0.220)	(0.197)		(0.216)	(0.225)	(0.212)
Adoption of practices	-0.260	0.289	0.420*	0.495**	-0.154	0.141	0.124	0.155
(6 per treatment)		(0.250)	(0.254)	(0.232)		(0.233)	(0.245)	(0.238)
Input use	0.028	-0.113	0.164	-0.171	0.039	0.020	0.115	-0.087
(fertilizer, chemicals, hired labor)		(0.220)	(0.223)	(0.205)		(0.217)	(0.229)	(0.222)
Final outcomes	-0.038	-0.126	0.190	0.003	-0.132	0.057	0.212	0.063
(yield, proportion sold, consumption)		(0.234)	(0.237)	(0.220)		(0.230)	(0.242)	(0.238)
N	53	69	50	72	49	75	56	64

Notes: PSS=Positive Seed Selection, PSSH=Proper Seed Storage and Handling. First column (per video treatment) shows mean in pure control group and other columns show differences with the pure control group. Dependent variables are indices of different survey questions pertaining to a given outcome category. All regressions include group fixed effects. Standard errors are in parentheses. *, **, *** denote significance at the 10, 5 and 1 percent level respectively.

While these results provide an indication of the role of spillovers in the sample, simple pairwise comparisons fail to take into account the fact that the assignment of farmers to each of the exposure groups is not randomized, as outlined Section 2.3.3. So, in what follows, we adopt the framework of Aronow and Samii (2017) to refine our results further. As inverse probability weighting is used in that methodology, we are prevented from using those observations for which assignment to any of the spillover conditions being compared is zero. This is particularly a problem for the estimation of the spillover effect (comparison between d_{00} and d_{01}) and the contaminated treatment effect (comparison between d_{00} and d_{11}), for which the amount of observations lost in this way makes estimation difficult.[18] As such, in what follows, we focus on the effect that interests us the most, namely the comparison between

[18]For that reason, numbers of observations in both groups of the pairwise comparison are always shown (number of observations in the pure control group compared with number of observations in the contaminated control, direct treatment and contaminated treatment group respectively). Other changes in sample sizes across different regression specifications reflect the attrition described in Section 2.3.2.

the pure control group (d_{00}) and the direct treatment group (d_{10}), for which the maximum amount of observations can be used.[19]

Table 2.3 shows that, looking only at the direct treatment effect, the PSS video has led to a significant increase in awareness about seed selection-related information, to the adoption of (some of) the practices explained in the video and to an increase in the probability of improved input use. However, these impacts do not seem to have translated into significant improvements in the final outcomes index.

Table 2.3: Main results (outcome indices) with spillovers - pairwise comparisons using Aronow and Samii (2017) methodology

	PSS				*PSSH*			
	d_{00}(mean)	d_{01}	$\mathbf{d_{10}}$	d_{11}	d_{00}(mean)	d_{01}	$\mathbf{d_{10}}$	d_{11}
Information awareness	-0.022	-0.197	0.448***	0.082	-0.145	0.162	0.042	0.151
		(0.209)	(0.146)	(0.160)		(0.166)	(0.204)	(0.158)
N	53	31/67	53/49	31/71	47	23/75	45/55	23/63
Adoption of practices	-0.260	0.666**	1.329***	0.958***	-0.154	-0.212	0.006	-0.320
		(0.316)	(0.246)	(0.269)		(0.206)	(0.236)	(0.251)
N	43	24/54	43/44	24/60	39	18/70	39/47	18/51
Input use	0.028	-0.074	0.420**	-0.160	0.039	0.183	0.246	0.010
		(0.202)	(0.177)	(0.205)		(0.203)	(0.213)	(0.215)
N	45	25/55	45/45	25/62	39	18/70	39/47	18/51
Final outcomes	-0.038	-0.105	0.151	-0.084	-0.132	0.666***	0.976***	0.433*
		(0.221)	(0.192)	(0.197)		(0.215)	(0.236)	(0.234)
N	45	25/52	45/45	25/61	39	18/68	39/47	18/49

Notes: First column (per video treatment) shows mean in pure control group (d_{00}) and other columns show coefficients of pairwise comparisons (using IPW) between the pure control group (d_{00}) on the one hand and the contaminated control group (d_{10}), the direct treatment group (d_{01}) and the contaminated treatment group (d_{11}) on the other. Dependent variables are indices of different survey questions pertaining to a given outcome category. Standard errors are in parentheses. *, **, *** denote significance at the 10, 5 and 1 percent level respectively. N denotes the number of observations used in each pairwise comparison, for each outcome (number of observations in the pure control group/number of obervations in the group being compared: d_{01}, d_{10} and d_{11} respectively).

We do not find similar impacts for the PSSH video treatment (see Table 2.3). It appears that providing information on storage practices for seed potatoes does not lead to improvements in the awareness about those practices, does not lead to the adoption of those practices and does not lead to a significant increase in input use. Given the lack of any

[19]The other effects are shown, but they will not be discussed.

direct or intermediate impacts, it is somewhat surprising to see that the coefficient of the impact of the PSSH video on the final outcomes index (which includes outcomes such as yield and consumption) is large and significant. In what follows, we further unpack these results (looking at some of the individual questions or outcomes behind each index) to disentangle the channels that are driving the observed impacts.

We start by looking at information awareness, which is reported in Table 2.4. We report how the PSS intervention affects selection-related knowledge and how PSSH affects storage and handling-related knowledge (see Appendix B1 for questions and answering possibilities). We find that 66 percent of farmers in the pure control group (d_{00}) know that the largest plants in the field need to be pegged for seed selection (*sel1*). This proportion increases to 80 percent in the pure treatment group (d_{10}), but not in a statistically significant way. For the question about the size of potatoes to be selected for seed (*sel2*), however, the pure control average is about 83 percent and the direct effect is significant. The question that was added at endline (*sel3*), did not really achieve its purpose: most of the farmers already knew the answer to the question, leading to too little variation to arrive at credible estimates.

Table 2.4: Information awareness results - pairwise comparisons using Aronow and Samii (2017) methodology

	PSS				*PSSH*			
	d_{00}(mean)	d_{01}	$\mathbf{d_{10}}$	d_{11}	d_{00}(mean)	d_{01}	$\mathbf{d_{10}}$	d_{11}
Question 1	0.660	-0.085	0.143	0.033	0.957	-0.024	-0.032	-0.029
sel1 (PSS) and *store1* (PSSH)		(0.103)	(0.093)	(0.099)		(0.020)	(0.032)	(0.023)
Question 2	0.830	0.157*	0.198***	0.066	0.936	0.005	0.001	0.028
sel2 (PSS) and *store2* (PSSH)		(0.083)	(0.068)	(0.087)		(0.033)	(0.038)	(0.029)
Question 3	0.943	-0.128***	0.014	-0.014	0.851	0.247***	0.153*	0.142
sel3 (PSS) and *store3* (PSSH)		(0.044)	(0.023)	(0.016)		(0.087)	(0.087)	(0.102)
N	53	31/67	43/49	31/71	47	23/75	47/55	23/63

Notes: First column (per video treatment) shows mean in pure control group (d_{00}) and other columns show coefficients of pairwise comparisons (using IPW) between the pure control group (d_{00}) on the one hand and the contaminated control group (d_{10}), the direct treatment group (d_{01}) and the contaminated treatment group (d_{11}) on the other. Dependent variables are responses (right/wrong) to multiple-choice questions on the videos (see Appendix B1 for exact questions and answering possibilities). *, **, *** denote significance at the 10, 5 and 1 percent level respectively. N denotes the number of observations used in each pairwise comparison (number of observations in the pure control group/number of obervations in the group being compared: d_{01}, d_{10} and d_{11} respectively).

For two of the questions on PSSH (*store1* and *store2*), we do not find any significant direct effects, confirming the findings from Table 2.3. However, both of these variables suffer from limited variability and awareness about this type of information seems to have been high overall, even in the control group, which means these results should be interpreted with caution. The storage and handling related question that was added in the endline survey (*store3*) does seem to be affected by interference: the proportion of farmers that answers correctly increases from 85 to 100 percent (but only significant at the 10 percent level). On the whole, the awareness of the practices in the videos is high for both treatments (and particularly for the PSSH video), which casts doubt on the original hypothesis of the intervention, namely that farmers have limited information about seed related agricultural practices. However, it could still be the case that, even for the information that the farmers already possess, the videos serve as a reminder or a confirmation of the value of those practices and in that way still lead to changes in behavior.

In Table 2.5, we look at how the videos have led to changes in the adoption of potato seed and storage practices. For practices related to seed selection, we find that around 21 percent in the pure control group pegs healthy plants (practice 1), and that this percentage increases by 37 percentage points in the direct treatment group. We also find large and significant effects of the PSS video on the practice of removing pegs from diseased plants (practice 2), harvesting pegged plants first (practice 3) and selecting potato tubers with at least four eyes (practice 5). The remaining two practices, namely throwing away rotten potatoes (practice 4) and selecting egg-sized potatoes as seeding material (practice 6), were already being applied widely with pure control averages around 95 percent.

Table 2.5: Adoption of practices results - pairwise comparisons using Aronow and Samii (2017) methodology

	PSS				*PSSH*			
	d_{00}(mean)	d_{01}	$\mathbf{d_{10}}$	d_{11}	d_{00}(mean)	d_{01}	$\mathbf{d_{10}}$	d_{11}
Practice 1	0.209	-0.048	0.365***	-0.025	0.769	-0.098*	-0.078	-0.158**
		(0.104)	(0.102)	(0.101)		(0.058)	(0.071)	(0.072)
Practice 2	0.140	0.118	0.511***	0.192**	0.769	0.032	-0.071	-0.092
		(0.078)	(0.091)	(0.081)		(0.063)	(0.082)	(0.087)
Practice 3	0.116	0.195**	0.525***	0.164**	0.410	0.031	0.008	-0.052
		(0.074)	(0.088)	(0.069)		(0.106)	(0.108)	(0.120)
Practice 4	0.953	-0.094**	-0.031	-0.029	0.282	-0.261***	0.030	-0.015
		(0.044)	(0.040)	(0.025)		(0.097)	(0.110)	(0.124)
Practice 5	0.651	0.263**	0.323***	0.331***	0.846	0.023	0.058	-0.059
		(0.110)	(0.095)	(0.101)		(0.078)	(0.077)	(0.098)
Practice 6	0.953	0.103	0.109**	0.118**	0.026	0.011	0.027	0.265
		(0.064)	(0.045)	(0.058)		(0.015)	(0.030)	(0.027)
N	43	24/54	43/44	24/60	39	18/70	39/47	18/51

Notes: First column (per video treatment) shows mean in pure control group (d_{00}) and other columns show coefficients of pairwise comparisons (using IPW) between the pure control group (d_{00}) on the one hand and the contaminated control group (d_{10}), the direct treatment group (d_{01}) and the contaminated treatment group (d_{11}) on the other. Dependent variables are the adoption (0/1) of different practices shown in the videos (a description of practices can be found in Appendix B2). *, **, *** denote significance at the 10, 5 and 1 percent level respectively. N denotes the number of observations used in each pairwise comparison, for each outcome (number of observations in the pure control group/number of obervations in the group being compared: d_{01}, d_{10} and d_{11} respectively).

The PSSH treatment seems to be far less effective in changing agricultural practices. Table 2.5 shows that for none of the storage and handling practices we inquire about, the direct treatment effect is significantly different from zero. However, it should be noted that control averages for 3 out of 6 practices are high, suggesting these practices had already been adopted by a majority of farmers, even before the video treatment. It could also be that cost plays an important role in explaining the lack of adoption of some of the storage related practices as opposed to the seed related practices which are labor-intensive, but do not require major investments. Indeed, the storage practices that are least applied require the purchase of an insecticide or a disinfectant (practices 3 and 6 respectively) or at least some changes to the potato storage facilities (practice 4). Even though the associated costs are relatively minor, we cannot rule out that, in this context, the informational constraint is

secondary to more binding cash or credit constraints.

Table 2.6: Input use results - pairwise comparisons using Aronow and Samii (2017) methodology

	PSS				*PSSH*			
	d_{00}(mean)	d_{01}	$\mathbf{d_{10}}$	d_{11}	d_{00}(mean)	d_{01}	$\mathbf{d_{10}}$	d_{11}
Seed	0.321	0.033	0.414***	0.027	0.383	-0.049	-0.035	-0.394***
		(0.098)	(0.091)	(0.095)		(0.104)	(0.102)	(0.100)
N	52	31/67	53/49	31/71	47	23/75	47/55	23/63
Fertilizer	0.511	-0.074	0.167	-0.107	0.513	0.111	0.242**	0.046
		(0.114)	(0.104)	(0.108)		(0.102)	(0.107)	(0.115)
N	45	25/55	45/45	25/62	39	18/70	39/47	18/51
Chemicals	0.867	-0.037	0.022	-0.086	0.846	-0.099*	-0.042	-0.097
		(0.061)	(0.053)	(0.065)		(0.058)	(0.060)	(0.065)
N	45	25/55	45/45	25/62	39	18/70	39/47	18/51
Labor	0.756	0.047	0.195**	0.066	0.795	0.225**	0.068	0.118
		(0.103)	(0.080)	(0.096)		(0.098)	(0.106)	(0.120)
N	45	25/55	45/45	25/62	39	18/70	39/47	18/51

Notes: First column (per video treatment) shows mean in pure control group (d_{00}) and other columns show coefficients of pairwise comparisons (using IPW) between the pure control group (d_{00}) on the one hand and the contaminated control group (d_{10}), the direct treatment group (d_{01}) and the contaminated treatment group (d_{11}) on the other. Dependent variables indicate probability of using (purchasing in the case of seed) the indicated item (0/1). *, **, *** denote significance at the 10, 5 and 1 percent level respectively. N denotes the number of observations used in each pairwise comparison, for each outcome (number of observations in the pure control group/number of obervations in the group being compared: d_{01}, d_{10} and d_{11} respectively).

We also examine in more detail if the videos lead to a change in input use (see Table 2.6). First, results suggest that the PSS treatment increases the probability of purchasing seed: 32 percent of farmers in the pure control reports to have purchased seed and this proportion increases significantly in the directly treated group. It thus appears that the PSS video has succeeded in making farmers more aware of the importance of good quality seed, inducing them to purchase seed from agro-input dealers instead of relying on recycled seed. For the PSSH treatment, we do not find significant direct effects on the probability of purchasing seed potatoes. Fertilizer use, on the other hand, seems to only have been affected by the PSSH treatment and not (significantly) by the PSS treatment. We do not find any effects from either video on the use of chemicals, but there is some evidence to suggest that the PSS video crowds in the use of hired labor, which could be a result of the labor-intensity of some

of the activities promoted in the PSS video such as pegging and checking the plants.

Finally, we conduct the same type of analysis for a set of final outcomes, including yield, market participation and household welfare (approximated by consumption expenditure). The results are reported in Table 2.7. We find that both the PSS video and the PSSH video have a significant impact on potato yields. In particular, while farmers in the pure control group report to have harvested about 4.9 MT/hectare, this increases to about 7.4 MT/hectare in the group that was directly treated with the PSS video. This corresponds to an increase of about 50 percent, albeit from a low base. For the PSSH experiment, yields among the directly treated are essentially twice those in the pure control.

Table 2.7: Final outcomes results - pairwise comparisons using Aronow and Samii (2017) methodology

	PSS				*PSSH*			
	d_{00}(mean)	d_{01}	$\mathbf{d_{10}}$	d_{11}	d_{00}(mean)	d_{01}	$\mathbf{d_{10}}$	d_{11}
Yield	7.590	-0.029	0.419**	-0.039	7.424	0.310*	0.714***	0.207
		(0.156)	(0.191)	(0.161)		(0.178)	(0.192)	(0.207)
N	45	25/52	45/45	25/61	39	18/68	39/47	18/49
Proportion sold	0.453	-0.168***	-0.219***	-0.102*	0.368	0.128*	0.172**	0.077
		(0.062)	(0.049)	(0.056)		(0.064)	(0.065)	(0.069)
N	45	25/55	45/45	25/61	39	18/70	39/47	18/51
Consumption	11.280	0.052**	0.237**	0.045**	11.259	-0.001**	0.229**	0.042**
		(0.053)	(0.060)	(0.066)		(0.087)	(0.105)	(0.097)
N	53	31/67	53/49	31/71	47	23/75	47/55	23/63

Notes: First column (per video treatment) shows mean in pure control group (d_{00}) and other columns show coefficients of pairwise comparisons (using IPW) between the pure control group (d_{00}) on the one hand and the contaminated control group (d_{10}), the direct treatment group (d_{01}) and the contaminated treatment group (d_{11}) on the other. Dependent variables refer to respectively yield (in log of kg of potato per hectare), the proportion of harvest that was sold (0/1) and consumption (in log of weekly UGX expenditures). *, **, *** denote significance at the 10, 5 and 1 percent level respectively. N denotes the number of observations used in each pairwise comparison, for each outcome (number of observations in the pure control group/number of obervations in the group being compared: d_{01}, d_{10} and d_{11} respectively).

We also find that the PSS video reduces the proportion of potatoes sold to the market. In the pure control group, farmers report selling about 45 percent of their harvest on the market. However, among the directly treated, this proportion is 17 percentage points lower. We find an opposite effect for the PSSH treatment: here, farmers in the direct treatment group sell a higher proportion of their potatoes in the market compared to farmers in the pure control

group. Both findings can be explained as follows: while the PSS treatment induces farmers to save more potatoes as seed rather than selling them as ware in the short run, the PSSH treatment is aimed at ensuring potatoes (primarily seed, but also ware) survive longer in storage, which in turns explains why more can be sold by PSSH treated households. Finally, we find that household welfare increases in both experiments. Farmers in the pure control group (for both treatments) spend on average about 79,000 UGX per week.[20] This increases to 105,000 UGX in the directly treated group, corresponding to an increase of about 35 percent. Unpacking the results behind the final outcomes index thus also shows that the lack of a positive effect of the PSS video on the final outcomes observed in Table 2.3 is entirely due to the negative impact of that treatment on market participation.

We see two potential explanations for the fact that we find significant impacts of the PSSH video on final outcomes, but not on direct or intermediate outcomes. First, we may have missed important channels towards these final outcomes other than those included in the survey or the analysis. For instance, while farmers might have already been aware of the information in the PSSH video and did not apply any of the practices for a variety of reasons, the video might have triggered an increased motivation on the part of farmers and induced them to adopt other beneficial practices. Second, as is clear from Table B.4, the direct treatment group for the PSSH treatment already had a higher level of potato production at baseline, which could explain both the higher yields and the higher consumption in our survey.

2.4.3 Varying the spillover radius

Aronow and Samii (2017) warn that, while not taking into account spillovers in the presence of interference will most certainly lead to biased results, the results would still be biased (but possibly in a different direction) if the specification of spillovers is done incorrectly. Effectively, the methodology exchanges one set of assumptions (a non-violation of SUTVA) for

[20] At the time of the survey, 1 USD was roughly equivalent to 3,650 UGX, which means that weekly expenditures of 79,000 UGX correspond to about 22 USD.

another, namely that the characterization of spillovers is correct. While we cannot guarantee that spillovers are captured correctly in our context, we can provide evidence for the fact that the results are not dependent on the arbitrarily chosen spillover radius and for the spatial and localized nature of spillovers.

To do so, we assess robustness of our results to variations in the spillover radius, which was hitherto somewhat arbitrarily fixed at 289 meters. As an illustration, in Figure 2.5, we show the direct treatment effect coefficient for the PSS treatment for the different outcome indices and for different spillover radiuses (from 100 to 700 meters) following the same procedure as above. As the spillover radius is increased, more control farmers are allocated to the contaminated control group (d_{01}), with eventually only the most remote control farmers still in the pure control group (d_{00}). Eventually, a point is reached where the pure control group becomes too small for any comparisons to still make sense.

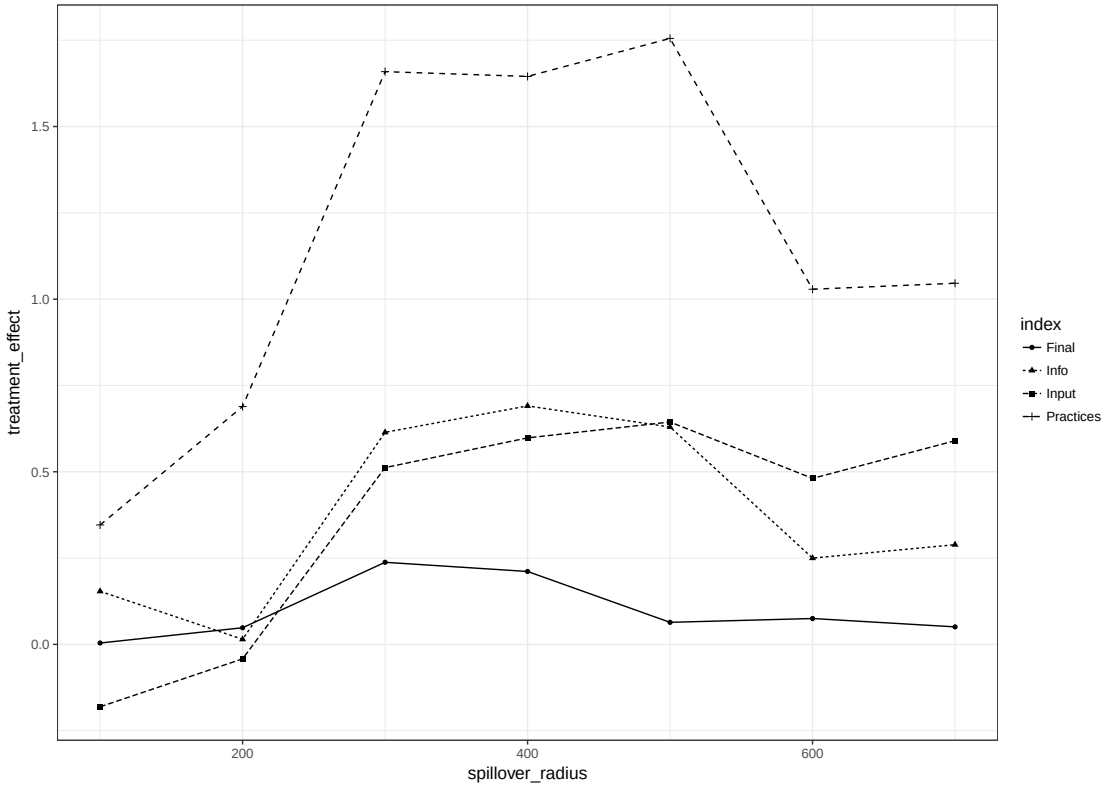


Figure 2.5: Variation in spillover radius (in meters) - PSS on main outcomes

By varying the spillover radius in this way, we are effectively relaxing the three assump-

tions mentioned in Section 2.3.3. First, by varying the spillover radius, we test whether or not the arbitrary choice of radius is at the origin of significant results we find. If this would be the case, we would only observe significant results for that spillover threshold (around 300 meters). Second, as the spillover radius is varied, we are also effectively changing the amount of farmers in one's vicinity it takes to be considered a contaminated control or treatment farmer. At higher levels of the spillover radius, we are comparing the most remote direct treatment farmers with the most remote control farmers to get the direct treatment effect. Now, as the spillover radius is tightened, both groups are increasingly more likely to contain farmers with more than one other (treatment) farmer in the neighborhood, but not close enough to be considered contaminated. As such, in tightening, we are relaxing the remaining two assumptions. Indeed, if the number of treatment farmers within a given spillover radius would make a difference (as opposed to the "at least one" approach we have taken) or if the treatment assignment of farmers outside of the chosen spillover radius would have an effect on a given farmer's outcomes, we would expect to see important changes in the direct treatment coefficients as the spillover radius is changed.

In short, if we believe spillovers are specified correctly, we should observe the direct treatment effect to be rather stable for different spillover radiuses around 300 meters. A small variation in distance between farmers should not have an impact on how they interact with one another (and thus generate interference) even as the number of farmers in the different groups changes. This is precisely what can be seen in Figure 2.5 and indeed confirms that the results in Section 2.4.2 are not a consequence of the arbitrarily chosen spillover threshold. We find that the PSS video leads to higher information awareness, higher adoption of practices and higher input use, with similar coefficients, for a relatively wide range of the spillover radius (between roughly 300 and 600 meters).

Appendix B5, which contains more details on the results underlying Figure 2.5 (also on the PSSH treatment), also shows this is not a consequence of having a stable number of observations across spillover radiuses. As expected, the number of observations in the

spillover groups (d_{01} and d_{11}) gradually increases as the spillover radius is widened while the reverse is true for the pure control and direct treatment groups (d_{00} and d_{10}), making the results less reliable at the lower and upper bounds of the spillover variation. However, we do see that, in spite of significant shifts in the number of observations between the different groups as the spillover radius varies between 300 and 600 meters, there is a remarkable consistency in the size and the significance of the direct treatment effect coefficients.

2.5 Discussion and conclusion

In this paper, we investigate if short, stand-alone video messages targeted to individual farmers can reduce potato seed degeneration among seed-recycling Ugandan smallholder potato farmers. In particular, we examine the impact of providing information on positive seed selection on the one hand, and proper storage and handling of seed on the other hand over the course of one year after the videos are shown. We judge the effectiveness in terms of the awareness of information, of practices adopted and inputs used. We also check if the interventions have an impact on outcomes further down the line, such as agricultural productivity, market participation and welfare.

Spillovers (or, put differently, interference between treatment and control) are important in our experiment. While spillover effects can impede the evaluation of an experiment, it should be considered a desirable outcome of an intervention that aims to disseminate agricultural extension information among smallholder farmers. To formally account for spillovers, we implement a randomization-based framework using the distance between farmers developed by Aronow and Samii (2017). We find that both videos had important beneficial outcomes. The video on seed selection (PSS) has led to increased awareness and subsequent adoption of practices shown, as well as a higher probability of using hired labor and of buying potato seed on the market. These improvements have resulted into robust progress in terms of yield and consumption and led to a decrease in the proportion of harvest that is sold. The video on

seed storage and handling (PSSH), on the other hand, did not engender the same increases in the awareness and adoption of storage-related practices, nor did it lead to a higher probability of using improved inputs (fertilizer being the notable exception). At the same time, the PSSH video did result in robust improvements in terms of yield, commercialization and consumption. We further argue that the relative success (at least in terms of adoption of practices) of the PSS treatment compared to the PSSH treatment is due to differences in the cost of implementation of some of the practices. Indeed, when we further unpack the results and look at the adoption of different practices individually, we notice that the practices where impact is highest were those that did not require a monetary investment. A higher share of the practices promoted in the PSSH video required an investment compared to the practices recommended in the PSS video, which could explain the lack of adoption.

The results in this paper have implications for agricultural policy and research in three distinct ways. First, we draw further attention to the issue of interference or spillovers in the design and the analysis of experiments. Often, due to time and budget constraints, randomization happens at the individual or household level, which provides more statistical power, but is more susceptible to interference than experiments where randomization takes place at a more aggregate level (for instance villages or sub-counties). We show how randomization-based inference can be used to address spillover effects ex-post. The only requirement of this methodology is that you need to specify how spillovers occur in your sample. But this is something that can easily be tested and varied in the analysis phase using qualitative methods. In other words, we demonstrate it is possible to compensate in the analysis phase for otherwise costly interventions or provisions in the design phase of an experiment. Further, our results confirm once more (see, for instance, Beaman and Dillon, 2018) that information delivered to a specific set of farmers will spread to those who live in their close vicinity. While it is not clear if this would hold for every type of information or every mode of information delivery, these results could potentially lead to cost and time savings in agricultural extension, even though the presence of spillovers certainly calls into question the market potential

of videos.

Second, our results also contribute to the discussion on the use of information technologies in agricultural extension. Our study demonstrates that farmers are open to new ways of learning about agricultural techniques. The videos were hailed as an interesting and engaging way to receive information and they were heavily discussed. While the set-up of our experiment does not allow us to compare the use of videos to alternative extension strategies, we can speculate about the type of agricultural information that is suitable to be spread through such a channel. It is clear that videos are best suited to spread information on simple agricultural techniques that have not yet been widely adopted but at the same time do not require substantial investments. Almost by definition, field- or farmer-specific information is not something that can be effectively conveyed through videos. In that sense, we consider the role of videos (or of information technologies more broadly) in agricultural extension to be complementary to more traditional methods. Videos can provide information on generic and cost efficient practices, while extension officers or experts provide farmers with tailored and more specific advice, constantly keeping an eye on other, non-informational constraints farmers may face.

Finally, our study also confirms the prevalence of seed recycling as an agricultural practice. It demonstrates there is a demand for interventions (information or otherwise) that help farmers improve practices related to seed quality. While it is too early to tell whether or not the adoption of some of the practices in our intervention will actually lead to meaningful improvements in seed quality, it is clear there is room for similar interventions (using videos or other information technologies) to be implemented wherever institutional constraints impede the development of formal seed systems.

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Appendix B

Appendix B1: Multiple-choice questions

Table B.1: Multiple-choice questions and answering possibilities

Code	Question	Answering possibilities (correct one in bold)		
sel1	Which plants should you peg for seed potato selection?	**The largest plants in the field**	The smallest plants in the field	Average sized plants in the field
sel2	What size should a seed potato tuber be?	The larger the better	**Size of an egg**	The smallest ones you find
sel3	Which plants should you peg for positive seed selection?	Random plants	Diseased plants	**Healthy plants**
store1	In which lighting conditions should you store seed potatoes?	In direct sunlight	In a dark place	**In indirect light**
store2	How should you store your seed potatoes?	In bags that have been thoroughly cleaned with JIK	**Spread out on racks or on dried grass on the floor**	In airtight containers or buckets with a closing lid
store3	Where should you ideally store your seed potatoes?	Together with other crops	Somewhere in the house	**In a separate store**
gen1	Which of the following statements is correct?	Immediately after harvest, you should thoroughly wash seed potatoes before putting them in storage using JIK	Immediately after harvest, you should thoroughly wash seed potatoes before putting them in storage using clean water	**You should never wash seed potatoes before putting them in storage**
gen2	When picking a field for Irish potato farming...	**Pick a garden that is in highlands and in isolated areas**	Pick lowlands with plenty of water	Pick a garden close to your house or in densely populated areas
gen3	How can you spot bacterial wilt in a potato tuber?	Malformations	**Puss in the eyes**	Cuts

Appendix B2: PSS and PSSH practices

Table B.2: PSS and PSSH practices inquired about in the survey

Code	PSS	PSSH
(1)	Pegged healthy plants for seed potatoes	Stored seed potatoes in separate room/store
(2)	Removed pegs from diseased plants	Stored seed potatoes on racks or on dried grass on the floor
(3)	Harvested pegged plants first	Applied malathion dust in storage for seed potatoes
(4)	Threw away rotten tubers or tubers with malformations after harvest	Stored seed potatoes in diffuse lighting conditions
(5)	Kept only seed potatoes with more than four eyes	Stored seed potatoes in a ventilated room
(6)	Used egg-sized potatoes for seed	Cleaned material (shovels and bags) using JIK

Appendix B3: Orthogonality after attrition

Table B.3: Descriptive statistics and orthogonality after attrition.

	(1)	(2)	(3)
Variable	Mean	PSS	PSSH
Household size	5.832	0.042	0.375
		(0.336)	(0.336)
Age of head (years)	44.059	3.009	0.432
		(2.200)	(2.201)
Male head (0/1)	0.855	-0.018	-0.024
		(0.052)	(0.052)
Head can read and write (0/1)	0.757	-0.005	-0.004
		(0.060)	(0.060)
Farming experience (years)	19.619	3.927*	1.094
		(2.077)	(2.077)
Welfare (log consumption)	14.075	-0.243	0.104
		(0.159)	(0.159)
Seed recycling (0/1)	0.637	-0.038	0.077
		(0.047)	(0.047)
Fertilizer use (0/1)	0.411	0.030	0.099
		(0.069)	(0.069)
Received training (0/1)	0.441	0.008	0.004
		(0.069)	(0.069)
Received credit (0/1)	0.834	-0.117*	-0.043
		(0.060)	(0.060)
Closest input provider (km)	7.248	-1.108	-0.432
		(1.180)	(1.181)
Nearest market (km)	6.144	0.399	-0.266
		(1.000)	(1.001)
Time to reach parcel (min)	40.223	-3.063	-4.282*
		(2.543)	(2.537)
Harvest sold as ware (%)	0.354	-0.012	0.067*
		(0.038)	(0.038)
Harvest kept as seed (%)	0.222	-0.009	0.011
		(0.019)	(0.019)
Potato production (kg)	816.010	2.186	127.793
		(121.380)	(121.456)
Potato share of ag. revenue (%)	0.574	0.012	-0.024
		(0.056)	(0.056)

Notes: PSS=Positive Seed Selection, PSSH=Proper Seed Storage and Handling. Columns (2) and (3) show the coefficients of both treatment indicators in a regression of the variable on both treatment indicators. Standard errors are in parentheses. Number of observations=211. Baseline data collected in 2013/2014. *, **, *** denote significance at the 10, 5 and 1 percent level respectively.

Appendix B4: Orthogonality of spillover conditions

Table B.4: Orthogonality across spillover conditions.

	PSS				*PSSH*			
Variable	d_{00}(Mean)	d_{01}	d_{10}	d_{11}	d_{00}(Mean)	d_{01}	d_{10}	d_{11}
Household size	5.830	0.271	0.570	-0.205	6.082	-0.388	0.186	-0.160
		(0.439)	(0.474)	(0.435)		(0.443)	(0.472)	(0.478)
Age of head (years)	45.604	0.990	2.276	1.313	47.367	-1.594	-2.439	1.601
		(2.909)	(3.139)	(2.882)		(2.915)	(3.103)	(3.012)
Male head (0/1)	0.792	0.034	0.048	0.027	0.816	0.027	0.005	-0.019
		(0.071)	(0.076)	(0.070)		(0.071)	(0.076)	(0.074)
Head can read and write (0/1)	0.679	0.074	0.081	0.015	0.735	-0.001	-0.110	0.047
		(0.082)	(0.089)	(0.082)		(0.082)	(0.088)	(0.085)
Farming experience (years)	22.660	-0.342	0.999	1.409	24.714	-3.141	-2.964	0.442
		(2.776)	(2.996)	(2.751)		(2.779)	(2.959)	(2.871)
Welfare (log consumption)	14.019	0.028	-0.113	-0.126	13.824	0.192	0.292	0.061
		(0.208)	(0.224)	(0.206)		(0.208)	(0.222)	(0.215)
Fertilizer use (0/1)	0.453	0.025	0.087	-0.036	0.469	-0.029	0.066	-0.032
		(0.092)	(0.099)	(0.091)		(0.092)	(0.098)	(0.095)
Received training (0/1)	0.377	0.043	0.103	0.025	0.429	-0.015	-0.036	0.009
		(0.091)	(0.098)	(0.090)		(0.091)	(0.097)	(0.094)
Received credit (0/1)	0.811	-0.047	-0.151*	-0.075	0.750	0.037	-0.054	-0.016
		(0.080)	(0.086)	(0.079)		(0.081)	(0.086)	(0.084)
Closest input provider (km)	4.920	3.598**	1.221	1.152	8.877	-3.279**	-3.408**	-2.130
		(1.578)	(1.703)	(1.563)		(1.588)	(1.691)	(1.641)
Nearest market (km)	5.998	0.431	0.344	0.470	7.776	-2.226	-1.121	-1.929
		(1.378)	(1.487)	(1.365)		(1.377)	(1.466)	(1.423)
Time to reach parcel (min)	36.361	3.167	-3.061	-4.022	35.828	2.516	-0.847	-4.097
		(3.285)	(3.450)	(3.217)		(3.336)	(3.434)	(3.466)
Harvest sold as ware (%)	0.227	-0.025	0.014	0.038	0.230	-0.001	0.040	-0.025
		(0.040)	(0.044)	(0.040)		(0.040)	(0.042)	(0.042)
Harvest kept as seed (%)	0.222	0.001	-0.003	-0.021	0.197	0.013	0.016	0.042
		(0.024)	(0.027)	(0.025)		(0.024)	(0.026)	(0.026)
Potato production (log kg)	6.182	0.101	-0.251	0.109	5.953	0.210	0.373**	0.354**
		(0.142)	(0.157)	(0.144)		(0.142)	(0.149)	(0.149)
Potato share of ag. revenue (%)	0.474	0.087	0.027	0.053	0.551	-0.019	-0.068	-0.035
		(0.075)	(0.081)	(0.074)		(0.076)	(0.081)	(0.078)
N	53	69	60	72	49	75	56	64

Notes: PSS=Positive Seed Selection, PSSH=Proper Seed Storage and Handling. First column (per video treatment) shows mean in pure control group and other columns show differences with the pure control group. Standard errors are in parentheses. Total number of observations=244. Baseline data collected in 2013/2014. *, **, *** denote significance at the 10, 5 and 1 percent level respectively.

Appendix B5: Varying the spillover radius - Tables

Table B.5: Main results with variation in the spillover radius (**information awareness index**) - comparisons using Aronow and Samii (2017) methodology

Spillover	*PSS*				*PSSH*			
radius	d_{00}(mean)	d_{01}	$\mathbf{d_{10}}$	d_{11}	d_{00}(mean)	d_{01}	$\mathbf{d_{10}}$	d_{11}
100m	-0.099	-0.390	0.154	-0.091	-0.074	0.390	0.015	0.358
		(0.273)	(0.135)	(0.239)		(0.308)	(0.168)	(0.270)
N	94	21/26	94/96	21/24	100	24/22	100/90	24/28
200m	0.015	-0.670***	0.015	-0.136	-0.032	-0.094	-0.211	-0.111
		(0.234)	(0.149)	(0.165)		(0.194)	(0.158)	(0.176)
N	70	28/49	70/61	28/58	72	34/49	72/69	34/48
300m	-0.048	-0.184	0.614***	0.103	-0.137	0.226	0.200	0.201
		(0.217)	(0.134)	(0.173)		(0.167)	(0.191)	(0.168)
N	50	33/64	50/47	33/66	46	23/71	46/51	23/59
400m	-0.033	-0.075	0.691***	0.204	-0.146	-0.115	0.076	-0.147
		(0.226)	(0.160)	(0.178)		(0.145)	(0.186)	(0.146)
N	38	24/73	38/33	24/77	34	18/80	34/38	18/69
500m	0.034	-0.205	0.630***	0.106	-0.347	-0.041	0.419	-0.085
		(0.216)	(0.182)	(0.165)		(0.225)	(0.275)	(0.234)
N	30	20/79	30/21	20/89	22	10/90	22/24	10/83
600m	0.257	-0.551**	0.250	-0.165	-0.482	0.103	0.711**	0.357
		(0.212)	(0.207)	(0.139)		(0.256)	(0.349)	(0.266)
N	21	13/88	21/14	13/95	15	10/96	15/19	10/88
700m	0.233	-0.511**	0.226	-0.144	-0.613	0.126	0.383	0.096
		(0.218)	(0.226)	(0.144)		(0.220)	(0.354)	(0.226)
N	18	10/91	18/13	10/96	13	8/98	13/16	8/91

Notes: First column (per video treatment) shows mean in pure control group (d_{00}) and other columns show coefficients of pairwise comparisons (using IPW) between the pure control group (d_{00}) on the one hand and the contaminated control group (d_{10}), the direct treatment group (d_{01}) and the contaminated treatment group (d_{11}) on the other. Dependent variable is the index of different survey questions pertaining to information awareness of the practices shown in the video (3 per treatment). Standard errors are in parentheses. *, **, *** denote significance at the 10, 5 and 1 percent level respectively. N denotes the number of observations used in each pairwise comparison, for each outcome (number of observations in the pure control group/number of obervations in the group being compared: d_{01}, d_{10} and d_{11} respectively).

Table B.6: Main results with variation in the spillover radius (**adoption of practices index**) - comparisons using Aronow and Samii (2017) methodology

Spillover	*PSS*				*PSSH*			
radius	d_{00}(mean)	d_{01}	$\mathbf{d_{10}}$	d_{11}	d_{00}(mean)	d_{01}	$\mathbf{d_{10}}$	d_{11}
100m	-0.192	0.523	0.346*	0.803*	-0.095	0.053	0.044	0.044
		(0.288)	(0.190)	(0.466)		(0.228)	(0.154)	(0.301)
N	77	17/20	77/84	17/20	88	20/21	88/77	20/21
200m	-0.245	0.721**	0.689***	0.901***	-0.128	0.148	0.008	0.131
		(0.048)	(0.219)	(0.293)		(0.213)	(0.171)	(0.258)
N	56	20/40	56/54	20/49	61	28/47	61/60	28/37
300m	-0.230	0.588*	1.659***	0.925***	-0.149	-0.353*	-0.142	-0.516**
		(0.069)	(0.244)	(0.286)		(0.199)	(0.234)	(0.249)
N	40	26/51	40/43	26/55	38	18/66	38/44	18/46
400m	-0.027	0.333	1.645***	0.801***	-0.426	0.286	0.373	0.086
		(0.285)	(0.278)	(0.260)		(0.211)	(0.288)	(0.257)
N	29	18/60	29/31	18/65	27	13/75	27/34	13/54
500m	-0.062	0.450	1.755***	0.775***	-0.607	1.155***	0.597	0.899***
		(0.133)	(0.317)	(0.249)		(0.246)	(0.433)	(0.317)
N	24	16/63	24/21	16/75	19	9/81	19/23	9/65
600m	0.187	-0.340	1.029***	0.008	-0.668	0.767***	0.765	0.586**
		(0.149)	(0.352)	(0.183)		(0.218)	(0.560)	(0.271)
N	16	9/71	16/14	9/81	13	9/86	13/18	9/70
700m	0.186	-0.220	1.046**	0.092	0.740	0.445**	0.700	0.308
		(0.368)	(0.459)	(0.188)		(0.192)	(0.420)	(0.240)
N	13	6/74	13/13	6/83	11	7/88	11/15	7/73

Notes: First column (per video treatment) shows mean in pure control group (d_{00}) and other columns show coefficients of pairwise comparisons (using IPW) between the pure control group (d_{00}) on the one hand and the contaminated control group (d_{10}), the direct treatment group (d_{01}) and the contaminated treatment group (d_{11}) on the other. Dependent variable is the index of different survey questions pertaining to the adoption of practices (6 per treatment). Standard errors are in parentheses. *, **, *** denote significance at the 10, 5 and 1 percent level respectively. N denotes the number of observations used in each pairwise comparison, for each outcome (number of observations in the pure control group/number of obervations in the group being compared: d_{01}, d_{10} and d_{11} respectively).

Table B.7: Main results with variation in the spillover radius (**input use index**) - comparisons using Aronow and Samii (2017) methodology

Spillover	*PSS*				*PSSH*			
radius	d_{00}(mean)	d_{01}	$\mathbf{d_{10}}$	d_{11}	d_{00}(mean)	d_{01}	$\mathbf{d_{10}}$	d_{11}
100m	0.032	-0.347	-0.181	-0.077	0.016	0.079	-0.036	0.054
		(0.315)	(0.155)	(0.286)		(0.345)	(0.154)	(0.290)
N	80	17/20	80/85	17/22	88	20/21	88/77	20/21
200m	-0.014	-0.116	-0.042	-0.125	0.013	-0.126	-0.470**	-0.384
		(0.252)	(0.183)	(0.241)		(0.242)	(0.198)	(0.244)
N	58	21/41	58/55	21/51	61	28/47	61/60	28/37
300m	0.120	-0.314	0.512***	-0.352	0.014	0.337	0.479**	0.079
		(0.201)	(0.164)	(0.199)		(0.208)	(0.214)	(0.230)
N	42	27/52	42/44	27/56	38	18/66	38/44	18/46
400m	0.115	-0.309	0.598***	-0.249	0.052	-0.290	0.100	-0.472**
		(0.211)	(0.210)	(0.209)		(0.190)	(0.211)	(0.207)
N	31	19/61	31/32	19/66	27	13/75	27/34	13/54
500m	0.129	-0.450**	0.644***	-0.474***	-0.076	-0.228	0.022	-0.404
		(0.187)	(0.172)	(0.174)		(0.248)	(0.291)	(0.273)
N	25	17/65	25/51	17/77	19	9/81	19/23	9/65
600m	0.022	-0.590***	0.481**	-0.687***	-0.366	0.025	0.378	-0.192
		(0.195)	(0.235)	(0.186)		(0.239)	(0.368)	(0.261)
N	17	10/73	17/14	10/83	13	9/86	13/18	9/70
700m	-0.115	-0.403**	0.590*	-0.542***	-0.521	-0.248	-0.040	-0.412*
		(0.199)	(0.300)	(0.193)		(0.210)	(0.381)	(0.228)
N	14	7/76	14/13	7/84	11	7/88	11/15	7/73

Notes: First column (per video treatment) shows mean in pure control group (d_{00}) and other columns show coefficients of pairwise comparisons (using IPW) between the pure control group (d_{00}) on the one hand and the contaminated control group (d_{10}), the direct treatment group (d_{01}) and the contaminated treatment group (d_{11}) on the other. Dependent variable is the index of different survey questions pertaining to input use (fertilizer, chemicals and hired labor). Standard errors are in parentheses. *, **, *** denote significance at the 10, 5 and 1 percent level respectively. N denotes the number of observations used in each pairwise comparison, for each outcome (number of observations in the pure control group/number of obervations in the group being compared: d_{01}, d_{10} and d_{11} respectively).

Table B.8: Main results with variation in the spillover radius (**final outcomes index**) - comparisons using Aronow and Samii (2017) methodology

Spillover	*PSS*				*PSSH*			
radius	d_{00}(mean)	d_{01}	$\mathbf{d_{10}}$	d_{11}	d_{00}(mean)	d_{01}	$\mathbf{d_{10}}$	d_{11}
100m	-0.038	0.044	0.004	-0.070	-0.066	0.575**	0.285	0.289
		(0.349)	(0.158)	(0.307)		(0.282)	(0.159)	(0.298)
N	79	16/18	79/84	16/22	86	19/21	86/77	19/19
200m	-0.057	-0.004	0.048	0.058	-0.200	0.515**	0.230	0.115
		(0.270)	(0.202)	(0.231)		(0.233)	(0.193)	(0.245)
N	58	21/38	58/55	21/50	61	28/45	61/60	28/35
300m	-0.100	0.030	0.238	-0.065	-0.071	0.894***	1.336***	0.781***
		(0.237)	(0.185)	(0.216)		(0.231)	(0.247)	(0.261)
N	42	27/49	42/44	27/55	38	18/64	38/44	18/44
400m	-0.073	-0.141	0.211	-0.156	-0.023	0.587***	0.902***	0.541**
		(0.239)	(0.218)	(0.227)		(0.206)	(0.289)	(0.221)
N	31	19/58	31/32	19/65	27	13/73	27/34	13/52
500m	-0.065	-0.280	0.064	-0.241	0.178	-0.030	-0.666	-0.056
		(0.224)	(0.210)	(0.197)		(0.246)	(0.722)	(0.241)
N	25	17/62	25/21	17/76	19	9/79	19/23	9/63
600m	-0.060	-0.269	0.075	-0.115	-0.179	-0.017	1.341***	-0.120
		(0.219)	(0.258)	(0.206)		(0.253)	(0.353)	(0.234)
N	17	10/70	17/14	10/82	13	9/84	13/18	9/68
700m	-0.203	-0.226	0.051	-0.087	-0.339	0.015	1.172***	-0.042
		(0.232)	(0.276)	(0.222)		(0.209)	(0.349)	(0.200)
N	14	7/73	14/13	7/83	11	7/89	11/15	7/71

Notes: First column (per video treatment) shows mean in pure control group (d_{00}) and other columns show coefficients of pairwise comparisons (using IPW) between the pure control group (d_{00}) on the one hand and the contaminated control group (d_{10}), the direct treatment group (d_{01}) and the contaminated treatment group (d_{11}) on the other. Dependent variable is an index of different survey questions pertaining to final outcomes (yield, proportion of harvest and consumption). Standard errors are in parentheses. *, **, *** denote significance at the 10, 5 and 1 percent level respectively. N denotes the number of observations used in each pairwise comparison, for each outcome (number of observations in the pure control group/number of obervations in the group being compared: d_{01}, d_{10} and d_{11} respectively).

Chapter 3

Fasting, Food and Farming: Value chains and food taboos in Ethiopia

Abstract*: The impact of food taboos – often because of religion – is understudied. In Ethiopia, religious fasting by Orthodox Christians is assumed to be an important impediment for the sustainable development of a competitive dairy sector and desired higher milk consumption, especially by children. However, evidence is limited. Relying on unique data, we shed light on three major issues. First, we observe that the average annual number of fasting days that Orthodox adults are effectively adhering to is 140, less than commonly cited averages. Using this as an estimate for extrapolation, fasting is estimated to reduce annual dairy consumption by approximately 12 percent nationally. Second, farms adapt to declining milk demand during fasting by increased processing of milk into storable products – fasting contributes to larger price swings for these products. We further note continued sales of milk by non-remote farmers and reduced production – by adjusting lactation times for dairy animals – for remote farmers. Third, fasting is mostly associated with increased milk consumption by the children of dairy farmers, seemingly because of excess milk availability during fasting periods. Our results suggest that fasting habits are not a major explanation for the observed poor performance of Ethiopia's dairy sector nor low milk consumption by children. To reduce the impact of fasting on the dairy sector in Ethiopia further, investment is called for in improved milk processing, storage, and infrastructure facilities.

Keywords: Dairy, Ethiopia, religion, fasting, value chains

*This chapter is co-authored with Eline D'Haene (UGent) and Bart Minten (International Food Policy Research Institute).

3.1 Introduction

Religious traditions are often reflected in food choices as various religious groups lay out food recommendations to their adherents (Norman, 2012). Even if foods are available and accessible, individuals might not consume specific food items because of these traditions (Farouk et al., 2015). However, despite the growing share of religious people worldwide (Pew Research Center, 2017a) and the acknowledged importance of religion in shaping the structure of institutions and markets (Iyer, 2016), the role of religion in shaping food choices, nutrition, and food value chains is still not well understood (Heiman et al., 2019).

Religious practices are especially prevalent for animal-source foods (ASF) (Meyer-Rochow, 2009). The practice of fasting, in particular, might reduce ASF consumption in two ways. First, aggregate consumption levels might be directly affected as adherents are not allowed to consume ASF during fasting periods. Second, fasting might result in lower availability and higher pricing of ASF over the long term due to lower investments and broader value chain effects. This reduction is unfortunate, as there is a strong link between the consumption of ASF and improved nutritional outcomes (Leroy and Frongillo, 2007; Randolph et al., 2007; Hoddinott et al., 2015).

We study the effects of fasting practices, focusing on the case of dairy production and consumption in Ethiopia, the second most populous country in Africa. We assess the effects of seasonal fasting rituals embedded within the Ethiopian Orthodox community, the dominant religious group in the country. During several fasting periods annually, Orthodox members are to refrain from consuming ASF. Fasting (and associated feasts) occur at different times throughout the year thereby creating considerable demand swings for ASF. This makes Ethiopian diets not only susceptible to agroclimatic patterns, but also to the sequential cycle of religious fasting. Studying this issue in Ethiopia is an important topic given low overall consumption of milk (MoA and ILRI, 2013), especially by children, and the potential prohibitive effects this has on investments in dairy production, possibly contributing to the

underdevelopment of the country's dairy sector compared to other countries in the region (e.g. Tegegne et al., 2013; Van der Lee et al., 2018).

We focus in this analysis on three research questions in particular. First, we evaluate the number of effective fasting days adhered to by Orthodox members. Fasting periods differ in length and cover both one-day fasts and longer fasting periods (16 to 55 days). However, as not all Orthodox Christians adhere to all fasts, it is difficult to assess the exact influence of fasting on Ethiopia's dairy sector. Several estimates on the number of fasting days annually can be found in the literature, with ranges of from 166 to 180 days (Bachewe et al., 2017; Abegaz et al., 2018), and from 180 to 250 days (Francesconi et al., 2010; MoA and ILRI, 2013) being cited. With unique household member-specific fasting data at our disposal, we are able to evaluate effective fasting practices, as well as beliefs. This is important to better understand demand swings and their importance for dairy markets.

Second, we look at what the effects of these demand changes due to fasting are on the dairy value chain and, more specifically, which adaptation strategies milk producing households develop to overcome the effects of low demand during fasting periods. Existing – mostly qualitative – studies show important effects of fasting on the value chain. A reduced, or even a complete lack of, market access as well as lower dairy prices during fasting have been found at the farm level (ADP-LMDP, 2013; Tegegne et al., 2013; Gizaw et al., 2016; Herego, 2017). Processing companies apparently cut down their operations during fasting periods by limiting the supply of milk from producers using quota systems, paying lower prices, or requiring a higher milk quality (ADP-LMDP, 2013; Zijlstra et al., 2015). There is, however, only limited quantitative evidence on the value chain effects of fasting and on adjustments made by producing households. Moreover, no attention has been paid to differential effects by the degree of market access of milk producing households.

Third, we assess the impact of fasting practices on children's milk consumption. Previous studies have illustrated negative repercussions of fasting on dietary diversity and intake of ASF for children, who are, in principle, exempt from fasting (Kumera et al., 2018; Desalegn

et al., 2019). In contrast to previous studies, we test the impact of fasting on milk intake of children within milk producing households, who are less affected by availability issues. We do so by relying on detailed consumption data collected in a survey that was partly rolled out during and outside of a major fasting period.

Relying on a unique primary dataset with a large number of dairy producers, we find that the Orthodox adult fasts on average 140 days per year and that annual milk consumption at the national level is reduced by about 12 percent because of Orthodox fasting practices. While effects in specific periods and locations might obviously be higher, this result suggests that fasting is only a partial explanation for the low dairy consumption in Ethiopia. Moreover, we find that price effects of fasting on milk are much smaller than reported in other studies, although we observe larger price swings for processed milk products. Several adaptation strategies are followed by milk producing households to reduce the economic impact of declining dairy demand during fasting, including increased processing of milk into storable milk products, reduced production (by adjusting lactation times of dairy animals) for remote farmers, and continued sales of milk for farmers with good market access. Finally, despite some children being affected by fasting practices, their number is found to be small. Based on detailed milk consumption data, we find no significant declines in milk consumption for young children during fasting. Fasting is actually found to be beneficial for most young children in milk producing households. Excess milk increases in these producing households during fasting periods, hence improving its availability for consumption by children in the household.

Our findings have several important implications. First, as the impact of fasting at the national level is found to be relatively small and as we find that children consume milk when it is available, even in fasting periods, this suggests that other issues, such as availability and affordability, and not fasting, are the main impediments to increased dairy consumption. This finding is corroborated by the high income and price elasticities for dairy products (Abegaz et al., 2018). Further investments to stimulate the dairy sector are therefore needed

to increase availability of dairy products at lower prices. In contrast to the rapid growth in crop output and productivity recorded in Ethiopia over the past 20 years, ASF output has grown slowly and productivity has stagnated. This is seemingly due to low availability and adoption of improved inputs in the dairy sector leading to high and increasing prices for dairy products (Bachewe and Minten, 2019).

Second, we find that some young children participate in fasting, even if the share is relatively small. Further efforts in improved information dissemination on the potential adverse developmental effects of fasting on children is therefore needed.

Third, to help smooth the effect of seasonal demand swings and possibly increase returns to investments in the sector, further efforts are needed towards enhancing processing practices (such as ultra-heat treated (UHT) and powdered milk), ensuring greater availability of chilling centers, as well as improving market access and transportation facilities to assure market integration and allow marketing to areas where fasting is less prevalent.

3.2 Background

Ethiopia hosts the largest Orthodox community outside Europe. In the last census in 2007, it was estimated that the community made up 43 percent of the total population in Ethiopia (CSA, 2010). Besides Orthodox Christians, Ethiopia is also home to Muslims, Protestants, Catholics, and traditional faiths (CSA, 2010).[1] Only the Orthodox and Islamic traditions prescribe fasting practices to their followers. While Islamic fasting is limited to the month of Ramadan, fasting in the Orthodox community entails abstinence from ASF during several official fasting periods, spread throughout the year. During those periods, no consumption of meat, eggs, or dairy products is allowed. Fasting periods consist of both one-day fasts and longer fasting seasons that often precede holy events. An overview of the fasting periods is given in Table 3.1.

[1]It has been noted that the Orthodox population in Ethiopia is more religiously observant compared to their European counterparts (Pew Research Center, 2017b).

The sequential cycle of Orthodox fasting makes demand for ASF products to vary considerably in the country, as has been shown in a number of studies. Hirvonen et al. (2015) found that diets are less diversified during the Orthodox Lent and Advent fasting periods, due to reduced intake of ASF, both for rural and urban households. Likewise, Abegaz et al. (2018) mapped seasonal per capita consumption of ASF and observed that drops and peaks in intake overlap to a large extent with Orthodox fasting and feasts.

Table 3.1: Overview of the obligatory fasting events and feasts in Ethiopia according to the Orthodox Church doctrine

Fasts	Timing
Advent fast	40 days, from November 28 – January 6
Epiphany fast	Fast on the eve of Epiphany
Nineveh fast	Three days (Monday to Wednesday), two weeks before the start of Lent
Lent fast (Easter fast)	55 days, starts on Monday, movable start (between February 8 – March 14)
Sene fast (Apostles fast)	10-40 days, starts Monday after Pentecost and ends July 12
Felseta fast (Assumption fast)	15 days, from August 7 – August 21
Weekly fasting	Every Wednesday and Friday (except for the period between Easter and Pentecost)

Source: Compiled by authors, based on Knutsson and Selinus (1970); Ware (1997); The Ethiopian Orthodox Tewahedo Church (2003).

These demand swings caused by fasting affect all actors along the dairy value chain, i.e. retailers, processors, and producers. Many processors cut down their capacity during fasting periods, with reductions of 25 percent being reported (Land O'Lakes, 2010). Moreover, they try to limit the supply of milk during fasting using quota systems, paying lower prices, or requiring a higher milk quality from their suppliers (Zijlstra et al., 2015). Some processors adapt during the fasting period by building up stocks of processed milk products that they can sell outside the fasting period, while others transport their products to areas where fasting is less prevalent (Land O'Lakes, 2010). Since end consumers, retailers, and processors all limit the quantity of milk they purchase, fasting necessarily also affects the dairy farmers. Many farmers indicate a reduced or even a complete lack of market access, lower sales, reduced

dairy prices, and increased processing of milk into less perishable products, like butter or cheese, during fasting (Tegegne et al., 2013; Makoni et al., 2014; Gizaw et al., 2016; Herego, 2017).

Other studies have examined the specific impact of fasting on the milk intake of young children (Kumera et al., 2018; Desalegn et al., 2019; Kim et al., 2019) and on lactating mothers (Desalegn et al., 2018) in Ethiopia. While pregnant and lactating women and children below the age of seven years in principle are exempt from fasting (Knutsson and Selinus, 1970),[2] all of these studies found negative repercussions of Orthodox fasting practices on dietary diversity and intake of ASF. Desalegn et al. (2019) found that maternal fasting adherence influences children's dietary intake and nutritional status significantly, even outside of official fasting periods.[3] Kim et al. (2019), who studied ASF consumption by children aged 6 to 23 months during Lent, observed that only a quarter of surveyed children consume ASF during the Lent fasting period, even though 80 percent of the surveyed households reported owning livestock. They found that caregivers are reluctant to feed ASF to their children during Lent, even when livestock products are available, because they fear the disapproval of their neighbors or the contamination of cooking utensils with non-fasting foods.

These trends are worrisome given low dietary diversity and low ASF consumption in Ethiopia, even outside of fasting periods. According to the 2016 Ethiopian Demographic and Health Survey, only 14 percent of the children aged 6 to 23 months received diets that met the recommended minimum dietary diversity score. Children under the age of two years consume little meat, fish, or poultry: only 8 percent for breastfeeding children and 14 percent for non-breastfeeding children. Although milk intake is somewhat higher, it is still low at 13 percent and 24 percent, respectively (CSA and ICF, 2016). The low inclusion of ASF in children's diets is believed to be an important driver of the high prevalence of malnutrition in sub-Saharan Africa (Willett et al., 2019). Yet, it has been shown that household cow

[2]Severely ill or weak persons also are not required to fast.

[3]A recent study by Potts et al. (2019) found that Muslim children had a higher probability (20 percent) of having consumed ASF as compared to children from Orthodox households and households adhering to other religions.

ownership increases children's milk consumption and promotes linear growth and reduces stunting in young children, especially so in rural areas with thin dairy markets (Hoddinott et al., 2015).

These studies demonstrate how Orthodox fasting practices might affect consumption and value chains of ASF. Yet, quantitative analyses of these effects remain limited – a research gap we address here.

3.3 Conceptual framework

To conceptualize the impacts of fasting, we rely on a simple demand and supply framework. We first look at the results of a one-commodity analysis and then expand this to two commodities, allowing for the possibility of processing liquid milk into butter.

In a one-commodity framework (liquid milk), prices and quantity consumed meet at an equilibrium price (P_{NF}) and quantity (Q_{NF}) during non-fasting periods (Figure 3.1, left side). Abstinence from dairy products by some people in Ethiopia during the fasting period leads to a shift downward from D_{NF} to D_F in the overall demand curve for milk. If supply stays constant, prices of milk will drop to P_F, and it will therefore become more accessible for those people that do not fast. For the latter group, consumption might therefore go up during the period of fasting. It is also possible that supply is adjusted down with the decline in demand during fasting periods, since lactation periods in dairy animals can be planned. In that case, the price declines associated with fasting periods might be smaller. However, as lactation periods cannot easily be adjusted for relatively short fasting periods, such effects will likely be relatively small and will only exist for longer fasts. Effects of fasting on prices and quantities consumed will depend on respective demand and supply elasticities as well as the share of the population that is affected by fasting, as that will affect the size of the shift.

If a second commodity is brought into the analysis and we allow for the fact that milk can be transformed to a storable product, e.g., butter, fasting might lead to a number of different

effects in the milk and butter markets. In this case, on top of demand shifts, there is a shift in the supply curve of liquid milk – from S_{NF} to S'_F – as well. While consumption is significantly reduced, price effects are much smaller as seen in the smaller differences between (P_{NF}-P'_F) than (P_{NF}-P_F). On the other hand, effects of fasting in the butter market will be magnified. We see a supply shift to the right because of the extra processing of liquid milk into butter during fasting. As the demand for this commodity is also affected by fasting habits, we further see a shift of the demand curve downwards, putting extra downward pressure on butter prices, which are reduced from P_{NF} to P_F, even without large changes in quantities consumed (Q_{NF}-Q_F).

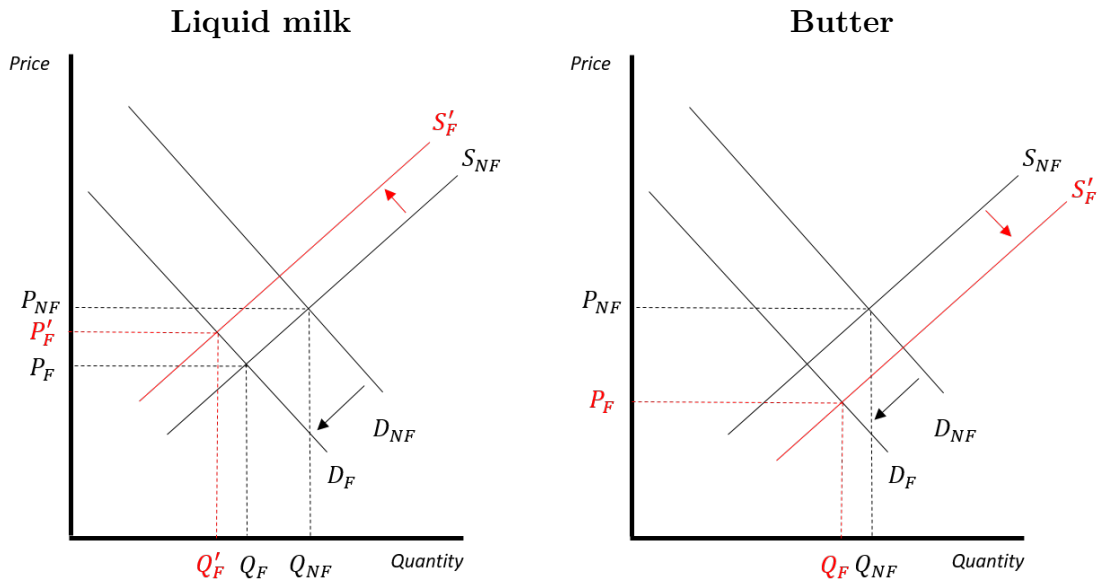


Figure 3.1: Demand and supply framework illustrating the impact of fasting on the liquid milk and butter markets

These simple diagrams give an indication of the forces at play in dairy markets because of fasting. The expected downward pressure on prices in butter markets is partly explained by opportunity costs for the storage of butter and should in more complete models be addressed by more sophisticated models that incorporate the costs of processing and storage (e.g., Williams and Wright, 2005). Other adaptation methods and processing possibilities for milk

should be considered as well. However, these considerations are beyond the scope of this analysis.

The purpose of this simple conceptual framework is to help set the stage for expected results of our analysis. First, we expect that dairy consumption by those not affected by fasting will go up because of price decreases. Second, milk production will go down during (longer) fasts. Third, price swings will be larger for storable dairy commodities than for liquid milk as storable products will be affected by supply increases on top of demand decreases. Finally, the predicted effects all depend on the magnitude of fasting adherence by the population at large and on the level of market integration, as they determine the size of these demand shifts.

3.4 Data and empirical strategy

We use unique primary data collected with the aim of mapping the supply chain of dairy products to Ethiopia's capital city, Addis Ababa, the most developed milk shed within the country. We surveyed 870 milk producing households with at least one cow in milk located in and around Addis Ababa (30 urban, 240 suburban, and 600 rural producers). Data collection took place between 22 January and 15 February 2018. More details on the sampling strategy and on how the sample compares to the broader Ethiopian population can be found in Appendix C1 and C2 respectively.

This paper looks at three research questions, as indicated in the introduction. It is important to keep in mind that 85 percent of the surveyed households reported being Orthodox Christian. The other surveyed households reported being Protestant (12 percent), Muslim (2 percent), Catholic (1 percent) or indicated that they adhere to other religious beliefs, e.g., traditional faiths (1 percent). To answer our first research question on effective fasting participation, we only examine data obtained from Orthodox households in our sample. For the remaining research questions on production adaptation and consumption, our analytical

sample is made up of both Orthodox and non-Orthodox households. In our regressions for these research questions, we include controls for religious affiliation of the household.

Our first study question is to assess the effective number of days annually that members of Orthodox households fast. To do so, we asked respondents (usually the household head) in Orthodox households to indicate for each household member above the age of five years whether or not this member observes any Orthodox fasting event. If a member was said to engage in fasting, we detailed for each of the seven major fasts, as outlined in Table 3.1, a member's observance with a dummy variable (yes/no). If a member participates in a particular fasting event, we assume that this member fasts during the entire prescribed fasting period. This method provides us with fasting data on 3,946 individuals. We extend this analysis by investigating the factors associated with fasting participation. To do so, we run a random and household-level fixed effect logit regression.

Second, to detail the impact of fasting on the value chain, we look both at the adaptation strategies of milk producers and at dairy prices. We start by analyzing the different strategies used by farmers to deal with fasting by looking at the impact fasting has on their milk production and the different milk output uses they adopt.

We further explore potential heterogeneity in adopted adaptation strategies, specifically that dependent upon the household's degree of market access. We proxy market accessibility by remoteness to Addis Ababa,[4] assuming that households located closer to the capital have better market access. We therefore categorize farmers in two groups, remote and non-remote, using the median of 1.54 hours travel time to Addis Ababa as a cut-off between the two groups.[5]

[4]The variable is defined and calculated in line with Vandercasteelen et al. (2018) using the Ethiopian road network and quality data (obtained from the Ethiopian Road Authority) combined with the farmer's self-reported travel time to the nearest road segment. The obtained measure thus captures the travel time (expressed in hours) from the farm's location to Ethiopia's capital city.

[5]When looking at the religious composition of both groups, we find that 80 percent of the remote farmers affiliate to the Ethiopia Orthodox Church and 16 percent reported to be Protestant. A somewhat higher share of non-remote farmers reported to be Orthodox Christians (90 percent), while 8 percent reported to be Protestant. We also tested a full-sample approach by including interaction effects, but this did provide the necessary statistical power. Therefore, we restrict our reported results to those of the split-sample analysis.

To appraise price effects linked with fasting, we use market prices reported by our participants over the 12 months preceding the survey. We further detail the effect of remoteness on seasonal price swings caused by fasting. We do so by using the reported prices that farmers obtained for dairy products that they sold in the middle of the most recent long fasting season and two weeks after this fasting season, when they had cows in milk. To assess these impacts of fasting, we run fixed effect regression models at the household level, splitting the data between remote and non-remote milk producing households, following the definition mentioned above.

Finally, we assess the impact of fasting on dairy intake of the household as a whole and the youngest child aged five years and under separately.[6] Furthermore, we test with detailed data what was consumed by the youngest child in the day before the survey and how this is affected by the fasting observance of the household head. Fasting observance is self-reported and equaled one if the household head indicated to have fasted the day before the survey. We again look at heterogeneity in these effects linked to market access.

To assess the impact of fasting on producer adaptation strategies and consumption, we use Ordinary Least Squares (OLS) and Tobit regressions. Using the time variation of our interview period (Table 3.2), we were able to develop two fasting indicators for each household surveyed, based on the number of consecutive official fasting days in the week and in the month prior to the interview. These fasting indicators are calculated using the official fasting calendar (as reflected in Table 3.1). We calculate these indicators on a weekly and monthly basis to accommodate the fact that outcome variables are based on either weekly (consumption) or monthly (production and output use) recall periods.

[6]Out of the 870 surveyed households, 310 had a child below the age of five years. 86 percent of these children are members of an Orthodox household, while 12 percent are part of a Protestant household.

Table 3.2: Timing of fasting periods and data collection, 2017 and 2018

Dates	28 Nov to 06 Jan	07 Jan to 21 Jan	22 Jan to 28 Jan	29 Jan to 31 Jan	01 Feb to 11 Feb	12 Feb to 25 Feb	26 Feb to 07 Apr
Fasting period	Advent	Weekly only	Weekly only	Weekly only	Nineveh	Lent	Lent
Data collection			X	X	X	X	

For both fasting indicators, a cut-off is chosen to distinguish between short and long fasting episodes. The cut-off is set at the average amount of consecutive fasting days, which for the weekly and monthly fasting indicator amounts to 4 days (varying between 1 and 7 days) and 10 days (varying between 3 and 17 days), respectively (Table 3.3). By dividing the sample in this way, we construct a treatment variable where the treatment equates the presence of a long fasting period in the past week or past month. In our sample, 31 and 60 percent of households were confronted with a long fasting period in the last week and month, respectively. The difference in likelihood of treatment between both fasting indicators can be explained by the presence of the Advent fasting period, which is covered in the monthly fasting indicator, but not in the weekly indicator.

Table 3.3: Descriptive statistics of the constructed fasting indicators

Variable	Unit	Mean (standard deviation)
Consecutive fasting days week	number (1–7)	3.09 (2.48)
Weekly fasting indicator	0/1	0.31
Consecutive fasting days month	number (3–17)	9.44 (3.71)
Monthly fasting indicator	0/1	0.60
Observations		870

Besides these main explanatory variables, we also included household and individual variables outlined in Table C.3 as controls. Regressing the fasting indicators on all covariates, using an F-test, revealed that neither of the two treatment variables withstands a joint orthogonality test. It shows, for example, that the variation in the sample across space (remoteness) is related to the variation across time (fasting indicators) in a non-random way. The controls include household socio-demographic characteristics, as well as controls

related to dairy production and marketing. We also control for within-sample concentrations of different religions in the village where a household resides. We assume that religious diversity in the immediate vicinity of a household, and particularly the concentration of Orthodox followers, may impact milk production and milk output use decisions. Finally, we include a series of individual control variables specifically related to the milk intake of children. In all regressions, standard errors are clustered at the village level.

Descriptive statistics of the dependent variables used in the OLS and Tobit regressions are summarized in Table 3.4. Average daily milk production in our sample is 3 liters per cow, of which 55 percent is processed into cheese, butter, or buttermilk, 25 percent is sold, 19 percent is used for own consumption, and a minor share (0.5 percent) is given away. Sales volumes vary considerably for all dairy products, driven in part by the fact that an important share (35 percent) of the dairy producers does not sell any dairy products.[7] Still, it can be observed that producers specialize in liquid milk sales, with processing at the farm level mainly intended for own consumption. Dairy products consumed within the household are almost exclusively sourced from own production (99.8 percent on average across all dairy products).

[7]We did not consider the sales of buttermilk, since buttermilk is usually not sold in the market.

Table 3.4: Descriptive statistics of outcome variables used in analysis of milk producer adaptation strategies and consumption

Variable	Unit	Household	Youngest child
Past month			
Milk production	l/cow/day	2.95 (3.85)	
Share milk home processed	%	54.98 (37.83)	
Share milk sold	%	25.62 (40.31)	
Share milk home consumed	%	18.78 (21.74)	
Share milk given out	%	0.50 (3.59)	
Sales quantities past month			
Milk	l	123.9 (351.7)	
Butter	kg	1.08 (2.87)	
Cheese	kg	7.90 (31.18)	
Past week			
Dairy consumption			
Milk	l	3.16 (4.44)	2.04 (2.67)
Buttermilk	l	1.70 (3.30)	0.40 (1.09)
Butter	l eq.[a]	2.16 (5.79)	
Cheese	l eq.	1.64 (3.57)	
Observations		870	317

Notes: Means are shown with standard deviations in parentheses. [a]For comparison purposes, kilogram (kg) amounts of processed products are transformed into liter (l) of milk equivalents. The conversion rates used are 20 l/kg for butter and 1.33 l/kg for cheese.

We collected separate milk intake data for the youngest child below the age of five years in each surveyed household. Average household milk intake fluctuates around 3 liters, of which the youngest child consumes on average 2 liters. Our data thus confirm that young children are prioritized when it comes to milk consumption, in line with the prevailing assumption in Ethiopia that milk is mainly meant for children (Kitaw et al., 2012).[8,9]

3.5 Fasting participation and beliefs

Table 3.5 summarizes the extent of participation in fasting periods throughout the year for Orthodox households. The number of fasting days on a yearly basis varies from 5.2 days

[8]Wastage of milk and related products does not appear to be an issue in our sample. A study by Minten et al. (2019), using the same producer data as this paper, assessed that the percentage of all produced milk spoiled at farm level was as little as 0.003 to 0.008 percent.

[9]Buttermilk, on the other hand, is mostly consumed by other household members, mostly women and elderly (Gonfa et al., 2001).

for young children to 142 days for elderly people. The fasting adherence of adults is around 140 days and thus 26 to 110 days below the estimates of 166 to 250 fasting days per year reported elsewhere (Francesconi et al., 2010; Bachewe et al., 2017; Abegaz et al., 2018). It is also to be noted that between 11 and 12 percent of Orthodox adults do not participate in any fast, possibly because of pregnancy or illness, but possibly out of choice. Furthermore, fasting adherence increases with age. Average participation among older children, who are supposed to participate in fasting periods, is rather low with about one-in-five participating. Adolescents fast more commonly, 65 percent on average, while observance reaches 90 percent among adults and the elderly.

Table 3.5: Participation rates and fasting days per age group for members of the Orthodox faith

	Participate in any fasting	Number of fasting days	
	%	Average	Standard deviation
Young children (5-6)	4.97	5.19	29.52
Older children (7-9)	22.75	34.08	65.97
Adolescents (10-19)	64.51	98.40	77.63
Adults (20-64)	88.53	140.36	57.91
Elderly (65+)	89.42	141.65	56.86

Only a small proportion of young children participates in fasting rituals, although they are in principle exempt from fasting. Among Orthodox surveyed households, we asked opinions about fasting observance by young children. Only 11 percent of the households disagreed or strongly disagreed that children less than 2 years old should not observe fasting. Four percent believed that children aged 6 to 23 months should stop eating ASF during fasting; 6 percent argued that these children should eat less frequently during fasting; and 5 percent though these children should be breastfed less during fasting. In general, Orthodox households in our sample stated that children should start observing fasting at the age of 9.2 years (with a 95 percent confidence interval of 8.6 to 9.7 years old). While these findings are lower than those reported by Kim et al. (2019), who find that only half of caregivers had positive attitudes towards the exemption of children from fasting practices, it is still worrisome to find in our

data that a number of young children are actively participating or are expected to participate in fasting.

To understand factors associated with fasting participation, we run a random and household-level fixed effect logit regression. A number of interesting results show up from that exercise (Table 3.6). First, participation rates differ greatly across the different fasting events. We observe that Lent, Felseta fast, and the weekly fasting days are the most adhered to, followed, at some distance, by the Nineveh and the Advent fasts. Second, women participate significantly less in fasting events than men. Third, as noted earlier, we also see strong associations with age. Finally, we note that household head controls, household size, and household income have no significant association with fasting participation. We do however observe significantly more fasting participation the farther that the household is located from Addis Ababa, whereas an increased concentration of Orthodox households at the village level significantly reduces fasting participation.

The results indicate that fasting is widespread in the Orthodox community, but that there is also significant heterogeneity in fasting adherence. Using these data, we calculate that annual milk consumption at the national level is reduced by about 12 percent because of Orthodox fasting practices – this calculation is based on 43 percent of the population being Orthodox (CSA, 2010); 38 percent of all days being fasting days (140 days out of 365); and children below 10 years of age, who represent 28 percent of the Orthodox population, being exempt from fasting.[10] While the effects of fasting on milk consumption in specific periods and locations might obviously be higher, this result suggests that fasting is only a partial explanation for low dairy consumption in the country. We now look at milk producer adaptation strategies, pricing effects, and consumption changes because of this fasting practice.

[10]We further assume no difference in consumption between Orthodox and non-Orthodox population and between children below 10 and others during non-fasting days. These estimates can obviously be improved, but the purpose of the exercise is only to give an idea on the order of magnitude.

Table 3.6: Factors associated with fasting participation

	Unit	Random effect		Fixed effect	
		Coefficient (S.E.)	z-value	Coefficient (S.E.)	z-value
Fasting events					
Advent fast	0/1	-4.64 (0.20)	-23.76	-4.36 (0.19)	-22.90
Lent fast	0/1	-1.27 (0.21)	-6.03	-1.21 (0.21)	-5.90
Nineveh fast	0/1	-4.14 (0.19)	-21.28	-3.90 (0.19)	-20.53
Sene fast	0/1	-6.04 (0.20)	-30.29	-5.69 (0.19)	-29.29
Felseta fast	0/1	-1.27 (0.21)	-6.03	-1.32 (0.20)	-6.45
Epiphany fast	0/1	-7.61 (0.21)	-36.19	-7.41 (0.21)	-35.80
Weekly fasting	0/1	Omitted		Omitted	
Individual controls					
Sex: female	0/1	-0.16 (0.06)	-2.55	-0.14 (0.06)	-2.31
Age					
5 to 6 years	0/1	-3.97 (1.14)	-3.47	-4.96 (1.14)	-4.34
7 to 9	0/1	2.48 (0.93)	2.67	2.24 (0.91)	2.47
10 to 19	0/1	2.86 (0.92)	3.11	2.64 (0.89)	2.97
20 to 64	0/1	3.28 (0.92)	3.57	3.06 (0.89)	3.44
65+	0/1	3.59 (0.93)	3.88	3.38 (0.90)	3.76
Schooling	years	0.01 (0.01)	0.55	0.00 (0.01)	0.38
Household head controls					
Sex: female	0/1	-0.57 (0.55)	-1.04		
Age	years	0.02 (0.01)	1.51		
Schooling	years	0.04 (0.04)	1.18		
Household controls					
Household size	#	0.04 (0.07)	0.57		
Total income	'000 ETB/month	-0.01 (0.03)	-0.19		
Orthodox concentration	%	-3.19 (0.97)	-3.29		
Remoteness	hours	0.25 (0.11)	2.19		
Observations		19,306		12,642	
Chi-squared		2,915.26		6,986.12	

3.6 Fasting, adaptation strategies, and dairy prices

3.6.1 Fasting and producer adaptation strategies

In this section, we look at different adaptation strategies developed by milk producing households (both Orthodox and non-Orthodox) to manage the reduced demand for liquid milk during fasting periods. We first look at production and output use. We find that long fasting periods reduce daily milk production by one-fourth on average (Table 3.7). This suggests

that farmers are aligning their production with fasting periods, especially since part of the data collection period coincided with the Advent fasting, a period during which milk output should be at its highest level (see Appendix C4). This confirms the predicted effect from the conceptual model in Section 3.3.

Furthermore, we observe that long fasting seasons reduce marketing possibilities, with especially milk sales dropping significantly (Table 3.7). Farmers turn the milk that is not sold into dairy products with a longer shelf life, processing up to 60 percent of their milk output during long fasts. The share of consumption does not change with the presence of long fasting periods, which translates into lower absolute levels of consumption given the decrease in milk production (for more detail, see Table 3.11). We further observe no change in the already low share of milk being given away. As we have no reliable estimates of wastage of milk, it is possible that a large part of the remaining milk is thrown away during fasting periods.

Table 3.7: Effect of the presence of a long fasting season in the last month on milk production and output use one month prior to the interview

	Milk production and output use last month				
	Milk production (l/day)	Milk sold (%)	Milk processed (%)	Milk consumed (%)	Milk given out (%)
Fasting past month (0/1)	-1.67*	-48.71***	19.64***	-1.15	-8.05
	(0.97)	(14.22)	(6.90)	(2.18)	(8.84)
Model employed	OLS	Tobit	Tobit	Tobit	Tobit
Household controls	Yes	Yes	Yes	Yes	Yes
Non-fasting mean	7.03	40.44	41.66	17.40	0.50
Observations	855	855	855	855	855
(Pseudo) R-squared	0.72	0.19	0.07	0.02	0.09

Notes: See Appendix Table C.3 for a complete list of controls. Total dairy production is not included as a control variable. Cluster robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

In further analysis (not reported), it was found that the increased proportion of milk being processed during fasting is especially transformed into cheese. The production of other processed products does not change significantly. Regarding sales volumes, we find that only milk sales are significantly affected by long fasting periods, being reduced on average by 28

percent (Table 3.8). This means that the cheese produced during long fasting periods is most likely not sold immediately but stored for sale or consumption after the fasting period. Milk sales do not completely drop to zero, since some milk buyers continue purchasing milk during Orthodox fasting. This is the case for about 18 percent of the farmers in our sample.[11] Using a robustness check (Appendix C5), we find that long fasting periods affect the decision to sell milk, but not sales volumes conditional on a farmer selling milk during a fast.

Table 3.8: Effect of the presence of a long fasting season in the last month on total dairy sales one month prior to the interview

	Total monthly dairy sales last month		
	Milk (l)	Butter (kg)	Cheese (kg)
Fasting past month (0/1)	-48.86*	0.59	4.00
	(24.89)	(0.35)	(3.38)
Model employed	OLS	OLS	OLS
Household controls	Yes	Yes	Yes
Non-fasting mean	173.35	0.70	5.37
Observations	855	855	855
R-squared	0.77	0.25	0.26

Notes: See Appendix Table C.3 for a complete list of controls. Cluster robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

We further assess heterogeneity of adaptation strategies with respect to remoteness (Table 3.9). We find that remote households have predominantly adapted to a culture of fasting by reducing their milk production, with total milk output falling by 60 percent during long fasting periods. Non-remote households, on the other hand, seem to have better access to buyers who continue purchasing milk during fasting, which enables them to maintain their milk production. However, we observe a slightly negative, yet not significant, trend in total milk output in these non-remote households as well. But, we find considerable heterogeneity in their ability to sell milk during fasting seasons and overall it seems that milk sales volumes tend to go down slightly. Milk sales of remote farmers, on the other hand, drop significantly (80 percent). As a result, both remote and non-remote households rely on processing to

[11] Anecdotal evidence suggests that some buyers keep on buying milk, although they do not need nor use this milk but rather throw it away afterwards (van der Valk and Tessema, 2010). Continuing buying milk during Orthodox fasting seasons seemingly helps buyers to assure supply from dairy producers in the non-fasting periods.

overcome Orthodox fasting events. For neither remote nor non-remote households, however, do sales of processed milk products increase during long fasting periods.

Table 3.9: Heterogeneity in milk production and output use adaptation strategies by remoteness to Addis Ababa

	Milk production and output use last month							
	Milk production (l/day)		Processing (%)		Milk sales (l)		Processed sales (kg)	
	Remote	*Not remote*	*Remote*	*Not remote*	*Remote*	*Not remote*	*Remote*	*Not remote*
Fasting past	-1.51**	-1.59	11.14	27.00***	-36.86**	-40.34	3.60	3.49
month (0/1)	(0.68)	(1.41)	(7.02)	(8.47)	(17.30)	(31.58)	(4.80)	(2.92)
Model employed	OLS	OLS	Tobit	Tobit	OLS	OLS	OLS	OLS
Household controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Non-fasting mean	2.32	10.42	63.30	26.06	46.12	265.14	7.41	5.10
Observations	427	428	427	428	427	428	427	428
(Pseudo) R-squared	0.39	0.77	0.02	0.08	0.30	0.86	0.60	0.20

Notes: Remote / Not remote = Below / Above median travel time to Addis Ababa (1.54 hours). See Appendix Table C.3 for a complete list of controls. Remoteness and access to the Addis market are not included as control variables and neither is total production for the regressions where milk production and share of processing are the dependent variables. Cluster robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.10.

3.6.2 Fasting and dairy prices

Looking at price effects linked with fasting, we find that prices for different dairy products are low during periods of abundant supply (from June until the end of the year) and low demand (the Advent and Lent fasting periods). Conversely, prices are at their highest level when high demand, such as for feasts like Christmas and Easter, interacts with a declining availability of dairy products, such as in January and February (see Appendix Figure C.2). Figure 3.2 also shows that price fluctuations are most pronounced for processed milk products, while milk prices seem to be barely affected by seasonality in supply or demand, although milk prices are slightly lower during Lent. Similar seasonal price variations for dairy products are reported by Bachewe et al. (2017). These results therefore confirm the predicted effect from the conceptual model in Section 3.3.

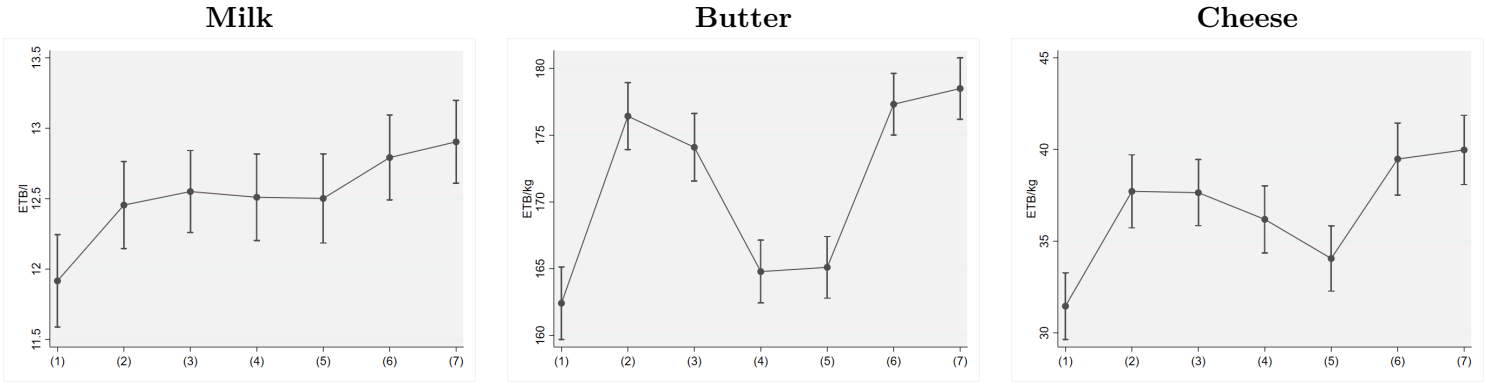


Figure 3.2: Average market prices of different dairy products throughout the year
(1) Lent; (2) Easter; (3) Easter-May; (4) Jun-Advent; (5) Advent; (6) Christmas; (7) Christmas-current
Note: ETB = Ethiopian Birr. At the time of the survey: 1 USD = 27 ETB. Prices are expressed in nominal terms. Whisker-plots around points are 95-percent confidence intervals.

We further look at the effect of remoteness of farmers on seasonal price swings (Table 3.10). We continue to see with these data lower price swings during the fasting seasons for liquid milk compared to processed milk products. While fasting leads to a price reduction of 3 to 5 percent for liquid milk, this is as high as 7 to 8 percent for butter, and 18 percent for cheese. We also note that for milk there are higher price differences for remote areas compared to non-remote areas. This indicates the importance of access to markets for highly perishable milk to reduce price volatility because of fasting. The limited effect of fasting on liquid milk prices seems to suggest that the magnitude of demand and supply shifts caused by fasting is almost equal for liquid milk, at least based on our data.

Table 3.10: Fixed effects analysis of heterogeneity in price differences by remoteness to Addis Ababa

	Dairy prices					
	Milk (ETB/l)		Butter (ETB/kg)		Cheese (ETB/kg)	
	Remote	*Not remote*	*Remote*	*Not remote*	*Remote*	*Not remote*
Fasting (0/1)	-0.559***	-0.396***	-12.24***	-13.69***	-5.94***	-8.09***
	(0.119)	(0.099)	(1.617)	(1.401)	(0.579)	(0.996)
Model employed	FE	FE	FE	FE	FE	FE
Non-fasting mean	10.96	13.37	168.42	175.70	32.49	44.58
Observations	60	234	305	183	118	151

Notes: Remote / not remote = below / above median travel time to Addis Ababa (1.54 hours).
*** p<0.01, ** p<0.05, * p<0.1

3.7 Fasting and consumption

Finally, we take a closer look at the impact of fasting on dairy consumption with detailed data at household level and for children below the age of five years. If there was a long fasting event in the week prior to the interview, households' dairy consumption decreases, but only significantly so in the case of butter, with intake almost cut by half (Table 3.11). Such drops are expected, since the majority of producing households (85 percent) are Orthodox Christian (Appendix Table C.3). The limited impact of fasting on weekly dairy consumption could indicate that adult household members compensate for the forgone consumption of dairy, as well as other ASF, during non-fasting days. Strikingly, it appears that households' milk consumption during long fasting episodes would be even lower, were it not for the fact that the youngest children are given considerably more milk in case of a long fasting event in the past week. Their milk consumption increases by 60 percent during long fasting periods – they consume on average one extra liter of milk. This is in line with the predictions in the conceptual model.

Table 3.11: Effect of the presence of a fasting period of more than four days in the last week on dairy consumption one week prior to the interview

	Dairy consumption past week				
	Milk household (l/ad.eq.)	Butter household (l/ad.eq.)	Cheese household (l/ad.eq.)	Buttermilk household (l/ad.eq.)	Milk youngest child (l)
Fasting past week (0/1)	-0.14	-0.19**	-0.13	-0.049	1.02***
	(0.10)	(0.08)	(0.092)	(0.055)	(0.33)
Model employed	OLS	OLS	OLS	OLS	OLS
Individual controls	No	No	No	No	Yes
Household controls	Yes	Yes	Yes	Yes	Yes
Non-fasting mean	0.64	0.41	0.34	0.43	1.76
Observations	848	849	841	847	267
R-squared	0.16	0.12	0.11	0.31	0.22

Notes: Household amounts are expressed per adult equivalent to account for household size and composition. For complete list of controls, see Appendix Table C.3. Cluster robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

For children aged five years and below, we test with detailed data what was consumed

in the day before the survey (Figure 3.3). Most of the children consume milk (72 percent) while the consumption of pasteurized milk and powder milk is limited (2 percent). This is not surprising given the availability of fresh milk in these producing households. Children do consume cheese and butter, although the likelihood is much lower than compared to milk (20 to 25 percent). The probability of consuming other ASF, such as meat, fish, or yogurt, is below 10 percent, except for eggs at around 50 percent. We find that a single fasting day does not impact negatively on their overall intake of dairy products. If anything, we see an increase in consumption of milk by children during fasting days, although this increase is not significant at conventional statistical levels. But, we observe that children consume less beef, pork, and lamb on fasting days, probably because these food items are less likely to be consumed and prepared at the household level during fasts.

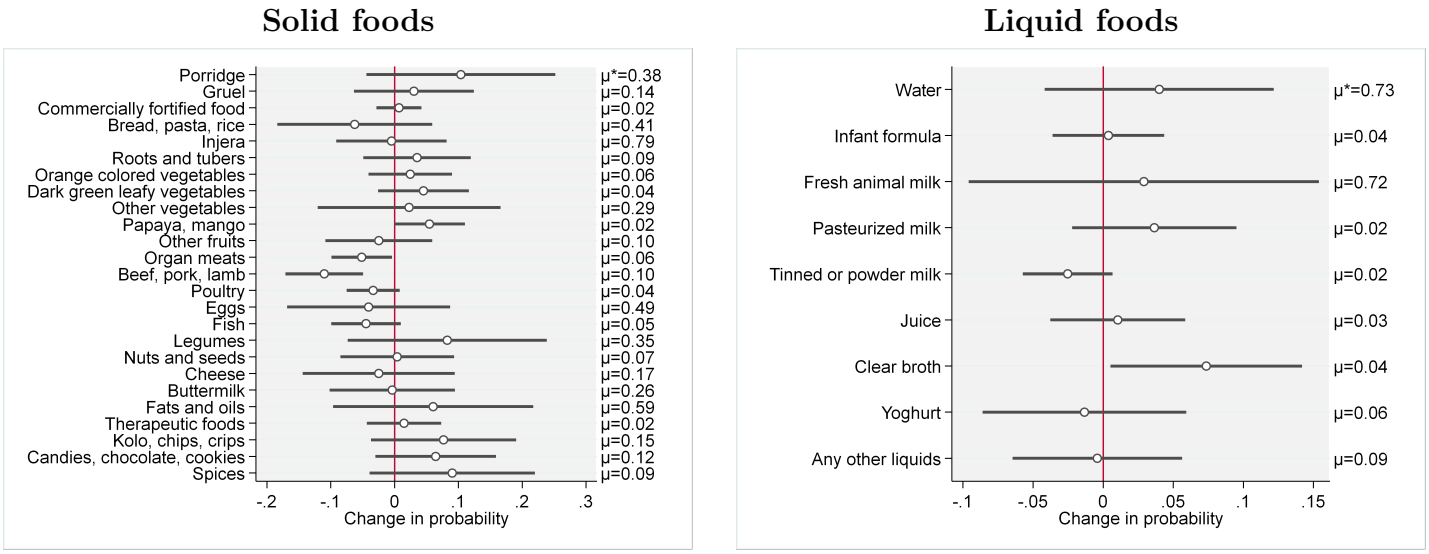


Figure 3.3: Impact of a fasting day on the likelihood of daily consumption of different food groups for the youngest child

Notes: *μ denotes the non-fasting mean of the dependent variable. Coefficients of the fasting day indicator are shown along with cluster robust 95-percent confidence intervals. For complete list of controls, see Appendix Table C.3.

One of the strategies that households have developed to overcome long Orthodox fasting periods is, thus, to allocate part of the surplus milk to their young children. These findings are different from those reported by Kim et al. (2019) who observed that, even in a setting where

80 percent of the interviewed households own livestock, only 25 percent of children consume any ASF during the Lent fasting period. An important reason for the increased consumption of milk by children that we observe seems to be the increased transaction costs to market milk during fasts. Marketing opportunities for milk drop significantly during fasting (Table 3.8) with buyers purchasing less or no milk during these periods. This increases transaction costs dramatically if farmers would want to search for alternative buyers to whom they could sell their milk. Since market prices of milk decrease during fasting (Table 3.10), a preferred option for farmers might be to channel part of the non-sold milk to their children. Of course, there is a limit to how much milk young children can consume. In our data, there appears to be an upper limit of about 7 liters per week for the youngest child. This implies that even during long fasting periods, allocating more milk to children can only partly solve the excess milk supply problem.

We also test heterogeneity in consumption with respect to remoteness (Table 3.12). There is large variability in milk consumption patterns among the non-remote households with some households consuming more and others consuming less milk during fasting periods. Remote households on the other hand, significantly reduce the amount of milk and processed milk products consumed during fasting. This could potentially be explained by differences in strictness to fasting adherence of remote and non-remote households, as is suggested by the results in Table 3.6. Yet, both types of households allocate more milk to children during fasting, significantly so among non-remote households.

Table 3.12: Heterogeneity in consumption adaptation strategies by remoteness to Addis Ababa

	Dairy consumption last week					
	Milk household (l/day)		Processed household (l/ad.eq.)		Milk child (l)	
	Remote	*Not remote*	*Remote*	*Not remote*	*Remote*	*Not remote*
Fasting past week (0/1)	-0.25**	-0.02	-0.64***	-0.24	0.98	1.45***
	(0.09)	(0.12)	(0.16)	(0.20)	(0.86)	(0.36)
Model employed	OLS	OLS	OLS	OLS	OLS	OLS
Household controls	Yes	Yes	Yes	Yes	Yes	Yes
Child controls	No	No	No	No	Yes	Yes
Non-fasting mean	0.57	0.78	1.33	0.85	1.59	2.11
Observations	422	426	420	419	133	134
R-squared	0.21	0.19	0.24	0.18	0.27	0.34

Notes: Remote / not remote = below / above median travel time to Addis Ababa (1.54 hours). For a complete list of controls, see Appendix Table C.3. Remoteness and access to the Addis market are not included as control variables. Cluster robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.10.

Finally, when comparing daily intake of children below the age of five years in remote and non-remote households, we find that fewer children consume fresh milk and buttermilk in non-remote households (64 percent of children in non-remote households versus 75 percent in remote households and 9 percent versus 35 percent, respectively). The consumption of pasteurized milk, powdered milk, and cheese does not vary between remote and non-remote households. Overall, we observe that a single fasting day seems to positively impact the intake of milk in non-remote households (as was observed in Table 3.11), whereas the opposite is observed for consumption of pasteurized milk (Figure 3.4). These figures suggest that non-remote households prioritize milk sales during non-fasting periods, and thus allocate less milk to their children, whereas surplus milk gets increasingly allocated to children in these households during fasting periods.

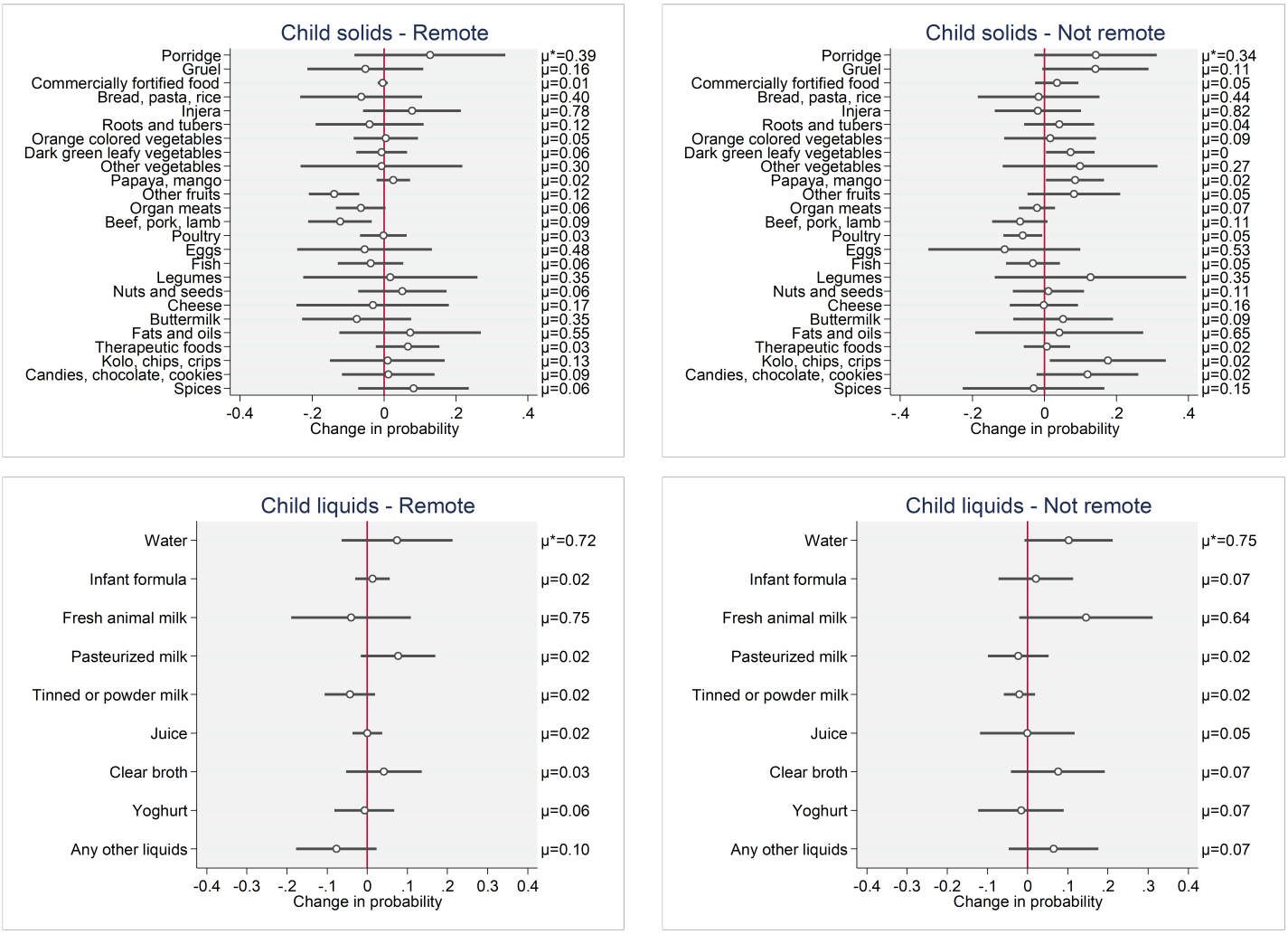


Figure 3.4: Impact of a fasting day on likelihood of daily consumption of different food groups for children in remote and non-remote households

Notes: *μ denotes the non-fasting mean of the dependent variable. Coefficients of the fasting day indicator are shown along with cluster robust confidence intervals. For a complete list of controls, see Appendix Table C.3.

3.8 Discussion and conclusion

The impact of food taboos on food consumption and value chains is not well understood. Fasting practices embedded within the largest religious community of Ethiopia, Orthodox Christians, create significant variation in demand for dairy products. However, evidence on adherence to fasting and its implications for the adaptation strategies of milk producers, for the pricing of dairy products, and on dairy consumption is limited. We study these issues in

this paper for dairy producers. Choosing this particular target group allows us to measure the simultaneous impact of fasting on dairy intake within the producer households, as well as on production, processing, and marketing decisions of dairy producers. No such comprehensive study has been undertaken in the Ethiopian context before.

We find that fasting adherence is widespread and that the average Orthodox Christian adult fasts for 140 days a year. Milk producing households adopt diverse strategies to overcome periods of reduced milk demand associated with fasting. Overall, we observe that such households are affected by two impact pathways during fasting periods. First, these households lower their own intake of dairy during fasting, which creates a surplus of milk at the household level. Second, as market opportunities are reduced during fasts, there are fewer outlets available for the surplus liquid milk. To manage this surplus milk, farmers adopt a combination of three strategies: (1) they reduce total milk output by aligning the number of cows in milk with fasting periods, (2) they increasingly channel produced milk to their youngest children, and (3) they expand processing of milk into less perishable dairy products, such as cheese or butter. The importance of each of these strategies, however, varies significantly along with the degree of access a milk producing household has to the major market of Addis Ababa. Remote households reduce their milk production significantly during longer fasting periods, process some of it into cheese or other dairy products, or feed some of their excess milk production to their children. Non-remote households, on the other hand, have been able to establish better arrangements with milk buyers so that they do not need to stop producing milk during fasting periods. Yet, during fasts, these milk producing households channel significantly more milk to their children and also process more into less perishable products. Furthermore, we find differential effects on prices for different dairy products, with small seasonal swings for liquid milk prices and larger ones for processed milk products.

Our results have several important policy implications. First, as the impact of fasting on milk consumption at national level is found to be relatively small and we find that children consume milk when it is available even during fasting periods, this suggests other issues

such as availability and affordability – instead of fasting – are the main impediments to increased dairy consumption in Ethiopia. Further investments to stimulate the dairy sector are therefore needed to increase availability of dairy products at lower prices. In contrast to the rapid growth in crop output and productivity recorded in Ethiopia, ASF output has grown slowly and productivity has stagnated, seemingly due to low availability and adoption of improved inputs in the sector. The result has been high and increasing prices for dairy products (Bachewe and Minten, 2019).

Second, we see a (small) number of children participating in fasts, even though they are, in principle, exempt from fasting. Further efforts at widely communicating the potential adverse developmental effects of fasting on children is needed.

Finally, to help smooth the effects of demand swings for milk and other dairy products and possibly to increase returns to investments in the sector, further efforts are needed towards enhancing processing practices (such as increasing production of UHT and powdered milk), ensuring availability of milk chilling centers, and improving transportation facilities in milk sheds and regionally to assure market integration and to expand dairy marketing to areas where fasting is less prevalent.

Furthermore, our findings point to a number of areas for further research. First, since our sample is not representative of the population at large, it would be useful to collect similar data with the same level of detail among all households, not only dairy producers. Second, future research would benefit from more focus on health outcomes and from repeated observations over time. Third, studies, in Ethiopia as well as in other countries, could target different religious groups to assess how their food habits and beliefs are related to food consumption and the development of food value chains. Finally, only dairy has been looked at in this study. It would be good to broaden the study to other ASF.

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Appendix C

Appendix C1: Sampling strategy

Producers are sampled from three sub-populations in and around Ethiopia's capital city, Addis Ababa: rural, suburban and urban populations. For rural producers, a three-step sampling process is followed. First, all woredas (an Ethiopian administrative unit comprising several kebeles or villages) of the rural regions are ranked and divided into quartiles based on remoteness (travel time) to Addis Ababa. 10 woredas are randomly, proportional to the number of cows, selected (four in Q1, and two each in Q2, Q3 and Q4). In a second step, three kebeles are selected from within each withheld woreda. For Q1 and Q2, a distinction is made between major road access kebeles and non-major road access kebeles. Two kebeles are randomly selected from the former category and one from the latter. Within Q3 and Q4, no such distinction is made and three kebeles are selected randomly. Finally, within each kebele, a census is drawn up of all households with dairy cows in milk. Of that list, twenty households are selected, ten from those who have three cows or more and ten from those with one or two cows.[12] The sampling procedure for the suburban farmers is similar, save for the fact that four kebeles (three on-road, one off-road) are randomly selected within each of the three suburban woredas. Finally, for the urban dairy farmers, a household survey was implemented with 30 randomly selected producers with one or two cows. The sampling strategy is summarized in Table C.1 while the farmers' geographic locations are shown in Figure C.1.

[12] In case there are not enough households with 3 cows or more, more households are selected from those with one or two cows, until the number of twenty households per kebele is reached.

Table C.1: Sampling strategy

	Urban	Sub-urban	Rural				Total
			Q1	Q2	Q3	Q4	
Woredas		3	4	2	2	2	13
On-road kebeles		9	8	4			21
Off-road kebeles		3	4	2	6	6	21
Farms	30	240	240	120	120	120	870

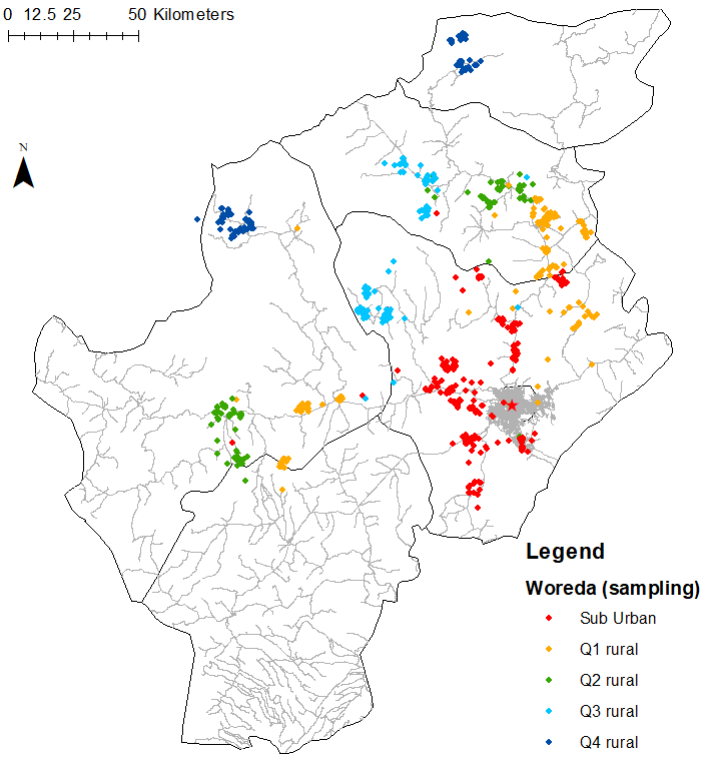


Figure C.1: Farmers' locations (the star indicates Addis Ababa)

Appendix C2: Comparison with LSMS data

Since all selected households are dairy producers, they are not necessarily representative for the population at large, which in turn might influence the external validity of our results. Because of this, we compare the households in our sample with households sampled in the same area and interviewed during the third wave of the World Bank's Living Standards Measurement Survey (LSMS).[13] We did so for several dimensions, the results of which can be found in Table C.2.

Household heads in our sample are more likely to be male, are slightly older, have fewer years of schooling and are predominantly Orthodox. The proportion of Muslims in our sample (1.72 percent) is considerably lower than that in the area (21 percent). Household sizes for our dairy producers are slightly bigger than those of more representative households, mostly driven by a higher number of (older) children. Judging by the type and number of assets owned, households in our sample do not appear to be considerably richer or poorer than their LSMS counterparts. Unsurprisingly, there are large differences in dairy-related measures, such as dairy consumption (which is up to 10 times as high for some products and almost entirely originates from own production) and cattle ownership. All this implies that our findings might not be suitable for extrapolation to the whole Ethiopian population.

[13] We deliberately select this dataset, since it covers a wide range of household related variables that match the variables in our dataset. Moreover, and more importantly, the period during which consumption data were gathered for the LSMS questionnaire (i.e. February-April 2016) overlaps well with the timing of our own survey.

Table C.2: Descriptive statistics for households in the National LSMS, the Addis Ababa buffer sample and the analysis sample along with t-test of difference

	Unit	(1) National LSMS sample (N=4,954)	(2) Addis LSMS subsample (N=842)[a]	(3) Survey sample (N=870)	(4) Difference (3)-(2)[b]
HH Head characteristics					
Sex	% male	69.35	65.40	91.6	26.2***
Age	years	46.36 (15.30)	46.60 (15.25)	48.95 (13.71)	2.35***
Schooling	years	3.65 (4.93)	5.03 (5.43)	3.76 (4.27)	-1.27***
Religious affiliation					
Orthodox	%	49.92	70.43	85.00	14.57***
Protestant	%	17.95	7.24	11.72	4.48***
Muslim	%	29.29	21.02	1.72	-19.30***
Other	%	2.62	1.19	1.38	0.19
Marital status	% married	69.34	66.35	90.92	24.57***
Household characteristics					
Household size	Number	4.72 (2.38)	4.45 (2.18)	6.02 (2.09)	1.57***
Infants (<1)		0.10 (0.31)	0.07 (0.27)	0.08 (0.28)	0.01
Young children (1-6)		0.78 (0.94)	0.62 (0.86)	0.62 (0.79)	0.01
Children (7-9)		0.41 (0.60)	0.29 (0.51)	0.52 (0.66)	0.23***
Adolescents (10-19)		1.30 (1.31)	1.18 (1.23)	2.11 (1.52)	0.94***
Adults (20-64)		2.25 (1.08)	2.37 (1.19)	2.43 (1.12)	0.07
Elderly (65 and above)		0.20 (0.45)	0.20 (0.44)	0.24 (0.51)	0.04
Asset ownership	Number				
Kerosene stove		0.07 (0.28)	0.14 (0.37)	0.10 (0.33)	-0.04**
Modern bed		1.43 (1.40)	1.67 (1.37)	0.60 (0.85)	-1.07***
Sofa/couch		0.17 (0.65)	0.27 (0.57)	0.38 (1.14)	0.11**
Radio		0.35 (0.54)	0.43 (0.54)	0.56 (0.64)	0.12***
Television		0.25 (0.46)	0.43 (0.53)	0.24 (0.49)	-0.19***
Mobile phone		0.96 (1.17)	1.39 (1.45)	0.87 (0.72)	-0.51***
Bicycle		0.03 (0.23)	0.03 (0.19)	0.01 (0.14)	-0.02**
Motorbike		0.02 (0.16)	0.01 (0.11)	0.01 (0.09)	-0.00
Car or truck		0.06 (0.82)	0.10 (0.78)	0.02 (0.17)	-0.07***
Dairy consumption					
Milk intake	Liter /adult eq./week[c]	0.34 (1.13)	0.25 (0.57)	0.64 (0.84)	0.39***
Own production		0.20 (1.05)	0.08 (0.29)	0.63 (0.84)	0.55***
Purchased		0.11 (0.42)	0.15 (0.51)	0.00 (0.03)	-0.15***
Gifts and other sources		0.02 (0.21)	0.01 (0.10)	0.00 (0.03)	-0.01**

Table C2 continued

	Unit	(1) National LSMS sample (N=4,954)	(2) Addis LSMS subsample (N=842)[a]	(3) Survey sample (N=870)	(4) Difference (3)-(2)[b]
Cheese intake	Liter eq./adult eq./week	0.05 (0.86)	0.03 (0.14)	0.31 (0.58)	0.28***
Own production		0.04 (0.86)	0.03 (0.12)	0.31 (0.58)	0.28***
Purchased		0.01 (0.07)	0.00 (0.03)	0.00 (0.00)	0.00**
Gifts and other sources		0.00 (0.05)	0.01 (0.07)	0.00 (0.00)	0.01**
Butter intake	Liter eq./adult eq./week	0.04 (0.67)	0.05 (0.94)	0.36 (0.48)	0.30***
Own production		0.02 (0.33)	0.01 (0.00)	0.34 (0.47)	0.34***
Purchased		0.03 (0.59)	0.05 (0.94)	0.00 (0.00)	-0.05
Gifts and other sources		0.00 (0.01)	0.00 (0.02)	0.00 (0.00)	0.00**
Consumer milk price	ETB[d]/liter	19.39 (17.29)	23.37 (23.44)		
Producer milk price				12.87 (3.27)	
Consumer cheese price	ETB/kg	50.21 (50.58)	53.08 (25.78)		
Producer cheese price				39.31 (19.37)	
Consumer butter price	ETB/kg	168.84 (135.9)	171.28 (105.5)		
Producer butter price				171.17 (43.29)	
Cattle ownership					
Total cattle	Number	2.80 (13.37)	2.24 (3.95)	9.46 (6.13)	7.22***
Total cross/exotic cattle	Number	0.08 (0.70)	0.12 (0.73)	3.05 (4.78)	2.93***
Total milking cows	Number	0.53 (1.14)	0.45 (1.54)	2.82 (2.17)	2.37***

Notes: Means are shown with standard deviations in parentheses.
[a]The Addis subsample of the LSMS dataset represents the part of the LSMS in a comparable geographical area as where the survey data of this paper was collected, i.e., it includes all LSMS households within a concentric circle of 170 kilometers surrounding Addis Ababa (with 170 km being roughly the furthest distance from Addis in the survey sample).
[b]A t-test (proportions test in the case of proportions) was conducted to compare the LSMS Addis subsample with the survey sample. The difference is shown as well as the significance of the difference. *** p<0.01, ** p<0.05, * p<0.1
[c]For comparison purposes, kilogram (kg) amounts of processed products are transformed into liter (l) of milk equivalents. The con-version rates used are 20 l/kg for butter and 1.33 l/kg for cheese.
[d]ETB = Ethiopian Birr. At the time of the survey: 1 USD = 27 ETB.

Appendix C3: Control variables

Table C.3: Descriptive statistics of the control variables

Variable	Unit	Household	Youngest child
Household controls			
Monthly total income	'000 ETB/month	3.68 (4.52)	
Household composition:			
Infants (<1 year old)	Number	0.08 (0.28)	
Children (1-6 years old)	Number	0.63 (0.79)	
Children (7-9 years old)	Number	0.52 (0.66)	
Adolescents (10-19 years old)	Number	2.11 (1.52)	
Adults (20-64 years old)	Number	2.44 (1.12)	
Elderly (65+ years old)	Number	0.24 (0.51)	
Sex household head: male	0/1	0.92	
Age household head	years	48.95 (13.71)	
Schooling household head	years	3.76 (4.27)	
Marital status household head:			
Married	0/1	0.91	
Widowed	0/1	0.06	
Divorced/separated	0/1	0.02	
Single	0/1	0.01	
Religious affiliation household head:			
Orthodox Christian	0/1	0.85	
Protestant	0/1	0.12	
Catholic	0/1	0.01	
Muslim	0/1	0.02	
Traditional faith	0/1	0.00	
Other religion	0/1	0.00	
Ethnicity household head:			
Oromo	0/1	0.86	
Amhara	0/1	0.12	
Tigrayan	0/1	0.00	
Gurage	0/1	0.01	
Other	0/1	0.01	
Total dairy production	l/month	400 (597)	
Total cows	Number	2.82 (2.17)	
Cross-bred cows	Number	1.14 (2.10)	
Cooperative member	0/1	0.04	
Access to Addis market	0/1	0.35	
Remoteness	hours	1.98 (1.46)	
Orthodox concentration (village)	%	84.45 (20.64)	
Youngest child controls			
Age	years		2.01 (1.32)
Sex: male	0/1		0.56
Breastfed yesterday	0/1		0.56
Vitamins yesterday	0/1		0.04
ORS (hydration) yesterday	0/1		0.03
Observations		870	317

Notes: When applicable, means are shown with standard deviations in parentheses.

Appendix C4: Seasonal milk production

Food production and consumption patterns vary with agricultural seasons in many countries. In Ethiopia, religion, in addition to weather cycles, also affects the dairy sector. Whereas the annual rainfall pattern affects dairy supply due to its impact on feed availability, the periodic occurrence of Orthodox fasting and feasts causes variation in demand for milk and other dairy products. We match both types of seasonality in Figure C.2 and show how both sources of variation in production and demand over a period of 12 months preceding the survey impact dairy cow productivity (Figure C.3); the number of cows in milk, both local and cross-bred (Figure C.4); and average market prices for different types of dairy products, as reported by survey participants (see Figure 3.2 in the main text).

Figure C.2 outlines the rainfall pattern and associated agricultural seasons as well as the timing of the main Orthodox fasts and feasts throughout the year. Seasonal rainfall distribution varies across different areas in Ethiopia, with some areas having spring rains. But generally most of the precipitation falls between June and September. The dry period usually takes places from February through May. Livestock feed availability follows this rainfall pattern, with feed being abundantly available from September to December, after which availability decreases. Critical feed shortages may occur between April and June (Gizaw et al., 2017).

This pattern of feed availability matches the seasonal pattern in dairy cow productivity in our sample (Figure C.3). Daily milk production per cow is at its lowest average level between January and June (2.6 liters/cow), after which it slowly increases to about 3.3 liters per cow for the period between September and December. Milk producing households seem to align their production practices with the agricultural seasons. As feed availability increases between June and December, farmers hold a rising percentage of cows in milk (Figure C.4).

Alternatively, one could argue that producers align their milk production to periods of reduced demand caused by fasting periods. They can do this by making sure that the dry periods of their cows coincide with long Orthodox fasting events. Some Orthodox fasting

events overlap with periods of potential feed shortage problems (Figure C.2). This is most obvious for the Apostles fast, which overlaps with the lean season during which the probability of acute livestock feed shortages is high. But also during the Lent fasting period, feed availability continuously decreases, causing economically rational producers to reduce milk production during this period.[14] However, given that the Orthodox fasting periods are scattered throughout the year, such a strategy may at best only partially tackle the mismatch between supply and demand.

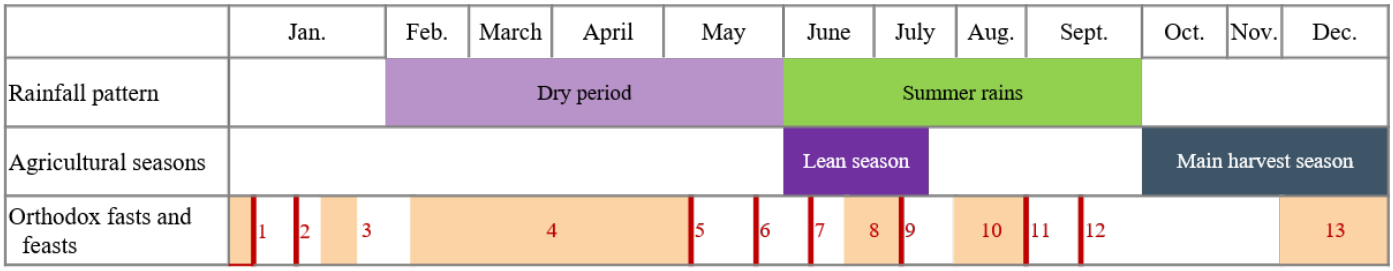


Figure C.2: Rainfall and agricultural seasons and the timing of main Orthodox fasts and feasts through the year

Notes: (1) Christmas, (2) Epiphany, (3) Nineveh fast, (4) Lent fast, (5) Easter, (6) Ascension, (7) Pentecost, (8) Apostles fast, (9) Feast of the Apostles, (10) Felseta fast, (11) Assumption feast, (12) Ethiopian New Year, (13) Advent fast. The dates for Lent, Easter, and associated fasts and feasts are not fixed calendar dates, but can vary by several weeks from year-to-year based on the lunar calendar.

[14] Alternatively, one could argue that it is not producers who adjust to the fasting periods, but that Orthodox fasting practices may have emerged in famine-prone Ethiopia to help reduce the pressure on food supply, as suggested by Dirks (1980).

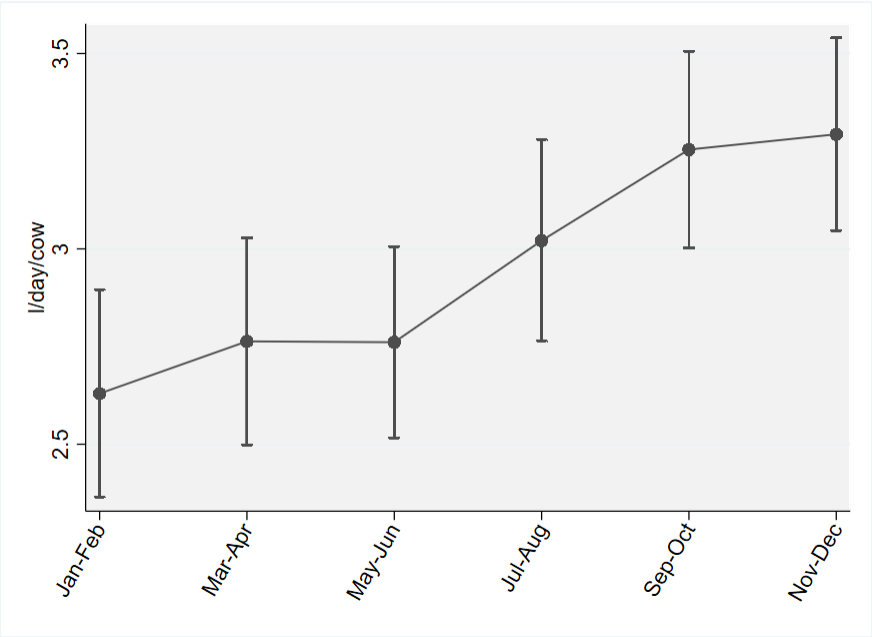


Figure C.3: Variation in average daily milk production per cow in milk through the year, liters

Notes: Whisker-plots around points are 95-percent confidence intervals.

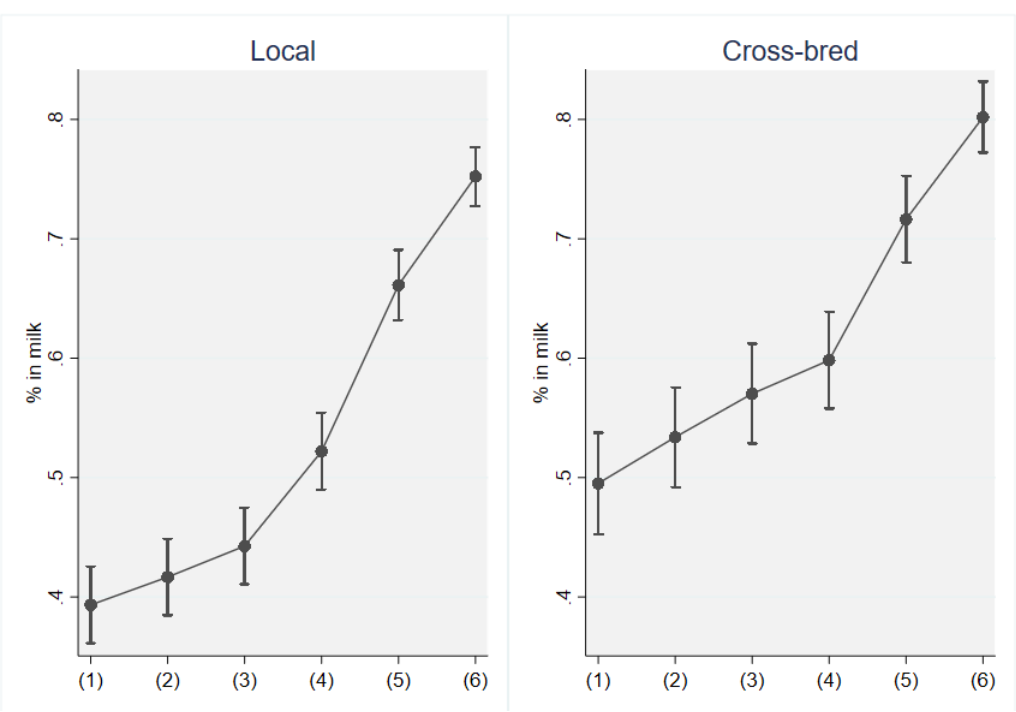


Figure C.4: Variation in local and cross-bred cows in milk through the year, share

(1) Jan-Feb; (2) Mar-Apr; (3) May-Jun; (4) Jul-Aug; (5) Sep-Oct; (6) Nov-Dec. Note: Whisker-plots around points are 95-percent confidence intervals.

Appendix C5: Market participation and supply

As a robustness check, we run two double-hurdle models to assess the impact of fasting on dairy market participation and dairy sales volumes. The results are presented in Table C.4. As expected, fasting only seems to significantly impact the decision to sell milk and not the subsequent volume of milk sold.

Table C.4: Effect of presence of a long fasting season in the previous month on likelihood to sell dairy products (first hurdle) and total dairy product sales over the month prior to interview, conditional on dairy market participation (second hurdle)

	Milk		Processed milk	
	Likelihood to sell	Sales Volume (l)	Likelihood to sell	Sales Volume (kg)
Fasting past month (0/1)	-0.85***	1.63	39.13	4.31
	(0.26)	(1.64)	(57.11)	(8.26)
Household controls	Yes		Yes	
Observations	855		855	
Log likelihood	-1750.57		-1982.24	

Notes: For a complete list of controls, see Appendix Table C.3. Total dairy production is not included as a control variable. Cluster robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1

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