The remarkable possibility that millets offer for an internal input based farming, free from chemicals and corporates make them the new age answer to a new age crisis. … the rejuvenation of millet farming, continuously undermined by the Green Revolution protagonists, is the only way we can ensure our food, fodder, health, nutrition, livelihood and ecological securities.

Sateesh P.V, 2008. p. III. Deccan Development Society

University of Alberta

Reconsidering Post Green Revolution Food Choices: New Processing Technologies and Food Security in India

by

Evan James Miller-Tait

A thesis submitted to the Faculty of Graduate Studies and Research
in partial fulfillment of the requirements for the degree of

Master of Science
in
Agricultural and Resource Economics

Department of Resource Economics and Environmental Sociology

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Fall 2013
Edmonton, Alberta

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Dedication

To Alex, for all of the love and support she gave to me during my three years in this program. Through all of my highs and lows, through lost passports and all-night study sessions, you were there. I could not have possibly done this without you.

Abstract

Finger millet (known as ragi) is a traditional grain that is more nutritious and more tolerant to environmental shocks than high yielding rice and wheat varieties. Accordingly, the promotion of ragi has been identified as an intervention that could improve the food security of households in India. Despite these benefits, ragi has largely been replaced by subsidized green revolution grains. To promote ragi consumption, scholars have advocated the introduction of innovations in processing ragi into flour. We investigate the determinants that drive households' use of ragi processing technology using a primary, georeferenced, household-level dataset collected in Kolli Hills, Tamil Nadu. We employ a two-stage technology adoption framework to analyze household-level decisions to produce ragi flour. We also analyze patterns of self-selection, which are caused by unobserved heterogeneity, to infer whether households with higher levels of welfare have a higher propensity to access these technologies.

Acknowledgments

My success is not entirely my own, and there have been several people who have helped me accomplish the goal of completing my master's degree. I would like to thank my supervisors, Marty Luckert and Sandeep Mohapatra, who have provided me with exceptional wisdom and guidance, not only in my research but in my development as an aspiring academic. I could not have asked for better mentors. I would also like to thank Brent Swallow, who acted as my third supervisor and contributed to the design of this study, as well as Vic Adamowicz and Scott Nielsen, who helped inspire and refine the methods I used in my analysis. I give thanks to all of the professors and support staff who have welcomed and assisted me in my time with this department. I would also like to acknowledge the Social Sciences and Humanities Research Council of Canada for their support in this research.

My thanks are due to those who helped me with the logistics of this research, and in other ways too numerous to count: John Pattison and Nita Selena, for tracking down GPS units, booking train tickets, and otherwise solving problems as they arose – often from across the globe; Oliver King and Siddick Abubacker, for helping me get set up and running in the field; Kumar Natarajan, Bala Murugam, Joseph, and Drooya, for helping me with odd jobs that kept things operating smoothly; and to my new friends Balu and Babu, who introduced me to life in Kolli Hills from a local perspective. I would especially like to thank P. Hariharasudhan, who was hired as my translator, but who quickly became my right-hand man, assisting and generally overseeing all the parts of the project. This research could not have succeeded without his dedication. Thanks are due to my team of enumerators – Jayamurugan, Dharmalingam, Servi, and Malarkodi – for their tireless efforts, and to S. Sathyaraj, who completed the data entry for all 575 household surveys.

Lastly, I thank all of my friends and family who have helped me get to where I am today. I give many thanks to my parents, Gail and Don, and to my grandparents, Malcolm and Myrna, who gave me so much, and who helped see me through my undergraduate degree and encouraged me to further my studies. And to my friends and classmates, Scott, Fiona, Sim, Shouyi, and Patrick, thank-you for making my time in this program so memorable. Thank-you for all of the long nights, groups projects, re-invented theorems, and general entertainment; I cannot imagine five other people I would rather share all of my classes and time with. I wish you all the best.

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List of Abbreviations

FAO..Food and Agricultural Organization

GIS ....Geographic Information System

GPS ....Global Positioning System

IHDS ....India Human Development Survey

INR... Indian National Rupee

MSSRF...M.S. Swaminathan Research Foundation

NRC ....National Research Council (of the United States of America)

SHG...Self-Help Group

Chapter 1. Introduction

Though the Green Revolution has played a large role in producing food for increasing populations, the mass production of calories has come with costs. For example, varieties of finger millet (*Eleusine coracana*, known in India as ragi), which have largely been replaced during the Green Revolution, are generally more nutritious than high yielding varieties of cereals such as rice, maize, and wheat (National Research Council (NRC), 1996). Ragi in particular has a high protein and mineral content. Although some rice varieties contain more protein by weight, the proteins found in ragi contain a high amount of the essential amino acid methionine. Because methionine is generally lacking in grain based diets, ragi might be considered a nutritional "super food" for much of the developing world (NRC, 1996).

As with many traditional grains, ragi is also well adapted to local climatic conditions and is genetically diverse. Further, relative to modern crops, traditional grains require fewer chemical inputs, are more tolerant to environmental shocks, and are predicted to be more robust to climate change (Altieri & Koohafkan, 2008; Seetharam *et al*, 1989). Accordingly, the promotion of traditional grains, such as ragi, has been identified as an intervention that could improve the food security of households in India and in other places such as Africa (NRC, 1996). Traditionally, ragi has been a popular staple amongst the working class in rural India because of its ability to provide sustenance for long periods of manual labour. Ragi grain can also be stored for a long time before consuming; some reports indicate that it can be stored upwards of 50 years (Food and Agricultural Organization (FAO), n.d.). As a result, stores of ragi grain can provide insurance against future food shortages.

Despite its potential benefits, the production and consumption of ragi has declined sharply in India. The consumption of ragi has declined in favour of subsidized green revolution grains, such as rice and wheat (NRC, 1996; Rao et al, 2003). These subsidies have driven down the prices for ragi, and as a result the production of ragi has been crowded out by the presence of more profitable cash crops such as cassava. Other factors which may contribute to this decline include the cultural stigma associated with this grain; historical preferences for ragi amongst the poor has caused it to become culturally stigmatized as a “poor person’s crop” and a “famine food” (NRC, 1996). Moreover, the drudgery associated with ragi cultivation and the preparation of this grain for consumption could be prohibiting ragi production amongst subsistence farmers (Finnis, 2009). Before being consumed, ragi must be ground into flour because there is a tough seed coat surrounding the grain. The traditional method of producing ragi flour is to manually grind the grain using a stone grinder. This method is both time and energy intensive, requiring approximately one hour between two people to produce a kilogram of flour (M.S. Swaminathan Research Foundation, 2012; field observations). Because producing flour is culturally defined as a female task, the costs associated with manually preparing this grain have historically been borne by female members of the household.

To help promote the consumption of ragi flour, scholars have advocated the introduction of innovations in processing ragi for small and large-scale entrepreneurs (e.g., Singh and Raghuvanshi 2012). These innovations have the potential to encourage ragi consumption by reducing the labour costs associated with the traditional methods of ragi flour production. However, structural deficiencies in markets typically characterize economies where ragi is argued to provide the largest benefits. These deficiencies include the inability of entrepreneurs to access credit, and a lack of information regarding local demand for milling services. As a result, few incentives exist for entrepreneurs to develop these technologies in areas where they have the greatest potential to address deficiencies in food security.

Recently, this technology has been introduced into rural villages by the M.S. Swaminathan Research Foundation (MSSRF) with the goal of reversing the decline in local ragi consumption and improving the welfare and food security amongst households in the community that have lower levels of welfare. Other goals for this intervention were that it reduce the drudgery faced by women in producing ragi flour and to encourage the local cultivation of ragi. The establishment of the flourmills was initiated by local village members. Entrepreneurial Self-Help Groups (SHGs) were established by village members to start-up and manage the operations of the flourmills. These groups each consisted of a minimum of 10-12 members. This number of people was needed to fulfill minimum requirements to open an account with a local bank in order to pay for the electricity to run the mill. The SHGs were also required to identify a piece of land already owned by a SHG member, or acquire a new piece of land, upon which to place the mill. Because the SHGs are responsible for obtaining the land, they dictate the location of the mill. The MSSRF purchased the milling unit and all necessary construction materials, while the SHG built the structure to house the mill and covered the costs of running and maintaining the mill. The members of the SHG collectively own and operate the milling centre as a private business.

This intervention provides us with an opportunity to investigate the introduction of a new technology, facilitated by SHGs. SHGs may be more effective at managing small business operations than larger centralized organizations, such as governments or non-profit organizations. In many centralized management systems there is a high potential for moral hazard problems that may arise due to the information asymmetries between the business operators and the organization that establishes the business. SHGs may be able to avoid such problems because their members likely have greater information to assess the trustworthiness of other members, and because their monitoring costs are likely lower. On the other hand, larger organizations may be better positioned to establish a capital-intensive enterprise such as a flourmill because they are likely to have greater access to credit. Although SHGs are often formed as a means for members to overcome personal credit constraints, it may be difficult for many SHGs to raise sufficient capital to purchase a flourmill. The use of SHGs to facilitate the introduction of this technology can enable development organizations to utilize the strengths of both management approaches; the organization, in this case the MSSRF, is able to overcome credit constraints of establishing the mill, while the SHG is able to avoid potential problems associated with management and supervision of the mill operations.

In response to the development of a local supply of ragi mills, local demand for milling services has emerged. However, there is little empirical evidence regarding how technological advances in processing have been received in rural communities. Basic questions for informing policymakers regarding the introduction of processing centres remain unanswered. My academic supervisors and I address this knowledge gap by investigating the outcomes of this intervention.

The objective of our research is to investigate the determinants that drive households' use of ragi processing technology. We begin our research with an exploratory analysis of how probabilities of adoption vary with household wealth and costs of accessing the mill. We estimate probability functions for households' adoption of milling services for the production of ragi flour, using local polynomial regressions. We then use a two-stage technology adoption framework as a basis for analyzing two key decisions made by the household regarding the production of ragi flour: 1) whether or not to adopt the processing technology (the adoption equation), and – conditional upon adoption – 2) how much ragi flour to produce (the intensity equation). We estimate these two stages simultaneously using maximum likelihood methods. This approach allows us to address a number of key policy questions: Is ragi flour a "poor-person's food" (i.e. an inferior good, as suggested by social stigma), the consumption of which declines with increasing wealth; or is ragi flour a normal good? How do demographic factors affect the adoption and intensity of use of this technology? What are the effects of the prices of ragi grain, ragi flour, and wheat flour on the adoption and intensity decisions? How do the travel costs of accessing these mills affect household's decision to adopt the milling services? In analyzing these questions, we pay attention to potential selection biases in adoption. For example, the innovativeness and productivity of households could drive self-selected groups to disproportionately adopt the processing technology. These unobservable variables may in turn be correlated with ragi flour consumption levels that can bias the intensity equation estimates. We explore whether the effects of these unobserved variables are consistent with increasing or decreasing welfare. Consumption is often used as a measure of welfare (Deaton, et al., 2002), and marginal changes in ragi flour consumption may reflect marginal changes in household welfare. The self-selection patterns of ragi flour consumption may therefore be indicative of unobserved levels of household welfare. Accordingly, we pay special attention to the patterns of self-selection in our analysis, and to the potential welfare implications of these patterns regarding the households that adopt this technology.

In the next chapter, we present a review of the relevant literature. In the third chapter, we present the empirical model used in our analysis. In the fourth chapter we discuss econometric considerations with respect to estimating this model, and in the fifth chapter we give background information on our study site and outline our data collection methods. In the sixth chapter we present the results from our analysis, and in the final chapter we present our conclusions.

Chapter 2. Literature Review

This review of the literature will cover several empirical works that are relevant to the research presented in this thesis. The first part of this review is an exploration of the literature on technology adoption, which will look at several of the factors which are commonly considered in adoption studies. Emphasis will be given to considerations which apply to our research objectives. The second part of the literature review will explore the relevance of patterns of self-selection. The problems of self-selection bias will be discussed, as will the potential for opportunities to gain insights into economic behaviour that can be afforded by analyzing patterns of self-selection.

2.1 Technology Adoption

The adoption of new agricultural innovations and technologies has received attention by a number of agricultural economists. Much of the work on technology adoption since the 1960s has focused on the adoption of Green Revolution technologies (Feder, Just, & Zilberman, 1985; Feder & Umali, 1993). Studies in this field typically consider either the adoption or diffusion of technologies, which are recognised as the two distinct yet related processes that govern the utilization of an innovation. Adoption is defined as the process governing the uptake of a technology or innovation by an individual farm or household. Diffusion, on the other hand, is conceived as aggregate adoption, or the penetration of a particular innovation into its potential market (Sunding & Zilberman, 2001). This technology has existed in our study area for approximately two decades, and the diffusion process has likely ended.[1] As a

[1] The survey used in this study collected information regarding the date that the households first started using this technology, for all households that have ever used this technology. In collecting our data, we focused our research efforts on two mills in our study site (see chapter 5). Diffusion rates appear to have already peaked for both of these mills: for the mill located in the village of Thanimathipatti, the first household from our sample adopted in 1995 and the rate of new adopters from our sample peaked in 2000; for the mill located in the village of Periakovilur, the first household from our sample adopted this technology in 2007, and the rate of new adopters from our sample peaked in 2009. Although we observed one new household adopting the technology in

result, factors that affect the rates of diffusion are not considered in our analysis. Because we are interested in the household-level factors that affect the utilization of flour milling technologies, and not the diffusion of this technology, we limit our review of the literature to studies that pertain to technology adoption. Although there are many differences in the technologies and innovations that have been studied in the literature, there are several considerations that pertain generally to many adoption studies, such as: the characterization of the adoption decision as a discrete or continuous decision, uncertainty and risk, and the role of geography and location of the farm or household. These considerations will be discussed in turn.

2.1.1 Characterizing the Adoption Decision

Adoption can be characterized as either a binary decision, to adopt or not adopt the innovation, or as a continuous decision, describing the intensity with which an innovation is utilized by the farmer (Sunding & Zilberman, 2001). Often, the choice of whether to characterize the adoption decision as binary or continuous depends on the nature of the technology or innovation under consideration. Harvesters or tractors are examples of technologies that are often characterized as a discrete choice. Other examples of technologies that have been treated as discrete decisions in the literature include the adoption of specific types of irrigation technologies (Green, Sunding, Zilberman, & Parker, 1996), precision farming technology (Sevier & Lee, 2004), and dairy breeding technologies (Khanal & Gillespie, 2013). Many divisible technologies, however, are more accurately characterized by a continuous adoption decision (Feder, Just, & Zilberman, 1985). New crop varieties are common examples of divisible technologies that are typically characterized by a continuous decision because the farmer can choose exactly how much of their land to devote to a particular crop (for example: Lin, 1991; Sall, Norman, & Featherstone, 2000; and Beke, 2011).

2012 in Periakovilur, neither mill site had a new household adopting this technology in 2011, suggesting that the process of diffusion has largely been completed in our study site.

Technologies that are characterized as a continuous decision are not limited to crop varieties. Chemical inputs are also divisible technologies that are represented by a continuous adoption decision. For example, Fufa and Hassan (2006) characterized the intensity of inorganic fertilizer use by maize farmers in Eastern Ethiopia as a continuous decision, and Galt (2008) modeled pesticide use by vegetable farmers in Costa Rica as continuous. Some authors have also chosen to model environmentally sound production practices as a continuous technology adoption decision. Goodhue, Klonsky, and Mohapatra (2010) modeled the adoption of alternative pest management practices as both a discrete and a continuous decision, as did Arslan *et al.* (2013) in their model of the area of land under conservation agricultural practices in Zambia. With respect to our study, because households are able to choose how much ragi flour to produce in a given month, the adoption of the flourmills is best characterized as a joint discrete and continuous decision: whether or not to adopt the technology, and the intensity of use, respectively.

An additional consideration that is often made in the technology adoption literature is the joint adoption of a technology of interest with some other technology. Many technologies are not adopted individually, but are jointly adopted with other complementary technologies. One example is high yielding crop varieties, which are often adopted as a package with other technologies such as chemical inputs (Feder & Umali, 1993). With respect to our study, discussions with MSSRF staff have indicated that there are no complementary technologies that are jointly adopted with the flourmills. Because these mills are a standalone technology, we do not consider any other jointly used technologies.

2.1.2 Uncertainty and Risk

Uncertainty and risk are two other considerations that are often relevant to many adoption studies (Feder, Just, & Zilberman, 1985). With respect to technology adoption, uncertainty is characterized as the household’s lack of knowledge about how a particular technology will perform. Risk is the variation in the quantity or quality of output from a given technology. The impact of risk on the household's adoption decision is determined by the risk aversion of the household. The concepts of uncertainty and risk are related, in that uncertainty about a new technology may increase the level of risk perceived by the household or farmer, but risk and uncertainty are distinct from one another. A farmer can reduce his or her uncertainty about a new innovation by discussing that technology with friends and neighbours that have already adopted, or, in the case of highly divisible technologies, by adopting that technology on a small scale to test the potential gains (Sunding & Zilberman, 2001). Risk, on the other hand, is a product of exogenous factors, and, for a given technology, cannot readily be reduced. Together, uncertainty and risk both tend to reduce the intensity at which a household will adopt a particular technology or innovation (Feder, 1980). To account for the importance of these factors, several studies have incorporated risk, risk aversion, and uncertainty into their adoption models. For example: Just and Zilberman (1983) consider the marginal effects of modern inputs on the risk associated with traditional and modern crop varieties; Collender and Zilberman (1985) explored the effects of uncertainty on the allocation of land between corn and cotton in Missouri; and Liu and Huang (2013) found that Chinese cotton farmers with greater risk-aversion utilize more pesticides.

Based on our field work and interviews with both mill operators and households, we feel that risk and uncertainty are not likely to be important factors affecting the decision to adopt modern flour milling technologies. There is little or no uncertainty regarding this technology. Because the prices of the milling services are relatively constant, there is almost no uncertainty with respect to the costs of producing ragi flour. The quality of ragi flour produced is also very consistent, so there is little uncertainty with respect to the outcomes of using this technology. The risks associated with this technology are also minimal. We identified that the biggest potential risk associated with using this technology was unexpected power outages. Individuals bringing their grain to the mill run the risk of the mill being temporarily inoperable due to a power outage, and thus not being able to produce flour. While this risk could potentially dissuade households from adopting this technology, we felt that this was unlikely to have a significant impact on the decision to adopt because unexpected power outages do not occur with great frequency.[2] Moreover, scheduled power outages, which occur daily, are generally known by households in Kolli Hills because power outages occur at the same time every day, with changes to this schedule being posted in local newspapers ahead of time (personal communication with MSSRF staff). In the event that a customer arrives during a power outage, some of the mill operators will accept the ragi grain and mill it when the power was restored, allowing the customer to attend to other business (personal communication with mill operators). The customer could then return at their convenience to pick up the flour, thus reducing the negative impact associated with the risk of the mill being inoperable due to power outages. Because uncertainty and risk are not likely to play a significant role in the decision to adopt this technology, we do not account for these factors in our analysis.

2.1.3 Role of Geography

The geographic location of the farm or household has long been recognised as an important factor affecting the adoption of a particular technology. Geographic location has been shown to affect the amount of time between a technology being made available and when it is adopted by a farmer. In a study on the diffusion of innovations, Rogers (1962) found that farms located farther from major centres adopted new varieties of corn later than farms located closer to those centres. Rogers attributed the later uptake of these varieties to the dynamic nature of technology diffusion, which is likely influenced by the uptake of that technology by one's neighbours. For some technologies, however, location and geography affect more than just the innovation's rate of diffusion. For example, Swinton (2002) found that spatial variables – captured by agro-

[2] We found that few households that brought ragi to the mill were affected by power outages.

ecological zones – were significant factors affecting the proportion of fields to which fallow cycles were adopted in crop rotations by farmers in Peru. Holloway, Shankar, and Rahman (2002) found that the farming practices of spatially-delineated neighbours had a significant influence on the adoption of high yielding varieties of rice in Bangladesh. Using geographic information system (GIS) data, Staal, Baltenwick, Waithaka, deWolff, and Njoroge (2002) found that geographic location significantly affected the uptake of market-oriented dairy production in Kenya; due to the need for readily accessible markets for livestock services and to sell milk, the distance to consumer markets and selling points was found to be an important factor affecting the uptake of dairy farming. These studies highlight the importance of geographical location on the adoption of certain technologies. Location of the household is also likely to play an important role in our research. However, because the process of diffusion is not likely affecting the patterns of adoption in our study site, neighbour effects – like those studied by Rogers (1962) – are not likely to play a significant role in the adoption of this technology. Instead, the relative location of households to the mills is likely to be significant. Households that adopt the flourmills must have access to that technology on a regular basis. Due to the fact that ragi flour spoils within a few weeks, households must consistently travel to the mills in order to continue utilizing this technology. Because of the need to consistently access the mills, the distance between the household and the nearest flourmill is likely to affect the adoption of this technology beyond its effects on the rate of diffusion.

2.2 Self-Selection

Patterns of self-selection may play a significant role in the adoption and intensity of use decisions. The existence of self-selection patterns has the potential to bias empirical estimates if unaccounted for in the empirical specification. However, if properly accounted for, these patterns may reveal important information about the unobserved characteristics of households that adopt a particular technology. This section explores the potential bias caused by patterns of self-selection and the interpretation of these patterns.

2.2.1 Correcting for Self-Selection Bias

Modelling the intensity of use of a technology can be relatively straightforward if all the farms or households in the population under consideration use this technology. In such cases, standard regression methods such as Ordinary Least Squares are often appropriate estimation techniques. However, because the intensity of use is truncated at zero for all households that do not adopt the technology, linear regression may be inappropriate for estimating the use of a technology or innovation in populations where some households are not adopters. Another issue that often arises in the modelling of economic behaviour is the potential for self-selection bias, which arises whenever individuals non-randomly select themselves to become part of a group. In the adoption literature, individuals that adopt a particular technology select themselves into the group of adopters. If selection into the group of adopters is non-random, then the group of adopters will not be a representative sample of the population under investigation. Performing a linear regression on the group of adopters that estimates the intensity at which a technology is used thus has the potential to produce biased estimates. One method that has been used to correct for these issues is the Heckman correction method (1976) which is applied to two-stage models, where the first stage models the binary decision to perform an activity and the second stage models the intensity at which that activity is performed. Potential selection bias is corrected for by including a transformation of the estimates from the first stage of the model as a regressor in the second stage of the model. To correct for potential selection bias, we employ the Heckman correction method in the estimation of our model. The estimation of our model with the Heckman correction method is described in Chapter 4.

2.2.2 Interpreting Patterns of Self-Selection

The Heckman correction method can be applied to correct for selection bias in a wide variety of activities that may be of interest to social scientists. In addition to correcting for potential selection bias, the Heckman correction method allows researchers to identify whether patterns of self-selection exist, and whether those patterns tend to increase or decrease the intensity at which the activity under investigation is performed. Some researchers have interpreted these patterns of self-selection to reveal unobserved characteristics about the individuals that have a greater probability of selecting themselves into the group of people that perform the activity under investigation. For example, in a study examining the wages earned by foreigners immigrating to the United States, Borjas (1987) interprets the patterns of self-selection as a reflection of the "quality" of immigrants in the labour market. Under the assumption that higher wages earned by immigrants are indicative of those immigrants having more valuable skills, self-selection patterns that result in an increase the average wage earned by immigrants are interpreted as a higher propensity for relatively skilled workers to immigrate to the US. On the other hand, self-selection patterns that result in a decrease in the average wage earned by immigrants are interpreted as a higher propensity for relatively unskilled workers to immigrate to the US. Likewise, Borjas and Bronners (1989) and Kawaguchi (2005), examining the wages earned by Caucasian Americans and African Americans, use similar interpretations to determine of the quality of workers of either race entering into either the wage or self-employment labour sectors. Dimova, Nordman, and Roubaud (2008) similarly used patterns of self-selection to comment on the unobserved entrepreneurial ability of West African workers seeking employment in the wage and self-employment labour markets.

In each of the studies presented in the preceding paragraph, the interpretations are relative to the dependent variable: wages. For a particular labour sector, higher wages tend to be earned by individuals that are more successful. Some factors that contribute to this success may be observed by the researcher, such as the individual's level of education, while others may not, such as the individual's level of intelligence, their innovativeness, or their productivity, etc. After controlling for observable factors that might contribute to higher wages, the patterns of self-selection must therefore be indicative of the effects of these unobserved characteristics that contribute to the individual's wage. Following the work of these and other authors, we will attempt to use patterns of self-selection to inform us about the unobserved characteristics of households that are adopting the milling technologies. Like the authors discussed above, the patterns of self-selection in our study must be interpreted with respect to the dependent variable: ragi flour consumption. As we alluded to in the introduction, marginal changes in consumption are indicative of marginal changes in household welfare. We therefore use the patterns of self-selection in our analysis to provide insights into the unobserved aspects of household welfare. The interpretation of the patterns of self-selection is given in Chapter 6.

Chapter 3. The Empirical Model

Households are often modeled as a producer and a consumer. In some cases, production decisions can be modeled independently from consumption decisions. However, in cases where consumption decisions affect production decisions, modelling production independently from consumption is inappropriate. These households are referred to as non-separable with respect to that production decision (de Janvry & Sadoulet, 2006). Because the ragi flour produced from these mills is primarily for home consumption, it would be inappropriate to model the adoption decision as independent from consumption decisions. Thus, to account for the non-separability of this decision, our empirical specification contains variables which are expected to affect the production of ragi flour, and variables which we expect to affect the demand for ragi flour and ragi flour consumption.

For each household i, we model the use of this technology as a two-stage adoption decision process: the binary decision to adopt this technology for the purpose of producing ragi flour (A_i), and the continuous choice of intensity of use (Q_i). We define the intensity of mill use as the natural logarithm of the quantity of ragi flour produced (kg) using this technology in one month per capita (i.e. $Q_i = \ln\left(\frac{kg.\ of\ ragi\ flour\ produced\ in\ one\ month}{adult\ equivalent\ household\ size}\right)$).[3] We consider the following econometric specification:

$$(1) \qquad A_i^* = X_i\alpha + e_i$$

$$A_i = \begin{cases} 1 & if\ A_i^* > 0 \\ 0 & otherwise \end{cases}$$

$$(2) \qquad Q_i^* = Z_i\beta + u_i$$

$$Q_i = \begin{cases} Q_i^* & if\ A_i = 1 \\ 0 & otherwise \end{cases}$$

[3] Adult equivalent household size: See Appendix A.

where the outcome variables A_i^* and Q_i^* denote the latent propensity to adopt and use the technology, respectively. A_i is equal to one if household *i* chooses to adopt the technology, and zero if otherwise. Its value is determined by whether the latent utility gain from using the technology (A_i^*) is positive. Q_i is equal to zero if A_i is equal to zero, and equal to Q_i^* if A_i is equal to one. The row vectors X_i and Z_i denote causal factors influencing technology use and intensity, respectively. These vectors contain household specific variables that are listed in Table 1.

Table 1. Variable definitions and predicted signs

	Definition	Predicted Sign: Adoption	Predicted Sign: Intensity
Dependant Variables			
Adoption (A_i)	Dummy variable; 1= household used a mill in the month previous to survey		
Intensity (Q_i)	Natural logarithm of: the amount of ragi flour produced in the previous month, divided by the *adult equivalent household size**		
Independent Variables			
Cultivates Ragi	Dummy variable; 1= household cultivated ragi in the year previous to the survey	+	
Travel Cost Index*	Euclidean distance between the household and the mill, multiplied by difference in elevation	−	
Household wealth index*	Asset index, divided by *adult equivalent household size*	+/−	+/−
Female Head	Dummy variable; 1=female head	+	+
Literate head	Dummy variable; 1= head is literate	+	+
Female head × Literate head	Interaction term; 1= head is female and literate	+	+
Widowed Head	Dummy variable; 1= head is widowed	+/−	+/−
Male dominant household	Dummy variable; there are more adult males in household than adult females	−	−
Proportion of household members that are children	Number of children, divided by household size	+/−	+/−
Number of Children Age 0-6	Number of children in household aged 6 and below	+/−	+/−
Number of Children Age 7-12	Number of children in household aged 7-12	+/−	+/−
Number of Children Age 13-17	Number of children in household aged 13-17	+/−	+/−
Senior Male in the Household	Dummy variable; 1= a household member is male and age 65 or older	+/−	+/−
Senior Female in the Household	Dummy variable; 1= a household member is female and age 65 or older	+/−	+/−
Buys Ragi Flour	Dummy variable; 1= household purchased ragi flour in the month prior to survey	−	−
Price of Ragi Flour	Price of ragi flour available to household (INR/kg)	+	+
Price of Ragi Grain	Price of ragi grain available to household (INR/kg)	−	−
Price of Wheat Flour	Price of wheat flour available to household (INR/kg)	+	+
λ_i †	Inverse Mill's Ratio (Heckman's Lambda)		+/−

* See Appendix A for the construction of this variable
† See Chapter 4 for a discussion on λ_i in the empirical specification

For the most part, we expect X_i and Z_i to contain the same variables, as many factors that affect adoption and intensity are the same. Table 1 shows that there are two variables, *Cultivates Ragi* and *Travel Cost Index*, which we expect to affect adoption but not intensity. Because of the need to grind ragi before it is consumed, we expect a household that *Cultivates Ragi* to have a greater propensity to adopt this technology. We observe that only 2.7% of randomly sampled households sell ragi grain. Because this grain cannot be eaten whole, households who cultivate ragi tend to grind it into flour. Although households do have the option of grinding this grain at home using a stone grinder, we find that only 2% of randomly sampled households grind this grain at home, while the majority of the households that produce ragi flour do so by bringing their grain to a flourmill. We do not, however, expect the decision to cultivate ragi to affect the intensity of use. Because ragi grain can be stored practically indefinitely (up to 50 years or more) without turning rancid or rotting, households that cultivate greater quantities of ragi are not compelled to process greater quantities of ragi to prevent spoilage. In contrast, ragi flour has a relatively short shelf-life of a few weeks. Therefore, households are likely to grind only enough flour for short-term consumption. This assertion is supported by the fact that we find a high degree of variation in the amount of ragi cultivated, but a low degree of variation in the amount of ragi flour produced. The mean amount of ragi cultivated is 51 kg per household per year, with a standard deviation of 41 kg and a coefficient of variation of 0.80. In contrast, the mean amount of ragi flour produced per month is 4.7 kg per household, with a standard deviation of 2 kg and a coefficient of variation of 0.43. This difference in relative variation suggests that the amount of ragi cultivated by a household annually is independent from monthly consumption decisions that drive ragi flour production.[4] The relative variations between the amount of ragi cultivated and amount of ragi flour produced also suggests that the

[4] Furthermore, in an exploratory analysis that is not presented, we found that after controlling for Z_i we did not observe a significant relationship between intensity and the variable *Cultivates Ragi*.

decision to cultivate ragi is likely to have little influence on the amount of ragi flour produced.

Travel Cost Index is a variable that approximates the cost for a member of household *i* to travel to the nearest flourmill. This variable is measured by the Euclidean distance between the household and the nearest mill, weighted by the difference in elevation between the household and the mill (see Appendix A). We predict that travel costs will decrease the probability of adoption, because they effectively increase the costs of accessing this technology. We argue that travel costs – which are most commonly in the form of walking to and from the mill – affect only the fixed costs of accessing the technology and therefore will influence the decision to adopt the technology and not the intensity decision. One could argue that because the household member who accesses these mills on foot must carry the weight of the ragi, an increase in the quantity of flour produced will lead to increased travel costs associated with the effort of carrying more weight to and from the mill; households that must travel greater distances to the mills may therefore choose to mill smaller amounts of ragi flour to reduce the costs of carrying a heavy load. However, we do not believe that the cost of carrying ragi significantly affects the amount of ragi taken to the mill. As mentioned above, the average amount taken to the mill is 4.7kg (± 2.0), a quantity that is likely dictated in part by the short shelf-life of ragi flour. Based on field observations, this weight seems small relative to weights of other items that are carried long distances, and we therefore do not expect travel costs to significantly affect the intensity decision. Moreover, if the weight of carrying this quantity of flour was a limiting factor, we would expect to see some households making multiple trips per month.[5] If households are making multiple trips, travel costs would therefore represent a variable cost and would need to be included in the intensity equation.

[5] Additionally, we do not observe any households taking grain to the mill for another household. This result suggests that all of the households that consume ragi flour produced from the mills bear the travel costs associated with accessing the mills, and that there is no direct effect of the adoption decisions of a household's neighbor on the household's own adoption decision.

However, there are no observations of multiple trips being taken to the mill within a month, so we therefore treat the *Travel Cost Index* as a fixed cost of accessing this technology.[6]

Table 1 shows that we expect the remaining explanatory variables to affect both adoption and intensity. We use *Wealth Index*[7], a measure of household wealth, to approximate household income because total household income is often difficult to measure accurately for subsistence households and because measures of wealth have been shown to be positively correlated with long term income levels (Sonalde *et al.*, 2008; page 18). We have no information to suggest how this variable might affect the rate of adoption, and we seek to understand the role of wealth in adoption. We are also unable to make a prediction with respect to the effect of household wealth on the intensity of use decision, because we do not know whether ragi flour is a normal good. The nutritional benefits of ragi flour suggest that it may be a normal good, of which we would expect to see wealthier households consume more. However, the cultural stigma surrounding this grain suggests that it may be an inferior good. If ragi is a normal good, we would expect a positive coefficient on *Wealth Index* in the intensity of use equation. Conversely, if ragi flour is an inferior good, we would expect a negative coefficient.

Characteristics of the household head, that is, whether the head is a *Female Head*, *Literate Head*, or a *Widowed Head*, are likely to affect the adoption and intensity of use decisions. Because women are often responsible for millet cultivation and post-harvest operations (FAO, 2013), and because this technology has the potential to reduce the amount of labour faced by women, we expect households with a *Female Head* will have a higher propensity to adopt this technology and will use this technology at a higher level of intensity than male-headed households. We expect heads that are literate to have a greater awareness

[6] In an additional exploratory analysis that is not presented, we found that after controlling for Z_i we did not observe a significant relationship between intensity and the *Travel Cost Index.*
[7] See Appendix A regarding the construction of this variable.

of the nutritional benefits of ragi. As a result, we expect that households with a *Literate Head* will also have a higher probability of adoption and will use this technology at a greater intensity. We also expect that the effect of literacy on adoption and intensity will differ between male and female headed households. We account for these differences by including the interaction term *Female Head* × *Literate Head* in our regression. Because we expect the variables *Female Head* and *Literate Head* to both increase the probability of adoption and intensity of use, we expect the interaction term *Female Head* × *Literate Head* to increase the probability of adoption and intensity of use. Households with a *Widowed Head* have been shown to differ significantly from other households with respect to household welfare (van de Walle, 2013) and their probability of adopting certain technologies (Barungi & Maonga, 2011). Although we expect the variable *Widowed Head* to affect the adoption and intensity of use decisions, we do not have expectations with respect to the effects of this variable on either decision.

We also expect that the gender composition of the household will affect the household's adoption and intensity of use decisions. We expect that *Male Dominant Households,* which have a greater number of adult males than females, will have a lower probability of adopting this technology and will use this technology at a lower intensity. Because cultural norms dictate that females are responsible for cultivating and processing ragi, and because imperfect labour markets limit the ability of households to hire additional labour, the economic decisions of households with relatively few females will be constrained by low levels of available "female labour" in comparison to households with more females. This labour constraint may therefore reduce the intensity of use.

The number and age composition of children in the household may also influence the adoption and intensity decisions. Often, children do not contribute as much as adults to the amount of labour available to the household for production. If the household's adoption and intensity of use decisions are determined by the labour available to the household, the *Proportion of Household Members that are Children* could influence ragi flour production; this variable may be inversely related to household labour supply, per person, which may in turn affect the adoption of this technology to produce ragi flour. Additionally, we expect that the *Number of Children Age 0-6*, *Number of Children Age 7-12*, and the *Number of Children Age 13-17* will all affect the adoption and intensity of use decisions. The preferences for ragi flour may vary with age, and could result in effects that differ by age category. These variables may therefore capture the effects of children's tastes for ragi flour. However, with no information regarding the role of children in ragi flour production or consumption decisions, we have no expectations with respect to whether the proportion of children in the household or the number of children of different ages will increase or decrease the probability of adoption or the intensity of use.

Because older household members may have preferences for ragi flour that differ from that of other household members, we expect that a *Senior Male in the Household* or a *Senior Female in the Household* may have an effect on the household's probability of adoption and intensity of use. However we have no expectation regarding the effects of these variables.

The market variable, *Buys Ragi Flour* is also predicted to be a determinant of adoption and intensity of use decisions. Because purchased ragi flour is likely to be a close or a perfect substitute for ragi flour produced using the milling technology in terms of taste and other qualities, households that purchase ragi flour will need to produce less ragi flour using the mills in order to attain a given level of ragi flour consumption. Households that obtain all of their ragi flour from the market will not need to adopt this technology. Thus we expect that a household that *Buys Ragi Flour* will have a lower probability of adopting this technology and will use this technology at a lower intensity.

We expect the *Price of Ragi Flour*, *Price of Ragi Grain*, and the *Price of Wheat Flour* to affect the adoption and intensity of use decisions. These prices are expressed as the price per kilogram that is experienced by household *i*. Variability in the *Price of Ragi Flour* and the *Price of Ragi Grain* that is experienced by different households is likely due to their ability to access central markets, as well as the ability of households to receive price discounts by purchasing larger quantities. Because of the substitutability of purchased ragi flour for ragi flour produced with the milling technology, we expect that households that experience a higher *Price of Ragi Flour* will be more likely to adopt this technology and will use this technology at a higher intensity. Because ragi grain is an input for the production of ragi flour, we expect that households that experience a higher *Price of Ragi Grain* will have a lower probability of adopting this technology and will use this technology at a lower intensity. The main source of variability of the *Price of Wheat Flour* is likely due to the different legislated prices that are available through the Public Distribution Service to low-income households and people that are otherwise identified as being disadvantaged such as being disabled, widowed, or terminally ill (Tamil Nadu Civil Supplies Corporation, n.d.). We expect that wheat flour is a substitute for ragi flour, and we therefore expect that households that experience a higher *Price of Wheat Flour* will be more likely to adopt this technology and will use this technology at a higher intensity.

Chapter 4. Econometric Considerations

In modeling our adoption problem, we attempt to account for unobserved heterogeneity. The two-stage econometric model yields estimates of the relationship between observed household attributes (such as household wealth and education of the head) and adoption behaviour. However, participation in the mills is also likely to be driven by unobservable attributes, which can cause some groups to disproportionately self-select into the group of households that adopt the processing technology. These unobservables may in turn be correlated with ragi flour consumption levels, which can bias the intensity equation estimates. Thus the presence of selection bias implies that $\rho = Cov(e_i, u_i) \neq 0$. We therefore control for potential selection bias using Heckman's correction method. Heckman (1976) shows that the effects of unobserved characteristics on self-selection can be captured by the inverse Mill's ratio, denoted by $\lambda_i = \frac{\phi(H_i)}{1-\Phi(H_i)} = \frac{\phi(H_i)}{\Phi(-H_i)}$, where ϕ and Φ are the density and distribution functions for a standard normal variable, respectively, and $H_i = -\frac{X_i\hat{\alpha}}{(\sigma)^{\frac{1}{2}}}$ where $\hat{\alpha}$ is a vector of estimates of α, and σ is the standard deviation of u_i. Heckman demonstrates that including the correction term λ_i as a regressor of Q_i (equation 2) will correct for potential selection bias. Thus, to account for selection bias, we rewrite the intensity equation as:

$$(3) \qquad Q_i^* = Z_i\beta + \lambda_i\beta_\lambda + u_i$$

In addition to controlling for potential selection bias, the inclusion of λ_i as a regressor in the intensity equation allows us to test for the presence of selection bias via a t-test of the correction term coefficient, $\beta_\lambda = \rho\sigma$. If β_λ is not significant, this implies that $\rho = 0$, and therefore that selection bias does not exist. If the coefficient is positive and significant, positive selection bias exists; this means that some unobserved characteristic that increases the propensity of households to self-select into the group of adopters is also increasing average levels of intensity, above what would be expected if the decision to adopt this technology was random. Likewise, if β_λ is negative and significant, negative selection bias exists, indicating that some unobserved characteristic that increases the propensity of households to self-select into the group of adopters is decreasing the average levels of intensity, below what would be expected if the adoption decision was random.

We employ this correction parameter for paying special attention to the patterns of self-selection. One of the challenges we face in addressing whether households with higher or lower levels of welfare have a higher probability of adopting this technology is the absence of detailed data with respect to the multitude of factors that contribute to household welfare. This problem could be magnified by the potentially large role played by unobservable factors in household economic behaviour. Following the work of Borjas (1987), Borjas and Bronners (1989), and Kawaguchi (2005), we attempt to profile the types of households that are self-selecting into the group of adopters. We look for evidence of unobservable aspects of welfare that may be driving this adoption decision. As we demonstrate in Chapter 6, the patterns of self-selection observed in the data can be useful for identifying whether households with higher or lower levels of welfare – based on unobserved characteristics – have a higher propensity to adopt this technology.

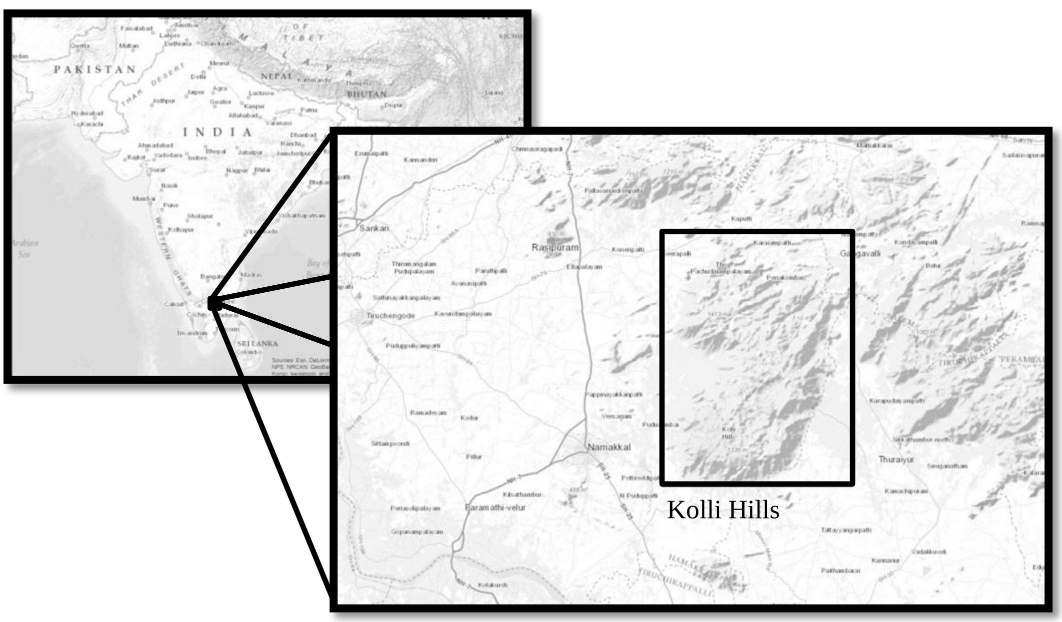
One problem that can arise in the estimation of a two-stage Heckman selection model is collinearity between λ_i and Z_i, which can reduce the efficiency of model estimates (Little & Rubin, 1987, p. 230). This collinearity can be reduced by including identifying variables (also known as exclusion restrictions) in the model. Identifying variables are variables that are included in X_i but absent in Z_i: variables expected to affect the decision to adopt, but not the intensity of use decision. Failure to include identifying variables can result in a high degree of multicollinearity, due to the high correlation between λ_i and Z_i (Leung & Yu, 1996). Bushway, Johnson, and Slocum (2007) argue that in the absence of technical grounds for identifying exclusion restrictions, the choice of which variables to exclude from the intensity decision must be made on substantive grounds. In the previous chapter, we argued that the variables *Cultivates Ragi* and *Travel Cost Index* would have an effect on the adoption decision, but not the intensity of use decision. These two variables therefore serve as our identifying variables, and their exclusion from the intensity equation may reduce the potential collinearity between λ_i and Z_i.

Chapter 5. Study Site and Data Collection

5.1 Study Site

Our study is based in the Kolli Hills region of Tamil Nadu, India. Kolli Hills (*Kolli Malai*, in Tamil) is a small mountain range that is part of the Eastern Ghats, and is located in central Tamil Nadu in the district of Namakkal (see Figure 1). 98% of the people living in this rural area belong to the scheduled tribal communities (Raghu, et al., 2013), which are recognised in India as being a marginalized social group (Chatterjee & Sheoran, 2007). Most households earn their primary income from agriculture and livestock, and the main mode of transportation for most residents is by foot (Raghu, et al., 2013).

Figure 1. Map of Kolli Hills



Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, and the GIS User Community

5.2 Data Collection

All of the data collection for this study was organized by myself and my academic supervisors, with support and input from staff members from the MSSRF. Originally, this data was collected with the intention of addressing two different research objectives. The first objective was to model household-level decision between using traditional versus modern flour milling technologies; based on misinformation about flour-milling decisions, we originally believed that more households used the traditional methods of producing ragi flour. This research objective was abandoned after the data was collected, revealing that few households continued to use traditional methods to produce ragi flour. The second objective was to evaluate the welfare benefits of these mills for the surrounding communities. This research objective is currently under investigation.

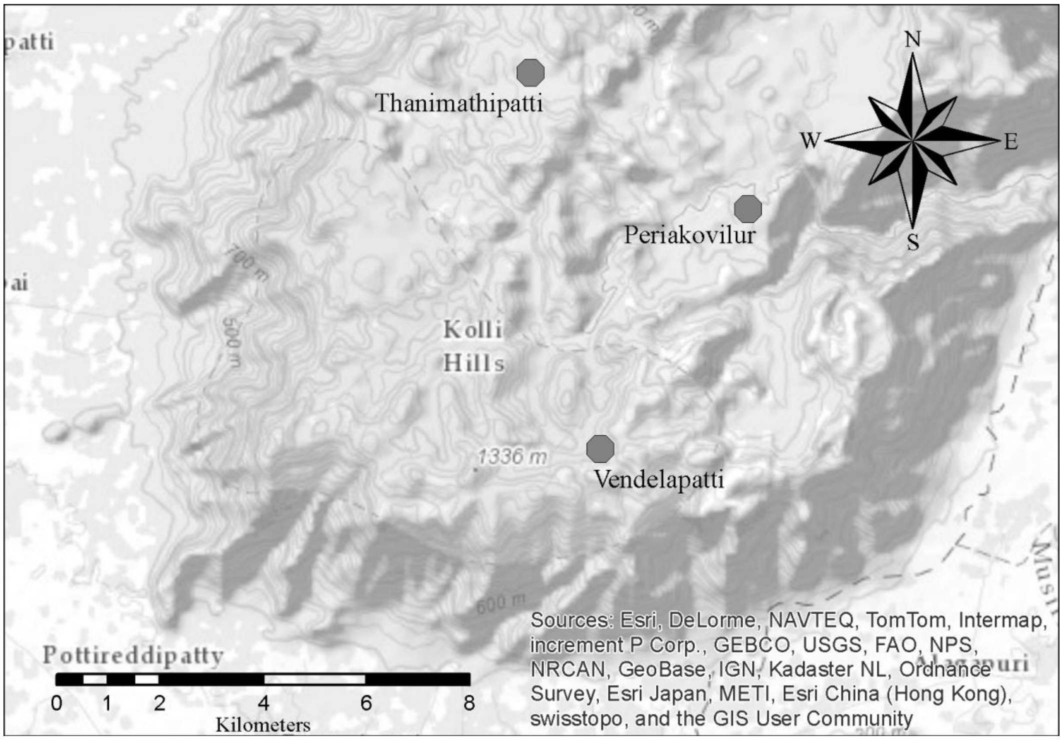
We conducted two preliminary surveys to help inform our study design and the creation of our main survey instrument. These surveys were translated and implemented by MSSRF staff. One survey targeted the owners and operators of the mills in our study site, and the other targeted customers of those mills that came in a single day. The goal of both surveys was to obtain rough estimates on: 1) the number of customers that came to the mills each day; 2) the distances and modes of travel for the average mill customer; 3) the frequency of mill visits by the customers; and 4) the average amount of grain brought to the mills.

On the day that we conducted our preliminary survey, a total of 25 customers came to the three mills. We found that the majority of customers walked to the mill, and that the average distance walked to the mill was 1.2 km; the greatest distance walked was 4 km. The preliminary survey indicated that customers came to the mills approximately once per month and that the average amount of grain brought by customers was 5 kg.

I travelled to the study site and collected primary data with household surveys. The survey was translated into Tamil by members of the MSSRF who were fluent in both English and Tamil. The data was collected from March until May, 2012. Because the literacy of the participants was a concern, the surveys were completed as an interview between household participants and trained enumerators. Four local enumerators were hired because of their fluency in Tamil and their familiarity with the study area. I trained the enumerators with the assistance of a translator. Pre-tests were conducted to ensure that the enumerators were comfortable and able to administer the survey, and to ensure that the questions were clear. The pre-tests were conducted on households who were not included in the final survey sample.

We employed a mixed sampling plan for the collection of our main survey instrument, which included a random sample and a sample composed entirely of adopters. The random sample was conducted to understand the true proportion of flour production strategies employed in our study site. Based on the frequency of customers who came to the mills during our preliminary survey, the average distances traveled to the mills, and on our the estimates of local population density (made by identifying individual households using satellite imagery from Google Earth, 2012), we concluded that a random sample would not provide sufficient observations of adoption for our analysis. The sample of adopters was therefore included as a means to augment the observations of adoption in the random sample. We correct for this mixed sample in the estimation of our model using sampling weights, as outlined by Greene (2007).

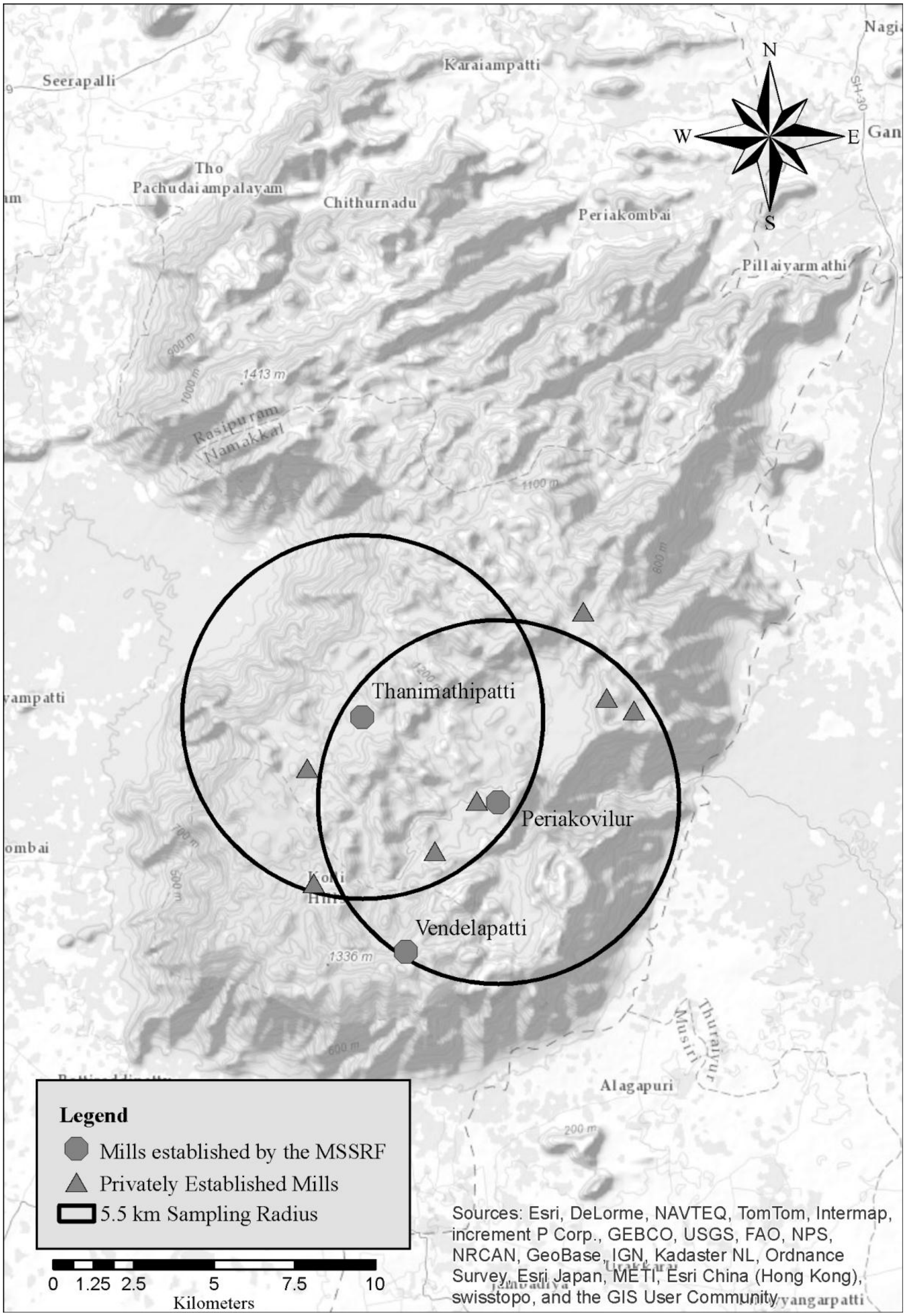
Figure 2. Map of MSSRF established mills in study site



We collected our sample of adopters from customers who visited either of two mill sites, one located in the village of Periakovilur, and another in the village of Thanimathipatti (see Figure 2). Three mills were originally identified as the sites from which we would collect our sample, however complications arose which prevented us from using data collected from one of the mill sites, located in the village of Vendelapatti. These mills were chosen because of their relative proximity to each other and their relative isolation from the other mills that were established by the MSSRF: properties which would be beneficial for addressing the original research objectives that were identified for this dataset. The sample of adopters was collected by having an enumerator posted at each mill in our study site every day during the mill's hours of operation, for the entire data collection period of six weeks. The enumerators collected the names and addresses of all customers who came to the mills during the collection period and were willing to participate in a follow-up survey conducted at their home. None of the customers who came to the mills during the collection of our sample of adopters refused to participate. In addition to completing the survey, enumerators also collected the global positioning system (GPS) location and elevation of the homes of participating households. Observations from 315 households who visited the mill were collected; however, five observations were excluded from our analysis for being incomplete. The sample of adopters was collected first in order to verify the maximum distance traveled by customers on foot; using the GPS data, we found this distance to be approximately 4.5 km. This distance was used to inform our random sampling plan.

Because we expected that the travel costs from the household to the mill would be a significant factor in the decision to adopt this technology, the relative location of the households to the mill was a key consideration in the design of our random sampling plan. We wanted to ensure that our random sampling plan would adequately represent the flour production decisions of households living near and far from the mills. Given that the maximum distance travelled on foot to the mill in the sample of adopters was 4.5 km, we decided to draw our random sample from a 5.5 km radius around each mill (see Figure 3). We thought that by extending our sampling radius beyond the maximum distance observed in the sample of adopters, we would have a greater chance of observing the full range of variation in the adoption decisions as they vary with respect to distance.

Figure 3. Map of mills visited by households in our sample and random sampling radii



The GIS software, Google Earth (2012), was used to plot the 5.5 km sampling radius around the two mills from which we collected our sample of adopters. This was cross referenced with a hard-copy map of block districts[8] in Kolli Hills. Complete household lists were obtained from each Block District Office that fell within these radii. The total number of households in this area was 4,243. These lists were compiled and households were randomly drawn from this list for possible inclusion in our sample. Enumerators contacted these households, and collected GPS and survey data from those households. Of the 275 households that were randomly selected, 262 households were willing to participate. However, six of these observations were excluded from our analysis for being incomplete. Because our refusal rate was low (4.7%) we are confident that our sample is representative of the population.

In the collection of our random sample, we found that several households visited mills other than the two from which we collected our sample of adopters; we identified seven privately established mills that were visited by households in our random sample. The emergence of privately established mills suggests that it may be possible for some entrepreneurs to overcome the barriers to entry into the market for offering milling services, without the assistance of an intervention. At the time that the sampling plan was created, neither the MSSRF staff nor my supervisors and I were aware of the existence of any privately established mills in the area. Because only 10.7% of the households in our total sample that brought ragi to a mill visited one of the privately established mills, we do not feel that the presence of privately established mills in our sample will affect the conclusions that can be drawn from our analysis about the intervention that was implemented by the MSSRF.

[8] Block districts are local government subdivisions in Tamil Nadu, which are composed of several villages.

Chapter 6. Results

6.1 Summary of Data

Table 2 gives the summary statistics of the variables used in our analysis from the random sample. We find that more households purchase ragi flour than produce it using the mills; 24% of our random sample adopts this technology for the production of ragi flour while 37% purchase ragi flour. 9% of the random sample buys ragi flour and produces ragi flour from the mills. The average amount of ragi flour produced is 2 kg per person per month (I_i= 0.56). We also find that 10% of the population cultivated ragi in the year previous to participating in our survey, while 27% of households bought ragi grain in the month previous to our study.[9] This suggests that a majority of the adopters of this technology are purchasing ragi grain, not growing it themselves. The average price of ragi grain is 15.07 Indian rupees (INR) per kg, and the average price for ragi flour is 23.09 INR per kg. The average price for wheat flour is 15.53 INR per kg. The average value for the *Travel Cost Index* is 0.17; the average distance between the household and the mill is 1.9 km, while the average difference in elevation between the household and the mill is 66 m. We find that 69% of adopters traveled to the mills on foot, and that the maximum distance travelled to the mills on foot is 3.6 km.[10] We also find that 11% of household heads are female and that 66% of household heads are literate. The literacy rate amongst female heads is lower than male heads; 4% of household heads are both female

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[9] The proportion of households that bought ragi grain is not presented in Table 2. Because ragi grain cannot be eaten without being ground into flour, the decision to buy ragi grain is likely confounded with the decision to produce ragi flour. Consequently, we chose to not include the decision to buy ragi grain in our analysis.

[10] The maximum distance travelled to the mills was 5.3 km, by motorcycle. This is also the maximum distance that any household in our sample lives from the nearest mill, suggesting that our sampling plan was unable to find a "choke distance", beyond which no households adopt this technology. Such a distance may not exist in this region; due to the number and placement of the mills, and the size of our study site, all households may live sufficiently close to a mill such that no household is located at a distance beyond which the probability of any household adopting this technology is zero.

and literate, meaning that only 36% of female heads are literate. We find that 22% of the households in our sample have more adult men than women, indicating that a majority of the households in our sample either have equal numbers of adult men and women or are dominated by females. We find that households tend to have more adults than children, with the average proportion of children in the household being equal to 37%. There are few households with members over the age of 65; 6% of households have a senior male member and 7% of households have a senior female member.

Table 2. Summary statistics of variables from the random sample

	Mean	Minimum	Maximum	Standard Deviation
Dependant Variables				
Adoption (A_i)	0.24			0.43
Intensity (I_i)	0.56	-1.31	1.61	0.57
Independent Variables				
Cultivates Ragi	0.10			0.31
Travel Cost Index	0.17	1.66×10^{-4}	0.53	0.18
Household wealth index	1.49	0	9	0.91
Female Head	0.11			0.31
Literate head	0.66			0.47
Female head × Literate head	0.04			0.19
Widowed Head	0.11			0.32
Male dominant household	0.22			0.42
Proportion of household members that are children	0.37	0	1.33	0.33
Number of Children Age 0-6	0.36	0	3	0.65
Number of Children Age 7-12	0.41	0	3	0.64
Number of Children Age 13-17	0.31	0	2	0.55
Senior Male in the Household (65+)	0.06			0.23
Senior Female in the Household (65+)	0.07			0.26
Buys Ragi Flour	0.37			0.48
Price of Ragi Flour	23.09	1	34	7.92
Price of Ragi Grain	15.07	3	34	4.71
Price of Wheat Flour	15.53	1	40	8.50

6.2 Exploratory Analysis of Adoption

We performed an exploratory analysis with a series of three non-parametric regressions. We began by exploring the relationship between the *Wealth Index* and the decision to adopt the milling technology for the production of ragi flour (A_i). Figure 4 shows a significant upward trend; as the household's *Wealth Index* increases, the probability of adoption increases. We also explored the relationship between the *Travel Cost Index* and the decision to adopt the mill. Figure 5 shows that there is a negative and significant correlation between the *Travel Cost Index* and the probability of adopting this technology. Given that we find significant relationships between adoption and the household's *Wealth Index*, and adoption and the *Travel Cost Index*, we also investigated the relationship between the *Wealth Index* and the *Travel Cost Index*. Figure 6 shows that there is a negative and significant correlation between the household's *Wealth Index* and their *Travel Cost Index*, indicating that, on average, the mills are located in closer proximity to wealthier households than less wealthy households.

Figure 4. Nonparametric regression of household wealth on the proportion of households that adopted the milling technology for the production of ragi flour

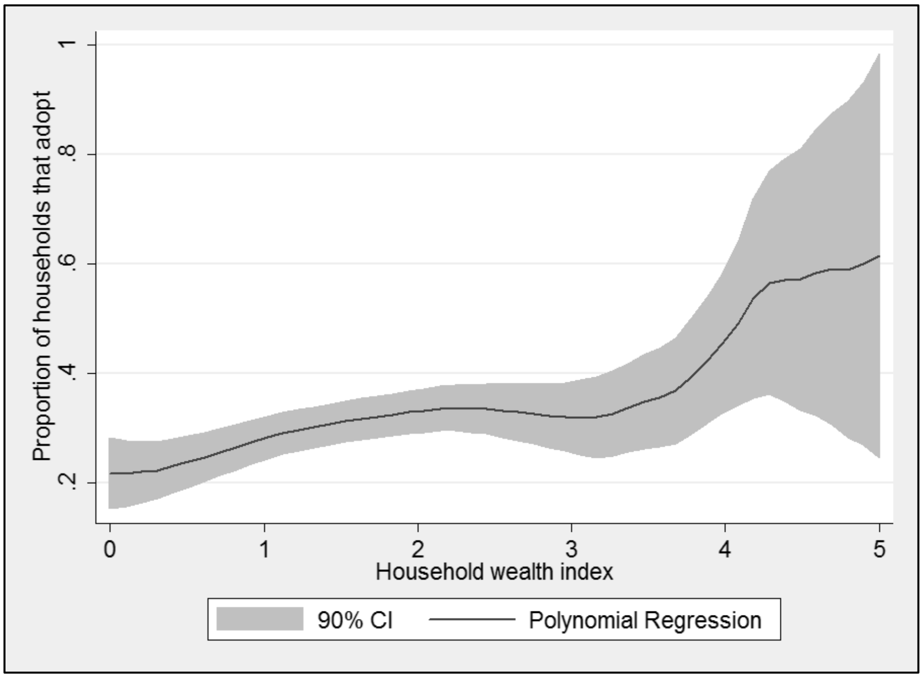


Figure 5. Nonparametric regression of travel costs on the proportion of households that adopted the milling technology for the production of ragi flour

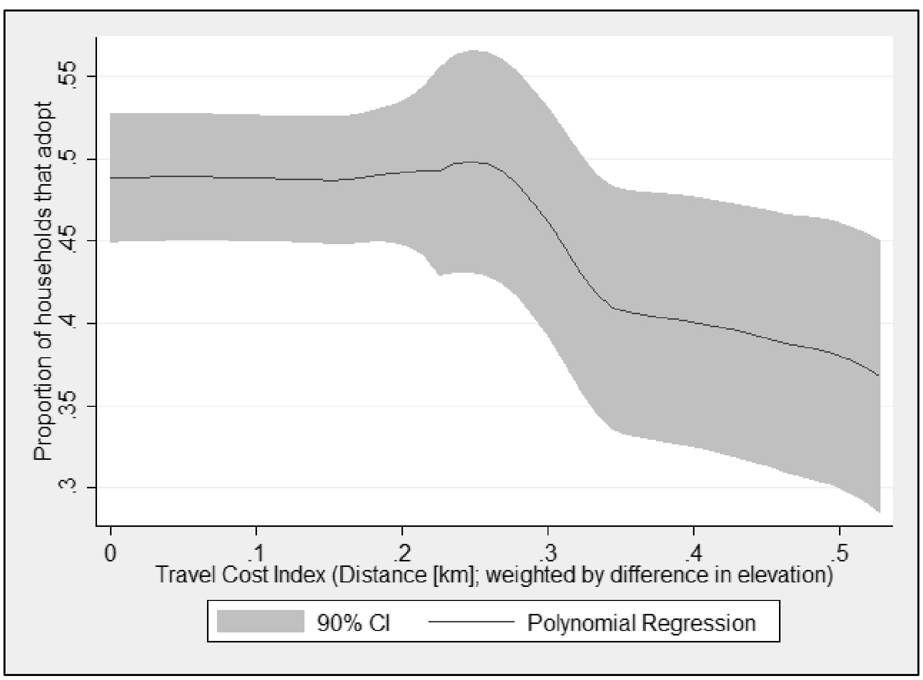
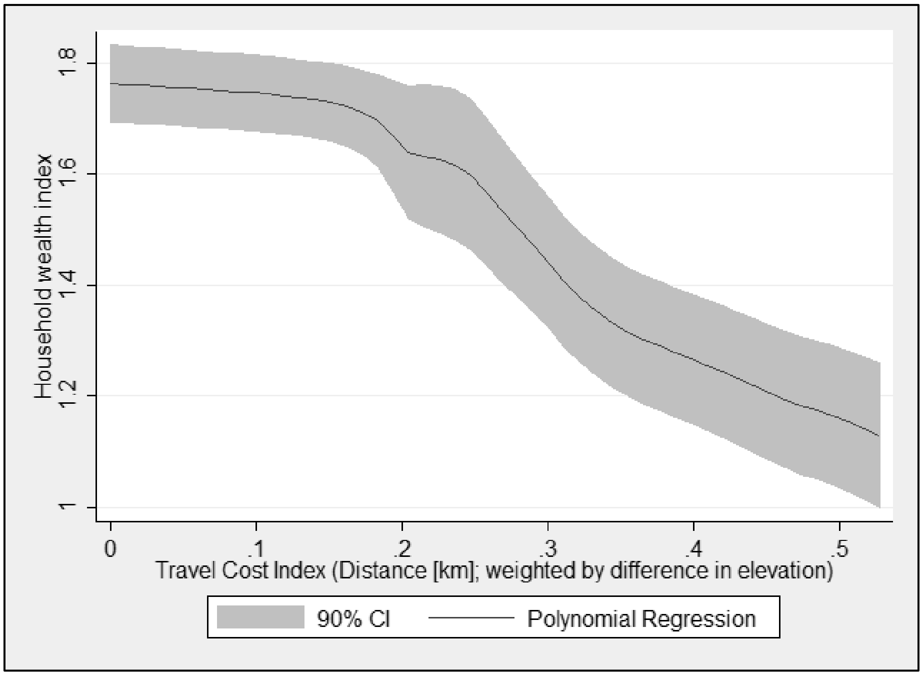


Figure 6. Nonparametric regression of household wealth and the travel costs



The positive relationship between the household's *Wealth Index* and adoption suggests that wealthier households are more likely to adopt this technology. The negative relationship between the *Travel Cost Index* and adoption is expected, since transportation costs have been shown elsewhere in the literature to be a deterrent to accessing natural resources (Alavalapati, 1990) and participation in markets (Key, Sadoulet, & de Janvry, 2000; Renkow, Hallstrom, & Karanja, 2004). However, the finding that the mills are placed in close proximity to wealthier households suggests that the location of the mills may contribute to the uptake of this technology amongst wealthier households. Taken together, these results beg the question: why are wealthier households more likely to adopt this technology? Is it because they have a greater inherent propensity to adopt this technology, or is it because the mills happen to be located in close proximity to wealthier households? We revisit this question in our adoption model by examining whether the household's *Wealth Index* increases the probability of adoption, independent of the effects of the *Travel Cost Index*.

6.3 Multivariate Analysis of Adoption and Intensity of Use

We evaluated the effects of household-level characteristics, prices, and travel costs on the adoption and intensity of use decisions. We also controlled and tested for the presence of patterns of self-selection, indicated by the selection term λ_i. We demonstrate how these patterns of self-selection can be used to reveal information about unobservable aspects of household welfare that are associated with a high probability of adoption. The results of this analysis are presented in Table 3.

Table 3. Results from the two-stage adoption model

	Adoption†		**Intensity**	
Cultivates Ragi	0.47	***		
Travel Cost Index (Distance to Mill × Elevation Gain)	-0.41	***		
Household wealth index	0.03		0.12	***
Female Head	0.18		0.83	***
Head is Literate	-0.07		0.13	*
Female Head × Head is Literate	-0.13		-0.42	*
Widowed Head	-0.11		-0.33	**
Male Dominant Household	0.07		-0.14	*
Proportion of household members that are children	-0.12		1.35	***
Number of Children Age 0-6	0.05		-0.36	***
Number of Children Age 7-12	0.05		-0.33	***
Number of Children Age 13-17	-0.05		-0.38	***
Senior Male in the Household (65+)	0.07		0.29	**
Senior Female in the Household (65+)	-0.03		0.00	
Buys Ragi Flour	0.03		-0.26	***
Price of Ragi Flour	6.89×10^{-4}		0.02	***
Price of Ragi Grain	-0.01		-0.03	***
Price of Wheat Flour	-0.01	**	0.02	***
λ_i			-1.70	*
Constant	0.00		-0.11	

= significant at the 90% confidence level; **=95%; *=99%*

† Marginal effects reported.

6.3.1 Adoption and Intensity

Both of our identifying variables, *Cultivates Ragi* and *Travel Cost Index*, are highly significant. As expected, we find that a household that *Cultivates Ragi* is more likely to adopt this technology. Households who cultivate this grain are 47% more likely to adopt this technology than households who do not. As expected, we also observe a negative and significant correlation between the *Travel Cost Index* and the probability of adopting the technology. Evaluating this coefficient at the mean difference in elevation between the household and the mill of 66 m, we observe that for each additional kilometre that the household is located away from the mill, households are 2.7% less likely to adopt the milling technology. We find that the price of wheat flour decreases the propensity for households to adopt this technology; as the price of wheat flour increases by 1INR/kg, households are 1% less likely to adopt this technology. One possible explanation for this result is that because the price of wheat flour available through the Public Distribution System is based partially on household income, the price effect of wheat flour could be confounded with an income effect.

None of the other variables included in the adoption regression are significant. Most notably, the lack of significance of the coefficient on the *Wealth Index* suggests that wealthier households do not have an inherently higher propensity to adopt this technology, after controlling for other factors. We expected that households who purchased ragi flour would have a lower propensity to adopt this technology. However, we find that households that purchase ragi flour do not differ significantly in their propensity to adopt than households that do not purchase ragi flour.

In our data, we observe that none of the households in our random sample sell the ragi flour that they produce.[11] Thus, we assume that ragi flour production is equivalent to consumption. We observe a positive and significant correlation

[11] However, in our sample of adopters, 2.2% of the households (or 1.09% of households in our total, unweighted sample) sold ragi flour.

between intensity of use and our proxy for income, the *Wealth Index*, which suggests that ragi flour is a normal good. For each additional asset that is owned per person in the household, the amount of ragi flour produced increases by 12%.

As expected, we observe positive and significant coefficients for the variables *Female Head* and *Literate Head* in the intensity equation. On average, female headed households produce 83% more ragi flour per person than male headed households. Households with literate heads produce 13% more ragi flour per person than households with illiterate heads. Unexpectedly, we find the coefficient for the interaction term *Female Head* × *Literate Head* to be negative and significant in the intensity equation. Comparing the net effect of the variables *Female Head*, *Literate Head*, and *Female Head* × *Literate Head*, we find that households with literate or illiterate female heads produce more ragi flour than male-headed households. Households headed by literate males produce more ragi flour than households headed by illiterate males, but households headed by literate females produce less ragi flour than households headed by illiterate females. Households with literate females produce: 54% more ragi flour than households with an illiterate male head, 41% more ragi flour than households with a literate male head, but 29% less ragi flour than households headed by an illiterate female. The finding that households headed by females produce more ragi flour than households headed by males, irrespective of literacy, is congruent with our expectations regarding the effect of female headship on the intensity of use. The cultivation of ragi and the production of ragi flour are considered female tasks, and the higher levels of ragi flour production amongst female headed households may be the result of cultural gender roles. However, the finding that households headed by illiterate females produce more ragi flour than households headed by literate females suggests that our expectation that households with literate heads would have a greater knowledge of the benefits of ragi flour, and would therefore produce a greater quantity of ragi flour, does not hold. As literacy rates increase amongst the household head, the consumption of ragi flour increases amongst male headed households, but decreases amongst female headed households. To the degree that household heads influence the amount of ragi flour consumed by the household, this result suggests that males and females have different tastes with respect to ragi flour produced from the mills; as literacy increases, male heads tend to increase the consumption of ragi flour produced from the mills, while female heads tend to decrease the consumption of ragi flour produced from the mills. The coefficient for the variable *Widowed Head* is negative and significant; households with widowed heads produce 33% less ragi flour per person than households with non-widowed heads.

As expected, we observe a negative and significant coefficient for the variable *Male Dominant Household* in the intensity equation. We observe that households dominated by men produce 14% less ragi flour per person than households dominated by females or households with an equal number of adult males and females.

The coefficient for the variable *Proportion of Household Members that are Children* is positive and significant in the intensity equation. A 1% increase in the proportion of household members that are children leads to a 1.35% increase in the production of ragi flour per person. If the *Proportion of Household Members that are Children* is inversely related to household labour supply, as suggested above, then this result may indicate that households with lower levels of available labour tend to produce greater quantities of ragi flour. We find negative and significant coefficients for the variables *Number of Children Age 0-6*, *Number of Children Age 7-12*, and *Number of Children Age 13-17* in the intensity equation. An additional child in the household age 0-6 decreases consumption by 36% per person, an additional child age 7-12 decreases consumption by 33%, and an additional child age 13-17 decreases consumption by 38%. These negative coefficients suggest that children of all ages consume less ragi flour, and that these consumption levels vary with age. These variables do not likely reflect the impact of children on the household's available labour supply, because these variables are independent of the household size and because the impact of children on the household labour supply is already controlled for with the variable *Proportion of Household Members that are Children*. Instead, these variables likely reflect the tastes for ragi amongst children of various ages. The negative coefficients on the variables *Number of Children Age 0-6*, *Number of Children Age 7-12*, and *Number of Children Age 13-17* suggests that children of all ages have lower preferences for ragi flour than adults. Because ragi is favoured for its ability to provide sustenance during long hours of manual labour, the lower preferences for ragi flour amongst children may be a result of the lower levels of manual labour performed by children. Alternatively, some school-going children may be obtaining lunch from their school and may therefore consume less food produced from their home overall; if children are receiving more meals outside of the home than adults, this may also explain the negative coefficients observed for these variables.

The coefficient for the variable *Senior Male in the Household* is positive and significant in the intensity equation, indicating that the presence of a male in the household that is age 65 or older increases consumption by 29% per person. In contrast, we find that the coefficient for the variable *Senior Female in the Household* is insignificant in the intensity equation, suggesting that the presence of a female in the household that is 65 or older does not significantly affect consumption levels of ragi.

The variable *Buys Ragi Flour* is negative and significant in the intensity equation. Households that buy ragi flour from the market tend to produce 26% less ragi flour using the milling technology. As expected, this result suggests that households that purchase ragi flour are substituting it for ragi flour produced from the mill.

All of the price effects that we observe are significant in the intensity equation and match our expectations. As the *Price of Ragi Flour* increases by 1 INR/kg, household production of ragi flour from the mill increases by 2%. As the *Price of Ragi Grain* increases by 1 INR/kg, the household production of ragi flour decreases by 3%. As the *Price of Wheat Flour* increases by 1 INR/kg, household production of ragi flour increases by 2%.

6.3.2 Patterns of Self-Selection

As mentioned above, patterns of self-selection observed in the data can contain critical information about economic behaviour. These patterns can give us useful insights with respect to unobserved attributes that are associated with households that self-select into the group of adopters. Our interpretation of these patterns of self-selection is based upon the coefficients that we observe for the *Wealth Index* and λ_i. The positive coefficient on the variable *Wealth Index* suggests that ragi flour is a normal good. By the definition of a normal good, we therefore expect that households with higher levels of income (approximated by the *Wealth Index*) will consume more ragi flour. We also expect that higher consumption levels of ragi flour will be associated with higher levels of household welfare. The selection term λ_i captures the effects of unobserved household characteristics that are associated with a higher probability of adoption. We observe a negative coefficient on λ_i, indicating that some unobserved household characteristic that is associated with a higher probability of adoption is associated with lower levels of ragi flour consumption. Given that ragi flour is a normal good, the negative coefficient implies that this unobserved characteristic is associated with lower levels of welfare. These results suggest that households with lower levels of welfare – based on unobserved characteristics – have a higher probability of adopting this technology.

Chapter 7. Conclusions

This study investigated the adoption of a technology that, by reducing the processing costs of a highly nutritious staple, has the potential to improve the food security of households in rural India. One of the goals of the intervention that established this technology in Kolli Hills was to improve the welfare and food security of households with lower levels of welfare. To gain an understanding of the adoption of this technology, we answered several research questions in our analysis.

In response to our first research question, whether ragi flour was a normal or inferior good, our analysis indicates that it is a normal good. This result gives us insights into the economic behaviour of households; consumption levels of ragi flour increase as household income increases.

Our second research question asked how demographic factors affect the adoption and intensity of use of this technology. Our results suggest that household demographic characteristics have an insignificant effect on the household's decision to adopt this technology, but that they do have significant effects on the intensity at which the households use this technology. We find that gender plays an important role in the amount of ragi flour produced, and that the effects of gender on the intensity of use may be influenced by differences in tastes between male and female head, as well as gender roles concerning the cultivation of ragi and the production of ragi flour. Female-headed households tend to use this technology at a higher intensity than male-headed households, and households than are dominated by adult males tend to use this technology at a lower intensity than other households. We also find that as literacy of the head increases, the consumption of ragi flour produced from the mills increases in households headed by males, but decreases in households headed by females. We find higher intensity of use amongst households with a male in the household who is age 65 or greater. We find that households with a greater *Proportion of Household Members that are Children* also tend to use this technology at a higher intensity. This may be caused by a lower per capita supply of labour in households with more children. The total number of children in different age categories decreases the consumption; children age 7-12 have the least reduction in the consumption of ragi flour while children age 13-17 have the greatest reduction in consumption. These results suggest that, compared to adults, children may have lower preferences for ragi flour.

Our data also suggests that the production of ragi flour may be influenced by the differences in the storability of ragi grain and ragi flour. Because ragi can be stored practically indefinitely, and because ragi flour spoils relatively quickly, there are few incentives to produce more ragi flour than what is required to meet short-term consumption decisions. This effectively makes the decision to produce ragi flour independent from the decision to harvest ragi, in the short term. Because of this independence, we find that the amount of ragi flour produced is largely driven by factors which influence household demand for ragi flour.

Our third research question asked how the prices of ragi flour, ragi grain, and wheat flour affect the adoption and intensity decisions. We find the *Price of Wheat Flour* has a negative effect on the probability of adoption. This finding was unexpected; however, this result may be confounded with an income effect that may be induced by legislated prices that are reduced for households with low levels of income. As expected, we find that the production of ragi flour increases as the *Price of Ragi Flour* increases, and that production decreases as the *Price of Ragi Grain* decreases. We also find that production of ragi flour increases as the *Price of Wheat Flour* increases, suggesting that wheat and ragi flour are substitutable. The policy implication of this result is that current subsidized prices for wheat flour may be crowding out demand for ragi flour, and that an increase in the subsidies for wheat will likely lead to a reduction in the amount of ragi flour consumed. Subsidies for wheat appear to be causing households to shift their consumption away from grains such as ragi which might contribute to their food security. To the degree that that the consumption of ragi improves household food security, this finding suggests that subsidies for wheat flour may be undermining food security in India.

Regarding our fourth research question – how do the travel costs of accessing these mills affect household's decision to adopt the milling services? – we confirmed our expectations that travel costs would reduce the probability that households would adopt this technology. This suggests that decision makers could potentially increase the adoption of this technology through the establishment of additional mills in areas that have poor access to milling services.

In our exploratory analysis we found that there was a higher rate of adoption amongst wealthier households and amongst households that live in close proximity to the mills. We also found that the mills tend to be located closer to wealthier households. We questioned whether the higher uptake of this technology amongst wealthier households was due to a higher propensity of wealthier households to adopt, or due to other factors such as the placement of the mills. In our multivariate analysis we found that wealthier households do not have a significantly higher propensity to adopt this technology after controlling for confounding factors such as the *Travel Cost Index*. This suggests that the higher uptake of this technology by the wealthy may be due in part to the placement of the mills in close proximity to wealthier households.

Our data revealed that, in addition to the mills established by the MSSRF, private mills have emerged in Kolli Hills. The emergence of privately established mills indicates that it is possible for some entrepreneurs to overcome the barriers to entry into the market for offering milling services, without the assistance of an intervention. We also investigated patterns of self-selection. We found evidence indicating that households that have lower levels of ragi flour consumption – based on unobserved characteristics – may have a higher propensity to adopt this technology. Because consumption is often used as an approximation of welfare, we argued that the lower levels of ragi flour consumption are indicative of lower levels of household welfare. Ideally, in order to investigate the adoption decisions of household welfare, one would use a longitudinal dataset that collected some robust measure of household welfare. However, the data that was used in this analysis was collected with the intention of addressing alternative research objectives and thus lacks these qualities. Despite these shortcomings, the dataset used in this study is the most comprehensive dataset with respect to the adoption of modern ragi flour milling technologies known to my academic supervisors and I. Patterns of self-selection were thus used as a means to explore the role of household welfare with respect to the adoption decision, in the absence of detailed data regarding household welfare.

Because lower levels of consumption are indicative of lower levels of welfare, it is possible that the households with lower levels of ragi flour consumption in our sample may also have lower levels of wealth. If these households do tend to have lower levels of wealth, then our results suggest that the technology is systematically being placed farther away from the households that this intervention was intended to target, and who have the highest propensity to adopt. Given that the SHGs were responsible for the placement of these mills, our analysis suggests that some conditions exist that encourage SHGs to place the mills closer to wealthier households. One possible explanation is that SHG members may decide on the placement of the mills to maximize profits, which is potentially better facilitated by placing the mills in closer proximity to wealthier households. Another possible explanation is that SHGs with wealthier members may be in a better financial position to assume the risk of operating a flour milling business and may choose to establish the mills in their own communities, which may also happen to contain wealthier households. Regardless of the specific incentives at work, our analysis suggests that using SHGs to implement this technology does not result in high rates of adoption amongst households with lower levels of welfare and lower levels of wealth. Given that tribal peoples tend to have lower welfare compared to other groups in India, one may argue that, on a national scale, this intervention is improving the welfare and food security of households with lower levels of welfare. However, this intervention, as implemented by SHGs, may not target the households with the lowest levels of welfare within a community. This intervention may therefore not be contributing to the food security of households with lowest levels of welfare. Despite the merits that this intervention might otherwise deserve, such as possibly encouraging the cultivation of ragi in Kolli Hills, or possibly reducing the drudgery faced by women, our results suggest that this intervention may not be an appropriate development tool for improving welfare or food security amongst households with the lowest levels of welfare in rural India.

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Appendix A: Constructed Variables

Adult Equivalent Household Size

Household size is an important demographic variable which affects income and consumption. In studying the consumption and production decisions of households, it is often necessary to control for variations in household size. Although household size can be calculated by adding the number of individuals in a household, this method does not account for the heterogeneity in the composition of ages of household members between different households. Because levels of consumption and the potential for income generation may differ between adults vs. children, a more useful measurement of household size is one which accounts for the heterogeneity of ages within the household. This is often achieved by the use of an adult equivalence scale, which assigns weights to members of certain age classes, before calculating the size of the household. To calculate the adult equivalent household size, we adopted the same adult equivalency scale that is used by Glewwe and van der Gaag (1990), which assigns a weight of 0.2 to children 0-6 years old, 0.3 to children 7-12 years old, 0.5 to children 13-17 years old, and 1 to persons age 18 and greater. While this variable is not included directly in any of our regressions, it is used to create per capita measures of other variables to control for differences in household size.

Household wealth

Because measures of income in subsistence-based economies are volatile, costly to collect, and prone to measurement error, it is often advantageous to substitute annual income for a variable which is both easy to measure and highly correlated with long term income levels. One such measure is the household assets index that is used by the India Human Development Survey (Sonalde *et al.*, 2008; page 18). Adapting this measure, we constructed an index variable based on several questions regarding household ownership of certain assets and housing materials. The measure used by the IHDS was deemed to be appropriate because it was developed within an Indian context and because of the strong evidence that household asset scales reflect the long-term economic level of the household.

The household asset scale used by the IHDS sums 30 binary variables regarding household assets. Because our survey did not collect the same list of variables, our measure of household assets sums those variables used by the IHDS assets index that were collected, plus a few additional assets. When choosing which assets to include, we used the same key criterion used by the IHDS to maintain consistency. The criterion is that the measure could only include assets that are strictly indicators of wealth. Car ownership, for example, is an indicator of wealth because less wealthy households would be unable to afford a car. On the other hand, the ownership of implements such as a hoe or spade is not strictly an indicator of wealth; while it is true that households with very low levels of wealth may not be able to afford these implements, very wealthy households who do not participate in manual labour may also not own these assets. Because non-ownership of these tools may indicate either high or low levels of household wealth, they could not be included in the index. This criterion was similarly applied to the other variables which were collected in our survey. Table 4 lists the variables used by the IHDS assets measure and the variables used in our study for comparison. To control for differences in household size, we divided this sum by the *Adult Equivalent Household Size* to create a per capita measure of household wealth.

Table 4. Comparison of household assets and housing variables used by the IHDS and this study to create the variable *Wealth Index*

Variables used by the IHDS	Variables used in our study	Mean
Any vehicle	Any vehicle	31%
Sewing machine	Sewing machine	0.8%
Mixer / grinder	Mixer / grinder	21%
Motor vehicle	Motor vehicle	27%
Any TV	Any TV	90%
Air cooler / cond		
Clock / watch		
Electric fan		
Chair / table		
Cot		
Telephone	Telephone	0.4%
Cell phone	Cell phone	65%
Refrigerator	Refrigerator	0%
Pressure cooker	Pressure cooker	5%
Car	Car	2%
Air conditioner		
Washing machine	Washing machine	0%
Computer	Computer	0.8%
Credit card		
2 clothes		
Footwear		
Piped indoor water		
Separate kitchen		
Flush toilet		
Electricity		
LPG		
Pucca wall	Pucca wall	80%
Pucca roof		
Pucca floor	Pucca floor	81%
	Radio	0%
	DVD player	3%
	Tape player	0.8%

Travel Cost Index

We expect proximity to a mill to significantly affect the decision to adopt this technology because there are greater costs associated with travelling longer distances. For the majority of people in our study, these costs are largely costs associated with the effort of walking. Distance to the mill was calculated as the Euclidean distance between the household and the nearest ragi mill, in kilometres. Changes in elevation increase the difficulty of walking over a given distance; Katch and McArdle (1993) show that caloric expenditures of walking are an increasing function of terrain inclination. Because our study site is hilly, we hypothesized that difference in elevation between the household and the mill would also affect the decision to adopt. Elevation from the household to the mill was calculated as the absolute value of the difference between the elevation of the household and the nearest ragi mill, in kilometres. To account for the added difficulty that is introduced by changes in elevation, we multiplied the distance from the household to the mill by the difference in elevation between the household and the mill. To avoid this weighting variable being equal to zero for households that were located at the same altitude as the nearest mill, we added one metre (0.001 km) to the difference in elevation for all households. This distance was thought to be small enough that it would not significantly affect our estimation, while at the same time it would avoid the weighted distance from being equal to zero.

Appendix B: Questionnaire Used to Collect Data

Adoption of Mechanized Milling Technology
Household Survey Information Sheet

We are here with a project that is studying poverty alleviation and malnutrition. This project is funded by the International Development Research Centre of Canada, and run by the M.S. Swaminathan Research Foundation (MSSRF) in partnership with the University of Alberta. We are here today to ask you to participate in a survey that is a part of that project. Through this study we hope to understand why people choose to use, or not use, mechanical mills to produce flour. We are asking because we would like to understand more about how you make decisions regarding the way you choose to produce flour. Though we do not believe that you will gain directly from this study, the results will help us understand how use the mechanical mills. This will help the MSSRF in the future design and placement of mills

As part of this study, we would like to ask you to participate in our survey. This visit will take about one hour. The information from the survey will only be used for the purpose of this study by researchers at MSSRF and the University of Alberta. The survey data will be stored by the researchers in Alberta, Canada on a password-protected computer. We will keep the data for at least 5 years.

We do not foresee any risks to you that may occur by participating in this survey. If you agree to participate, your answers will be protected. The general information from the study will be public, but the information will not be linked to any one person or household. The results from this study will be used as part of a thesis, and may appear in conference publications and academic publications.

If you choose to participate, you may withdraw before the end of this study. We expect this study to be completed by May 1, 2012.

If you have concerns about this study, you may contact the University of Alberta Research Ethics Office at (780) 492-2615 (this office will accept collect calls). This office has no affiliation with the study participants.

Tear off sheet and hand to respondent

Adoption of Mechanized Milling Technology
Household Survey

Introduce yourself and ask to speak with the head of the household. If the head is not available, ask to speak with someone who can speak for the household (such as the Head's Spouse). The head or household representative will be the respondent for this survey.

Hello, I am here from the Alleviating Poverty and Malnutrition Project that the M.S. Swaminathan Research Foundation is running in partnership with the University of Alberta. I am here today to ask you to participate in a survey that is a part of that project. A member of your household may have already been contacted by someone on our project. We are interested in households that produce flour from ragi, wheat, or paddy

Ask the respondent:

Does your household grow or purchase ragi, wheat, or paddy in grain form? YES / NO

If respondent answers NO, thank them for their time and leave

Can I tell you about our study? YES / NO

If respondent answers YES, proceed with the script on the information form

If respondent answers NO:

Is there a better time that I could come back and ask you to participate in this survey?
YES / NO

If YES, note date and time to come back:

____

If respondent answers NO, thank them for their time and leave

RESEARCH CONSENT FORM

Title of Research Project: Adoption of Mechanized Milling Technology

Household Survey

Investigators:

Investigators are from the Faculty of Agricultural, Life and Environmental Sciences, University of Alberta and the M.S. Swaminathan Research foundation, Chennai, India
Nat Kav, Professor, Faculty of ALES, University of Alberta, 1-780-492-2908, nat@ualberta.ca
Brent Swallow, Professor, Faculty of ALES, University of Alberta, 1-780-492-6656, brent.swallow@ualberta.ca, Bala Ravi, Senior Advisor ( ) 011-91-44-22541229

Consent:

Please circle your answers or have the enumerator circle after reading the questions:
Do you understand that you have been asked to be in a research study? YES NO

Have you read and received a copy of the attached Information Sheet? YES NO

Do you understand the benefits and risks involved in taking part in this research study? YES NO

Have you had an opportunity to ask questions and discuss this study? YES NO

Do you understand that you can quit taking part in this study at any time? You do not have to say why. YES NO

Has confidentiality been explained to you? YES NO

Do you understand who will be able to see or hear what you say? YES NO

Do you know what the information you provide through the survey will be used for?
YES NO

Do you know that the information that you provide will be used for a written thesis, conference presentations, and academic publications? YES NO

Do you give us permission to use your data for the purposes specified? YES NO

Signature ________________________________

The Adoption of Mechanized Milling Technology

Survey #:_______________

Date of Survey (DD/MM/YYYY):	/ /			
Enumerator Name:				
Head of Household Name:				
Respondent's Name:				
Was a member of the household contacted at a mill to participate in this study?	(0=NO, 1=YES) Name? ________________________			
Has respondent read and signed the consent form?	**(0=NO, 1=YES)**			
If NO, please ask the respondent to read and sign the consent form. **If respondent cannot understand the form, please read it to him / her, and ask the respondent to sign or indicate with an 'X'.**				
Time interview started:	HH:		MM:	
Time interview ended:	HH:		MM:	

Panchayat Name:		Panchayat Code:	
		Village Code:	
Hamlet Name:		Hamlet Code:	
Waypoint #:			
Elevation			
Accuracy			
Coordinates:			

The box below should be completed after the interview & shows the data transfer from the field to the computer:

Name of Field Partner:	
Survey checked by Field Partner (sign & date – DD/MM/YYYY):	Signature: Date: / /
Name of Data Entry person:	
Date of data entry (DD/MM/YYYY):	/ /
Computerised survey checked against paper survey? (tick when done) – Person who checked should sign with date	Checked (tick): Signature: Date: / /

Note to Surveyor: Signature or thumb impression must be obtained after the survey is completed.

SECTION A: HOUSEHOLD MEMBERS AND DEMOGRAPHIC INFORMATION

I would like to start by asking you for some information about the members of your household.
Fill the table in one row at a time. Start with the head, followed by the respondent (if different from head), the spouse or spouses, children (ranked from old to young) and lastly other household members – include only members who live there at least 2 months per year.

Person ID#	Name	Respondent (Yes=1, No=0)	Relation to head	Gender 0= Male 1= Female	Age (yrs)	Highest Level of education **completed**	Technical Degree/ Diploma/ Certificate	Primary activity	Home occupancy	Current Marital Status	Weight (kg)
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]
1	**Head:**										
2											
3											
4											
5											
6											
7											
8											
9											
10											

3) RELATIONSHIP TO HEAD		[6] HIGHEST LEVEL OF EDUCATION COMPLETED	[7] Have any kind of technical degree/ diploma/ or certificate at the undergrad/ graduate level?	[8] Which of the following BEST describes this person's primary activities?	[9] HOME OCCUPANCY	[10] MARITAL STATUS
1= Head 2= Spouse of Head 3= Married Child 4= Spouse of Married Child 5= Unmarried Child 6= Grandchild 7=Father/ Mother 8= Father-in-law/ Mother-in-law 9= Brother/ Sister 10= Brother-in-law/ Sister-in-law 11= Other relatives 12= Servants/ employees 13= Other non-relatives		0= Not Literate: below Primary 1= Literate: below Primary 2= Primary School (1-5) 3= Upper Primary School (6-7) 4= High School (8-10) 5= Higher Secondary School (11-12) 6= College/ University (Undergraduate) 7= Graduate 8= Post-Graduate Studies	0= No 1= Yes (Specify)	1 = Farmer 2= Self Employed Non-farm 3= Formal Wage Employment 4= Casual Wage Employment 5= Student 6= Retired 7=Not Working/ Unemployed 8=Infant (<5 years of age) 9= Disabled/Sick and unfit for work 10= Other (Specify)	1= Permanent Resident 2= Sometimes Away (< 3 months/year away) 3= Frequently Away (3 – 6 months/year away) 4= Usually Away (6-9 months/year away) 5= Mainly Away (>9 months/year away)	1= Never Married 2= Currently Married 3= Widowed 4= Divorced/ Separated 5= Engaged 9= Other (Specify)

SECTION B: OCCUPATIONAL INFORMATION

Now I would like to find out about paid work performed by members of your household who are age 15 or older. **Fill the table in one row at a time, for each household member above the age of 15. Copy the Names from Section A. ENSURE THAT THE PER SON ID# MATCHES THE NAMES FROM SECTION A.**

For persons of aged 15 years and above										
Person ID #	Name	Assured (100) days work NREGA (No=0/ Yes=1; specify)	**for those who got work in public works (entry 1 in col. 3)**			Not NREGA (No=0/ Yes= 1; specify)	**for those who got work that was NOT public work (entry 1 in col. 8)**			
			number of days worked	wages received (Rs.)			number of days worked	TOTAL wages received (Rs.)		
				Cash/ day (Rs.)	total (*col. 4 *col. 5*)			cash (Rs.)	in kind (Rs.)	Sum (*col. 10 + col. 11*)
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

Col. 6 & 11: have the respondent estimate the value (in rupees) of the "in kind" payments

SECTION C: FLOUR PRODUCTION

Now I would like to ask you some questions about your production of flour. Are there other members of your household who could help us answer some questions about flour production?

Copy the names from section A. ENSURE THAT THE PERSON ID# MATCHES THE NAMES FROM SECTION A. Indicate whether the household member is present.

Ask the Respondent the following questions, and have him or her confirm the response with present household members:

Which members of your household have brought grain to the pulverizers?
Which members of your household have ground grain at home?

Record the responses in the table below.

ID #	**Name**	**Presence** (1= Present, 0=Not Present)	**Brings Grain to the Pulverizer?** *(circle one)*	**Grinds Flour at Home?** *(circle one)*
1.	**Head:**		**YES / NO**	**YES / NO**
2.			**YES / NO**	**YES / NO**
3.			**YES / NO**	**YES / NO**
4.			**YES / NO**	**YES / NO**
5.			**YES / NO**	**YES / NO**
6.			**YES / NO**	**YES / NO**
7.			**YES / NO**	**YES / NO**
8.			**YES / NO**	**YES / NO**
9.			**YES / NO**	**YES / NO**
10.			**YES / NO**	**YES / NO**

C.1 Mechanical Flour Milling Activities

Ask the Respondent the following questions, and have him or her confirm the response with present household members:

What is the approximate date when your household first started using the pulverizers? ________________
How many times has someone in your household has taken gain to a Mechanical Mill during the last 4 weeks? _______
If the number the number of times that grain was brought to the pulverizer in the last 4 weeks is equal to 0, skip section C.1 and continue with section C.2.

The next questions ask you to recount details about your household's most recent trips to the pulverizers. Please recount the following details of the trips taken to the pulverizers in the last 4 weeks, ***STARTING WITH THE MOST RECENT TRIP****.*

C.1 Pulverizer Activities

Can you please tell me the following information about the most recent trip?
a. Trip #: __1___ b. Mill Location: __________ (Code: ______) c. Day of Week:_______ d. Date:__________
e. Total Quantity of ALL Grains brought to the mill:___________ kg
f. *Who went on this trip?* **>Include non-household members on the trip (give ID# of "x")**
What types of grain were brought to the pulverizer, and in what quantity did each person bring? What quantity of flour?

Name:	ID#	Kg Grain Carried from Home to Mill			Kg Grain Carried from other location to Mill			R.s Paid
		Ragi	Rice	Wheat	Ragi	Rice	Wheat	

g. **How did you acquire this grain (i.e. grew it, bought it, received as gift, other…) :___________________________**
h. Did you pay anyone to go to the mill on this trip? ***YES / NO (indicate amount paid above)***
Trip Diary: *I will now ask you some questions about the different activities that you may have performed on the way to or from the pulverizer.* ***"Activities"*** *include things such as* ***walking, riding the bus, visiting a friend, waiting at a bus stop or at the pulverizer, buying or selling something, etc.*** *To begin, what time did you leave your home? How did you travel? How much was carried by each person? What did you do next?*

For all HH members (and non-HH members on trip):						Weight (kg) Carried by Each Individual, by Item				**Detour 0=No/ 1=Yes;** Time & Dist.
						ID#: ___		ID#: ___		
Start Time	End Time	Activity	Dist. (km)	Tot. Rs Earned	Tot Rs Paid	Grain/ Flour*	Oth	Grain /Flour	Oth	

Indicate weight of each grain type by writing the letter code in front of each weight in kilograms (R=Ragi, PP= Paddy, PR= Paddy Rice, W=Wheat)

Detour: After table is completed, go row by row and ask if there was a detour: *If you were walking straight to the mill, or straight home, what time and distance travelling would you have saved instead of performing this activity?*
> Fill out additional sheets for trips to the mill if more than one trips occurred in the last 4 weeks. Staple these to this survey package

C.2 Home Flour Milling Activities

Ask the Respondent the following questions, and have him or her confirm the response with present household members:

Now I would like to ask you about your household's activities to grind grain into flour at home.
How many times has someone in your household ground grain AT HOME using the stone grinders during the last 4 weeks? _______

*The next few pages of this survey ask details about your household's most recent occasion's on which grain was ground into flour at home. Please recount the following details of these occasions in the last 4 weeks, **STARTING WITH THE MOST RECENT**.*

I will ask you some questions about the different activities that members of your household may have performed on each occasion when grain was ground. "Activities" include things such as turning the grinding stone, pouring grain into the grinding stone while someone else grinds, destoning, cleaning up afterwards, etc. For each activity, please indicate the total time spent performing that activity. Additionally, I would like to know the amount of grain/ flour that was ground or destoned by each individual.

If different grains are ground, even if right after another, record this as a separate occasion

Occasion 1
a. Day of Week:_______ b. Date:__________
c. Type of Grain:_________________
d. Total quantity of GRAIN ground:___________ kg
e. Total Quantity of FLOUR produced: __________kg
f. . *How did you acquire this grain (i.e. grew it, bought it, received as gift, other…) :*_____________________________
Diary
> Include non-household members present on the occasion (give ID# of "x"). For activities not listed, specify as "other" in provided columns

Name	ID#	Kg of Grain Destoned	Time Spent Destoning	Kg of Grain Ground	Time Spent Grinding	Time Spent Other: _____	R.s Paid

Was anyone paid for any of the activities listed above? If so, indicate how much they were paid in the "Rs. Paid" Column
Were any other activities performed to complete this task? If so, specify this in the "Time Spent Other" column and indicate the time spent by each individual.

> Fill out additional sheets for home milling if more than one home milling occasion occurred in the last 4 weeks. Staple these to this survey package

SECTION D: PARTICULARS ON GRAIN AND FLOUR PRODUCTION

Now I am going to ask you some questions regarding the production and consumption of grain and flour in your household and in your village

D.1 Mill Choice Set

Please list the location of all mechanical mills that grind grain in Kolli Hills that you are aware of, and if you have ever brought grain to this mill.

Mill Name (Village & Location)	**Mill Code**	**Brought Grain? (Yes=1 / No=0)**

D.2 Household Level Production/ Consumption

I would now like to ask you some questions about your household's production of grain and flour. I will ask you about Ragi, Wheat, and Paddy.

	Ragi	*Wheat*	*Paddy/ Rice*
Does your household grow this grain? (YES= 1, NO = 0)			
(a)***IF YES***, indicate the amount (kg) of grain harvested during the **LAST HARVEST**.			
(a) Does your household ever purchase this in grain form? (YES=1, NO=0)			
(b) If your household purchases this in ***grain form****, indicate the quantity (kg) purchased over the last* ***4 weeks****.(Grain not purchased =0)*			
(c) If grain is purchased, indicate the quantity (kg) bought the ***last time*** *the grain was purchased. (Grain not purchased =N/A)*			
(d) If grain is purchased, indicate the ***price/kg*** *paid during the* ***last time*** *the grain was purchased. (Grain not purchased =N/A)*			
IF GRAIN NOT PURCHASED: What price/kg do you think you could buy the grain for? (Grain **IS** purchased = N/A)			
(a) Does your household ever sell this in grain form? (YES=1, NO=0)			
(b) If your household sells this in ***grain form****, indicate the quantity (kg) sold over the last* ***4 weeks****. (Grain not sold =0)*			
(c) If grain is sold, indicate the quantity *(kg) sold the* ***last time*** *your household sold this grain. (Grain not sold =N/A)*			
(d) If grain is sold, indicate the ***price/kg*** *earned during the* ***last time*** *the grain was sold. (Grain not purchased =N/A)*			
IF GRAIN NOT SOLD: What price/kg do you think you could sell the grain for? (Grain **IS** sold = N/A)			

(a) Does your household ever purchase this in flour form? (YES=1, NO=0)			
*(b) If your household purchases this as **flour**, indicate the quantity (kg) purchased over the last **4 weeks**.(Flour not purchased =0)*			
*(c) If flour is purchased, indicate the quantity (kg) bought the **last time** the flour was purchased. (Flour not purchased =N/A)*			
*(d) If flour is purchased, indicate the **price/kg** paid during the **last time** the flour was purchased. (Flour not purchased =N/A)*			
IF FLOUR NOT PURCHASED: What price/kg do you think you could purchase the flour for? (Flour **IS** sold = N/A)			
(a) Does your household ever sell this in flour form? (YES=1, NO=0)			
*(b) If your household sells this as **flour**, indicate the quantity (kg) sold over the last **4 weeks**. (Flour not sold =0)*			
(c) If flour is sold, indicate the quantity *(kg) sold the **last time** your household sold this flour. (Grain not sold =N/A)*			
*(d) If flour is sold, indicate the **price/kg** earned during the **last time** the flour was sold. (Grain not purchased =N/A)*			
IF FLOUR NOT SOLD: What price/kg do you think you could sell the flour for? (Flour **IS** sold = N/A)			
(a) Does your household ever pay someone to mill this grain with a stone grinder, for the benefit of your household? (YES=1, NO=0)			
(b) **If YES:** How many times did your household pay someone to grind this grain for you over the past four weeks?			
If YES: On the last time that your household paid someone to grind this grain for you;			
How much grain was ground? (kg)			
How much time did it take? (minutes)			
How much did you pay them? (INR)			
(a) Does your household ever pay someone to bring this grain to a pulverizer, for the benefit of your household? (YES=1, NO=0)			
(b) **If YES:** How many times did your household pay someone to bring this grain to a pulverizer for you over the past four weeks?			
If YES: On the last time that your household paid someone to bring this grain to the pulverizer for you;			
How much grain was brought? (kg)			
How much time did it take? (minutes)			
How much did you pay them, in excess of the mill fees? (INR)			
(a) Does anyone in your household ever grind grain using the stone grinder for another household?			
(b) **If YES**: How many times did someone in your household grind grain for another household over the past **4 weeks?**			
(c) **If YES:** On the last time that someone in your household ground grain for another household:			
How much grain was ground? (kg)			
How much time did it take? (minutes)			
How much were they paid? (INR)			

(a) Does anyone in your household ever bring this grain to the pulverizer for another household?			
(b) **If YES**: How many times did someone in your household bring this grain to the pulverizer for another household over the past **4 weeks?**			
If YES: On the last time that someone in your household brought grain to the pulverizer for another household:			
How much grain was brought? (kg)			
How long did it take? (minutes)			
How much were they paid, in excess of mill fees? (INR)			

D.3 Village-Level Grain Production / Consumption

I would now like to ask you some questions about the production of grain and flour in your village. I will ask you about Ragi, Wheat, and Paddy.

Approximately how many households live in your hamlet? ___________

	Ragi	*Wheat*	*Paddy/ Rice*
How many households in your hamlet grow this grain?			
How many households in your hamlet purchase this grain?			
How many households in your hamlet sell this grain?			
How many households in your hamlet purchase this as flour?			
How many households in your hamlet sell this as flour?			

How many households in your hamlet grind ANY grain into flour using a stone grinder? ________

How many households in your hamlet bring ANY grain to the mechanical mills? _________

SECTION E: HOUSEHOLD CHARACTERISTICS AND HOUSEHOLD ASSETS

Now I am going to ask you some questions regarding the characteristics of your household and your household's assets

E.1 Home ownership & type

Enumerator activity: If possible, observe the materials rather than asking the farmer. Circle all that apply

Home ownership (Code a)	Floor material (Code b)	Wall material (code c)	Roofing material (code d)
a)Ownership	**b) Floor material**	**c) Wall material**	**d) Roofing material**
1 = Owned 2 = Rented 3 = Leased 4 = Other (specify)	1= earth/mud 2= cement 3= tiles 4 = Other (specify)	1= earth/mud 2= bamboo/iron sheets 3= cement/bricks 4 = timber (wood) 5 = stone 6 = Other (specify)	1= thatch grass / palm leaves 2= iron/tin sheets / asbestos 3= tiles 4 = concrete 5 = Other (specify)

E.2 Family Land Holdings

	Category	Total
1	Total wet land	
2	Total up (dry) land	

E.3 Social Category

What Social Category do you belong to? [Tick mark]

1 = General/ forward caste (FC)	2 = Backward caste (BC)	3= Most backward caste (MBC)	4 = Scheduled caste (SC)	5=Scheduled tribe (ST)

E.4 Religious Affiliation

What is your religion? [Tick mark]

1 = Hindu	2 = Muslim	3= Christian	4 = Sikh	5= Jain	6= Other (specify)

E.5 Household assets

How many of the following assets does your household currently own?

	Name of Asset	Total Number owned	Value when purchased (INR) for 1 item	Age of asset (years)
	Domestic			
1	Cooker/gas stove			
2	Refrigerator			
3	Radio			
4	Tape recorder			
5	Television			
6	DVD player			
7	Mobile phone			
8	Landline phone			
9	Computer			
10	Mixer-Grinder			
11	Washing machine			
12	Sofa set			
13	Sewing machine			
14	Mosquito Nets			
Others (Specify): *				
15				
16				
	Transport			
18	Car/truck			
19	Motorcycle			
20	Auto-rickshaw			
21	Bicycle			
22	Bullock cart			
Others (Specify):*				
23				
24				
	Farm			
26	Hoe			
27	Spade/shovel			
28	Plough			
29	Sprayer pump			
30	Irrigation pump			
Others (Specify):*				
31				
32				
3 3				

* e.g. camera, videocam, lorry, bus, emergency lantern.

E.6 Savings / Debt

Now I would like to ask you about your household's savings and debt.

How much does your household have in savings in banks, credit associations or savings clubs? ___________ INR

How much does your household have in outstanding debt? ___________ INR

Thank-you for your time!