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:

Decision-Making within the Household:

The Role of Autonomy and Differences in Preferences

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Decision-making within the Household: The Role of Autonomy and Differences in Preferences *

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Abstract

We use a field experiment to identify how differences in preferences and autonomy in decision-making result in sub-optimal adoption of technologies that can maximize the welfare of all members of the household. We create income-earning opportunities to empower subjects and elicit their willingness-to-pay (WTP) for improved cookstoves through a real stove purchase experiment with randomly chosen wives, husbands and couples. Experimental results suggest that women, who often are responsible for cooking and for collecting fuelwood, reveal a higher preference than men for the improved stoves. Results also show that women who have higher decision-making autonomy and those who make the stove decision individually reveal higher WTP than those who have lower decision-making autonomy and those who make the stove decision with their husbands. A follow-up survey conducted 15 months after the stove purchase shows that autonomy does not affect stove use. Our findings highlight the importance of considering division of labor, different preferences, and bargaining power differences within the household when promoting adoption of new household technologies.

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Keywords: Preference Difference, Decision-making Autonomy, Willingness-to-pay.

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1 Introduction

Household-level decisions made by spouses - who often have different preferences and bargaining power - have significant implications for the welfare of all members of the household, including children. There is consistent evidence on the differences in spending patterns - driven by differences in preference - between men and women in both developed and developing countries, which draws on observational data. For example, Browning et al. (1994) and Phipps and Burton (1998) in Canada and Bourguignon et al. (1993) in France document that women have different spending patterns than men. Women in developing countries spend a larger proportion of their income on children's and household goods (Hoddinott and Haddad, 1995), and children's health (Thomas, 1990), and micro-finance credits have a larger impact on household outcomes when women are the clients (Pitt and Khandker, 1998). In South Africa, pension income received by women has been shown to have a larger impact on the health status of children than pension income received by men (Duflo, 2003). In this paper, we use a novel field experiment to investigate to what extent differences in preferences between couples, mainly driven by division of labor within the household, and differences in intra-household decision-making power lead to sub-optimal household decisions.

We created income-earning job opportunities for randomly selected wives, husbands and couples in the Tigray region of Ethiopia and conducted a real improved stove purchase experiment. The improved stove we offer, known as the "mirte stove", reduces fuelwood consumption by 50%, protects the cook from flames, and reduces smoke and indoor air pollution by 90%.[1] Consequently, it enhances the welfare of women, who are the default cooks of the household and are responsible for fuelwood collection, more than for men.[2] We use the Becker-DeGroot-Marschak (BDM) method (Becker et al., 1964) to elicit willingness to pay (WTP) by our subjects. BDM is an incentive-compatible method of eliciting WTP because subjects make real trade-offs when they make decisions (Alem and Dugoua, 2017; Hoffman, 2009; Lusk et al., 2001). We refer to the joint WTP (revealed by the couple) as the "household-level preference" and the individual WTP revealed by wives and husbands as "wives' preference" and "husbands' preference" respectively. Preferences revealed in this way show to what extent the "household-level" preference resembles the wives' or the husbands' preference. However, individual/joint preferences may still be confounded by decision-making autonomy (power) within the household. For example, a wife who has low decision-making autonomy (power) may reveal a low WTP in the individual decision, not because she does not want the improved stove, but because she knows that her husband, who is the default head of the household, will not approve such a purchase. Thus, a low-power wife will very likely reveal the

[1] See "http://stoves.bioenergylists.org/stovesdoc/Bess/Mirte.htm" for a description of the "mirte" stove, and appendix A for a photo of the stove taken in the field.

[2] In many developing countries, children also benefit from reduced fuelwood collection time and reduced indoor air pollution (WorldBank, 2011).

preference that her husband would normally reveal. In order to tease out to what extent spouses feel empowered to make the stove purchase decision using the household's income, we randomly assign wives and husbands to an additional treatment which involves making the stove purchase decision using the income the couple earned.

Experimental results suggest that wives, who by default are the household cooks and are responsible for fuelwood collection, are willing to pay 60% more than husbands for the improved stove, and wives who make the decision individually are willing to pay 40% more than those who make the decision together with their husbands. However, there is no statistically significant difference between husbands who make the decision individually and those who make the decision jointly with their wives. Tobit regression results also show that wives who have high autonomy in decisions regarding the purchase of their own material items are willing to pay significantly more than are husbands who are autocratic (i.e., those who do not allow wives to make such decisions), and wives who make the stove purchase decision individually are willing to pay more than those who make the stove purchase decision together with their husbands. The results are robust to alternative specifications and definitions of decision-making autonomy. A follow-up household survey conducted 15 months after the stoves were offered shows that decision-making autonomy does not have any effect on how quickly the stove was put in use. Our results highlight that differences in preferences, driven by division of labor within the household, and differences in bargaining power among women and men play significant roles in the speed of adoption of modern technologies such as improved cookstoves, which improve the welfare of all members of the household.

This paper contributes to a body of research in economics on intra-household decision-making and the role of empowering women. Previous studies in developed countries (Browning et al., 1994; Chiappori, 1992; Mazzocco, 2007) reject the collective model of the household, which assumes that household members achieve Pareto-efficient outcomes even if they have different preferences and bargain over possible outcomes.[3] In a developing country context, Udry (1996), in Burkina Faso, rejects Pareto efficiency at the household level by showing that plots managed by women are cultivated much less intensively than similar plots within the household managed by men, while Robinson (2012), in Kenya, finds risk-sharing in the household to be Pareto-inefficient. Contributing to this, more recently, Schaner (2015) documents that poorly matched spouses in urban Kenya forgo a significant amount of income due to differences in time preferences, and Almås et al. (2015) show that women in urban Macedonia are willing to sacrifice household income to gain control over resources. In order to improve the economic position of women and benefit children, most conditional cash transfers in developing countries make women to be the recipient of the transfer (Ferreira et al., 2009). Women also engage in informal strategies such as saving in ROSCAs -

[3]Other studies conducted in developed countries (Bourguignon et al., 1993; Browning and Chiappori, 1998; Chiappori et al., 2002), however, document evidence consistent with efficiency.

Rotating Savings and Credit Associations Anderson and Baland (2002) to improve their economic position. Using carefully designed income income-earning opportunities and a novel experimental design, we provide new evidence by isolating the role of preference differences (which are likely driven by division of labor within the household) from the role of bargaining power in household decisions.

The paper also speaks to the literature on technology adoption in developing countries in general and adoption of improved cookstoves in particular. Modern technologies, such as improved seed, fertilizer, insecticide-treated bed nets, water purifiers, improved cookstoves, and solar powered lighting devices significantly improve productivity and welfare of poor communities, but their adoption and diffusion rates have been sub-optimally low. Some of the key reasons include uninsured risk (Alem et al., 2010; Dercon and Christiaensen, 2011; Lamb, 2003), liquidity constraints (Alem et al., 2017; Cohen and Dupas, 2010; Dupas, 2014; Giné et al., 2008; Grimm et al., 2017; Tarozzi et al., 2014), behavioral biases (Duflo et al., 2011), and limited experimentation (Conley and Udry, 2010; Foster and Rosenzweig, 1995). In order to reduce the significant negative consequences of biomass fuel use for households and the environment, a number of recent studies (Bensch and Peters, 2015; Beyene et al., 2015; Hanna et al., 2016; Miller and Mobarak, 2014; Smith-Sivertsen et al., 2009) use a randomized experimental set-up to examine the factors that promote adoption of improved cookstove technologies in developing countries.[4] These studies identify liquidity constraints, poor social networks, lack of continuous technical support, and technical designs that alter taste of food cooked explain the low adoption of improved biomass cookstoves.

A paper with a similar research question to ours, Miller and Mobarak (2013), points out a different reason - gender differences in preferences within households - to explain the low adoption of improved cookstoves. These authors offer either a "health-improving" or a "budget-saving" stove at randomly assigned prices to both women and men in rural Bangladesh. They document that women appear to show a stronger preference for any improved stove when offered for free, but, when a small price is charged for either stove, women become less likely than men to adopt, implying their lack of authority to make a purchase. Our experimental design, combined with the income-generating activity we offer to participants, allows us to clearly identify the impact of preference differences and the magnitude of the impact of decision-making power within the household on WTP for the improved cookstove, which is a continuous measure of adoption. Our outcome variable of interest - average WTP by households - is of key importance to policymakers

[4]Nearly 3 billion people in developing countries, and almost all rural households in Africa use biomass fuel (such as firewood and charcoal) in order to meet their cooking needs. Biomass fuel use has been a key cause of deforestation and forest degradation (Campbell et al., 2007; Mercer et al., 2011), loss of of biodiversity and destruction of local ecosystems (Allen and Barnes, 1985; Geist and Lambin, 2002; Hofstad et al., 2009; Köhlin et al., 2011), indoor air pollution, which accounts for 3.3% of global burden of disease and 2 million premature deaths per year (WHO, 2009), and climate change, through emission of harmful greenhouse gases including black carbon and carbon dioxide (Grieshop et al., 2011; Kandlikar et al., 2009; Sagar and Kartha, 2007).

and other stakeholders, who need to estimate the amount of resources required to speed up adoption in cases where revealed WTP is less than the cost of production, which appears to be true in our case.

The rest of the paper is organized as follows. Section 2 describes the context, data and experimental design. Section 3 presents the conceptual framework, which motivates our empirical strategy. Section 4 describes the variables of interest and the empirical strategy. Section 5 presents results from our stove purchase experiments, tobit regressions, and key robustness checks. Finally, Section 6 concludes the paper.

2 Context, Data and Experimental Design

2.1 *Context*

The survey and experiment were conducted in the Tigrai region of Ethiopia in July 2013. The Tigrai region, located in the North of the country, comprises the three main agro-ecological zones of the country, "Dega", "Woynadega" and "Kola". It is also a region where households have differing access to fuelwood, some with relatively high access, others with low access. Households in the areas with low access to fuelwood have to travel on average 30 km/day to collect fuelwood, while those in high-access areas travel only 6 km/day. Having such a variation in climate and forest conditions provides a favorable opportunity for the improved stove purchase experiment, because the demand for an improved stove may vary depending on weather and access to fuelwood.

Improved stoves have been introduced in Ethiopia in general and in the Tigrai region in particular since the 1980s. Different government and non-government institutions have been involved in the development and dissemination of several types of biomass cookstove technologies (Gebreegziabher et al., 2006). However, the efforts made by these institutions to disseminate the various types of improved stoves have not been very successful, partly due to technical problems related to the stoves themselves (some of the stoves were not really improved or were poor quality) and partly due to negative perceptions by households (Plan and Finance, 2011). Unlike the old generation of improved stoves that were used in previous programs, the new stoves, known as "mirte" stoves, have quality control assurance during the manufacturing process, and use energy more efficiently with better combustion (Gebreegziabher et al., 2006; Plan and Finance, 2011). Because of its superior technical design, the "mirte" stove reduces fuelwood consumption by 50%, protects the cook from flames, and reduces smoke and indoor air pollution significantly. However, even with such improvements in efficiency and quality, the adoption rate of the stove is disappointingly low. For example, in the Tigrai regional state, take-up of the stove is less than 1% (Plan and Finance, 2011).

2.2 *Data collection*

Baseline and follow-up surveys were conducted in 12 randomly selected villages (kushets) in the region representing the major weather and forest conditions. For the baseline survey, conducted during July-October 2013, a total of 600 sample households were randomly selected from these villages (i.e., 50 households from each village). A total of 300 households were used for the stove purchase experiment; in the current study, we focus on these 300 households, which are located in the six villages (Adiagam, Adidemishash, Adielmela, Adimoknney, Menkere, and Garasa 1) where the new generation of improved stove had not been introduced. The remaining 300 households were selected from six other villages which received the improved stove for free. These households will be used to assess the impact of the stoves in a separate study.

We conducted the baseline survey two weeks before the stove purchase experiment and free distribution of the improved stoves. In these villages, after short introductions about the study by village cadres and enumerators, both husbands and wives were asked if they were willing to be interviewed. If both agreed, the village cadre left and the interview began. Both spouses in all households were available and volunteered to be interviewed. We conducted the survey with one village at a time, i.e., all the 15 enumerators we hired interviewed all 50 subjects in all villages, except in two of the free distribution villages, where 48 and 49 households were interviewed. In the survey, households were asked about fuelwood collection and use, cooking practices, awareness about the adverse consequences of cooking with traditional stoves, awareness about improved cookstoves, household decision-making power, and other socioeconomic variables. About 15 months after the baseline survey, we conducted a follow-up survey of all households that participated in the baseline survey. In addition to most of the information collected during the baseline, we collected detailed information on stove use and experience in the follow-up survey.

2.3 *Experimental Procedure*

In the villages where the stove purchase experiment was conducted, 10 husbands, 10 wives and 30 joint couples from each village were randomly recruited to participate in the experiment. We informed the subjects that they were randomly selected to come to the farmers' training center on a specified date for two to four hours of compensated physical work (weeding) and for two more hours to participate in a study. In order to avoid information spread, pre-experiment spousal influence and self-selection in attending the experiment, no information was provided about the stove purchase experiment prior to arriving at the farmers' training center. All those randomly selected were willing to come and participate in the physical work and the experiment. The physical work was introduced to ensure that subjects would buy the improved stove using income earned from this work. Conducting an experiment with real labor income offers the advantage of observing the

extent to which households can commit to purchase decisions using income obtained in exchange for labor. This is important because almost all households in the study area depend on earned income (mainly agricultural income). Our aim was to make the experiment as realistic as possible and reduce the risk that subjects might treat windfall income and earned income differently in the decision to buy the stove. This is in line with the theory of mental accounting, which stipulates that consumers tend to arrange expenditures into separate mental accounts and how the money is spent depends on how it is acquired (Clingingsmith, 2015; Hoffman, 2009; Thaler, 1990). These studies document that subjects are likely to share less from an earned dollar than from a windfall dollar. Christiaensen and Pan (2012) found that farmers in China and Tanzania tend to spend earned and unearned income differently, the former on necessity goods/services and the latter on alcohol and other luxury items. Our subjects made their purchase decisions using earned income.

In cooperation with the administrators of the farmers training centers, as well as village leaders and village cadres who were involved in the baseline survey, we organized farmers to arrive at the place of the experiment at different times. Husbands and wives who were invited to come alone arrived at 8:00 a.m. and couples arrived at 10:00 a.m. We had 100% show up on time because, two weeks before the experiment, village leaders and village cadres reminded the subjects that, if they arrived late, they would be excluded from the list of those who would participate in the compensated work. Upon arrival, the husbands and wives who came alone were told to weed for four hours per person in the center plots and stay for two more hours for the study, while the couples were required to weed for two hours per person and stay for two more hours for the study. It was required that both partners work for these hours.[5] They were also informed that, at the end of the study, remuneration would be paid in proportion to the time spent on the weeding task. A husband/wife who worked alone for four hours would earn ETB 150 (USD 7.5)[6] and a couple who worked together for two hours would also earn ETB 150. Subjects were also informed that it was not possible to choose only one of the two activities (either weeding or participating in the experiment). No payment would be offered if they did not participate in both activities. All subjects agreed to these terms and participated in both activities.

After completing the weeding task, we gathered all the subjects in one place and gave them a demonstration of the attributes of the new improved stove. In the demonstration, the experimenter explained the fuel saving, smoke reduction, time saving, life span and other attributes of the stove. The same demonstrator was used in all villages to avoid the effect of the demonstrator. Once the demonstration was done, we divided the subjects into five treatment groups and placed them in separate places that were far apart. The groups were: a group of wives who were invited alone and

[5]Lunch and other refreshments were provided to all subjects and the survey team between the manual work and the experimental sessions.

[6]At the time of the experiment, 1 ETB = 0.05 USD.

would make the stove purchase decision alone using the income they had earned individually; a group of husbands who were invited alone and would make the stove purchase decision alone using the income they had earned individually; a group of wives who were invited with their husbands and would make the stove purchase decision alone using the income the couple had earned; a group of husbands who were invited with their wives and would make the stove purchase decision alone using the income the couple had earned; and a group of couples who would make the stove purchase decision jointly using the income the couple had earned.

Figure 1 presents a summary of the groups and number of subjects in each group. As explained above, we had subjects who made decisions individually using individually earned income, while others decided individually using jointly earned income. We introduce this design to investigate to what extent husbands and wives treat individually earned income and "household" or "joint" income differently in the purchase decisions. With this approach, we can test the hypothesis in the intra-household literature that women in developing countries have limited access to household income to make material purchases for themselves and their children (Kishor and Subaiya, 2008; Miller and Mobarak, 2013; Orfei, 2012).

Figure 1 about here

In each of these five groups, we asked the subjects to make the purchase decision based on the Becker-DeGroot-Marschak (BDM) random price mechanism. This method has been used in other contexts, for example to elicit WTP for mosquito bed nets (Hoffman, 2009), for tender beef steak (Lusk et al., 2001), and for solar lanterns (Alem and Dugoua, 2017). The mechanism works as follows: participants were asked to bid a price for an improved stove by stating their maximum willingness to pay. Subjects were given a color copy of currency notes representing actual currency and an envelope in which to place the maximum amount they were willing to pay for the stove. At the end, all five groups were gathered in one place and a random price was selected from a bucket containing the following prices: 30, 45, 60, 75, 90,105, 120, 135 and 150. The prices were unknown to the participants. Those who bid at or above the randomly drawn price would purchase the item at the price drawn, and those who bid below the price would not be allowed to purchase the stove. Under this procedure, it would be in the best interest of the participants to bid according to their actual valuation of the improved stove. In order to make the information flow consistent, one experimenter explained the mechanism of the BDM for all groups in all villages. Before the actual bidding for the improved stove, we conducted several practice sessions using the purchase of pencils until all subjects understood the game. To make the bids for the stove as confidential as possible, subjects were placed as far apart as possible and instructed to keep their bids confidential. If they had questions, we asked them to raise their hands and the experimenter would give answers privately. They were told that, at the end, all groups would be gathered in one place and each

subject would pick a random price from a bucket containing the prices set between 30 - 150 ETB.

3 Conceptual Framework

This section develops a framework to model willingness to pay for a household durable, taking into account differences in preferences and intra-household bargaining power between wives and husbands, and derives some testable predictions. We follow Anderson and Baland (2002) and model a household comprising two members who are involved in decision-making (i.e., spouses), $i \in w, h$, a wife and a husband. Both members consume a private good c and a household durable S. There is a difference in preference and consequently in WTP for the household durable (S), the improved cookstove in this case. In the context of most developing countries and as supported by the descriptive statistics we present in the next section, improved cookstoves benefit women more than men because both cooking and fuelwood collection are women's tasks.

For simplicity, consider a one-period utility maximization problem with two goods. The utility of the wife is given by

$$U^w = u(c) + \gamma S, \tag{1}$$

where c represents household consumption of private goods, u(.) is increasing and concave, and $S = 1$ when the household durable is purchased, and zero otherwise.[7] The utility of the husband, on the other hand, is given by

$$U^h = u(c) + \eta S, \tag{2}$$

where $\eta < \gamma$, i.e., the husband gets a lower level of utility than the wife from the improved cookstove and, consequently, he is willing to pay less for it.

The purchase decision or WTP is therefore a utility maximization decision subject to budget constraints. The individual (the wife or the husband) decides whether to pay the retail price (p) if

$$WTP \geq p. \tag{3}$$

Prediction 1: Because the improved stove benefits women directly (and children indirectly) more than men, wives would be willing to pay more for the stove than would husbands.

It is however important to note that autonomy in decision-making may be confounded in the revealed WTP. Let WTP_w and WTP_h be observed willingness to pay of wives and husbands

[7] It is plausible to assume that the household durable S provides a flow of services for later periods as well (Besley et al., 1994). Relaxing the assumption in this way won't change the predictions of the model.

respectively, i.e., WTP revealed during the experiment. Let WTP_w^* and WTP_h^* represent the latent levels of willingness to pay that are free of direct spousal influence. Consider $(\alpha_w, \alpha_h) \in [0, 1]$ to be the wife's and the husband's decision-making power in the household. A value of 0 represents no power and 1 represents full power in decision making. Thus, $(\alpha_w + \alpha_h) = 1$.

A wife who purchases the stove in the absence of her husband might face a punishment D_w later if the husband does not want to have the stove.[8] Suppose the probability of punishment is given by $1 - \alpha_w$. However, a husband who took part in the stove decision but who decided not to buy would also face a punishment D_h, given the stove would have benefited the wife. Assume the probability of punishment by the wife is given by $1 - \alpha_h$. In the absence of spousal influence, wives and husbands will decide to buy the stove if the net benefits exceed 0, i.e.,

$$WTP_w^* - p \geq 0 \tag{4}$$

and

$$WTP_h^* - p \geq 0 \tag{5}$$

respectively. If the wife's and the husband's preferences match, neither of the spouses will face any punishment even if they have low decision-making power. The probability that the husband likes (approves) the purchase decision of the wife is given by

$$\phi^h(WTP_h^* - p \geq 0) = 1 - \Phi^h(p) \tag{6}$$

where Φ^h and ϕ^h are the cumulative and density probability functions of WTP_h^* respectively, i.e., the husband's latent WTP. Consequently, a wife taking part in the stove purchase experiment will purchase the stove if her expected payoff ≥ 0, i.e.,

$$E[payoff]_w = [(1 - \Phi^h(p))(WTP_w^* - p) + \Phi^h(p)(\alpha_w(WTP_w^* - p) + (1 - \alpha_w)((WTP_w^* - p - D_w)] \geq 0 \tag{7}$$

$$= WTP_w^* - p - (1 - \alpha_w)\Phi^h(p)D_w \geq 0 \tag{8}$$

Using Equations 4 and 8, the revealed WTP of a wife who makes the stove purchase decision in the absence of her husband is given by

[8] The punishments can be expressed in the form of arguments, nagging and yelling. See Ashraf (2009) for punishments couples exercise in a similar setting in rural Philippines.

$$WTP_w = WTP_w^* - (1-\alpha_w)\Phi^h(p)D_w \tag{9}$$

Prediction 2: Equation 9 demonstrates that a wife's revealed and latent WTP will diverge if she has no autonomy in decision-making. In other words, she will reveal WTP that will very likely be accepted by her husband, i.e., his WTP.

The husband who makes the stove purchase decision in the absence of his wife may face punishment, depending on his decision-making power, if he decides not to buy the stove. In this case, the probability that the wife accepts her husband's decision not to buy the stove is given by

$$\phi^w(WTP_w^* - p \leq 0) = \Phi^w(p) \tag{10}$$

where Φ^w and ϕ^w are the cumulative and density probability functions of WTP_w^* respectively, i.e., the wife's latent WTP. The husband will therefore buy the stove if his expected payoff from the purchase is ≥ 0.

$$E[payoff]_h = \Phi^w(p)[WTP_h^* - p] + (1-\Phi^w(p))[\alpha_h(WTP_h^* - p) + (1-\alpha_h)(WTP_h^* - p + D_h)] \geq 0 \tag{11}$$

$$= WTP_h^* - p + (1-\alpha_h)(1-\Phi^w(p))D_h \geq 0 \tag{12}$$

Using Equations 5 and 12, the husband's revealed WTP will therefore be given by

$$WTP_h = WTP_h^* + (1-\alpha_h)(1-\Phi^w(p))D_h. \tag{13}$$

Prediction 3: Equation 13 shows that the revealed WTP of the husband is inversely related to his decision-making power in the household.

If the wife has high decision-making power, the husband's revealed preference will converge to his wife's preference. For the spouses who make the stove purchase decision jointly, the revealed willingness to pay may therefore represent each spouse's latent WTP depending on their bargaining power.

We now describe the experimental and survey data that we use to evaluate theoretical predictions 1-3.

4 Empirical Strategy

4.1 *Variables*

Alternative approaches have been used in the empirical literature to explore the links between decision-making power and various household outcomes. One approach is to use indirect measures of power from survey data, such as an individual member's asset ownership, income share, or education, and link this measure to an observed household outcome. In this approach, a woman/man with a higher share of assets or income in the household is assumed to have greater decision-making power. The most frequent income and asset types used in the literature are unearned income such as transfers (Duflo, 2003; Schultz, 1990; Thomas, 1990), inherited assets (Quisumbing, 1994), assets brought into marriage and current assets (Quisumbing and de la Briere, 2000). The key limitation of this approach is that it does not directly show how individual preferences affect household decisions, because individual and household (joint) preferences are not separately observed, i.e., one cannot tell whether the observed choice of a member is taken at her/his own preference or at the behest of the other spouse.

Another survey-based approach is to use a direct measure of power of members and link it with observed household outcomes. Couples are asked survey questions on whether they have the final say about specific or multidimensional household decisions (Allendorf, 2007; Becker et al., 2006; Chakraborty and De, 2011; Friedberg and Webb, 2006; Mabsout and van Staveren, 2010). In this approach, individual preferences are assumed to be reflected in the observed household choices where the individual has high decision-making power. As discussed in detail below, we use this approach to elicit decision-making power by couples in a household.

The final approach is to use lab-in-the-field experiments and directly estimate the influence of household members on joint decisions (Carlsson et al., 2012,1; De Palma et al., 2011; Yang and Carlsson, 2012). The advantage of this approach is that both individual members' preferences and their joint (household-level) decisions are observed. It is therefore possible to directly estimate the extent to which household (joint) decisions are influenced by individual spouse preferences (decisions). The approach provides useful insights on bargaining power because it reveals both individual and joint choices of the same household, which are difficult to elicit using observational data. Our approach also relies on a novel experimental set-up to elicit individual and joint WTP and their difference.[9]

Outcome Variable

We conduct the stove purchase experiment on randomly selected husbands, wives and joint couples to elicit WTP for the stove, our key outcome variable of interest. As long as the samples

[9]Most recently, Almås et al. (2015) use a novel strategy to identify decision-making power itself using a lab-in-the-field experiment, where they elicit WTP by women for gaining control over household income.

of husbands, wives and joint couples are selected randomly, we can consider their revealed WTP to represent the individual and joint preferences, respectively, of the same household. By comparing individual husband's and wife's preferences with the preferences of couples, we can infer the extent of spousal influence on joint decisions. We then control for the direct measure of decision-making power in a regression to shed light on its link with WTP for the improved stove. Below, we explain how the decision-making autonomy variable - our key explanatory variable of interest - has been constructed.

Explanatory Variable of Interest

Taking the patriarchal nature of the society into account, we use the term "autocratic" if the husband makes the decisions regarding the wife's personal expenditures on his own, "moderate" if he makes the decisions with his wife and "non-autocratic" if he lets his wife decide on her own. Conversely, a wife has "high autonomy" if she can make the decision on her own, "moderate autonomy" if she makes the decision with her husband and "low autonomy" if her husband makes the decision.

Our measure of autonomy (or autocracy) is a continuous variable based on the response of husbands and wives to separate survey questions about decisions regarding the wife's personal expenditures (e.g., purchase of clothes and shoes). For robustness checks, we also ask questions on decisions regarding the purchase of household durables. For each of these two decision categories, we assign a value of 1 when the wife reports she has full autonomy to decide (i.e., the husband is non-autocratic), 2 when she reports both make the decision (the husband is moderately autocratic), and 3 when she reports her husband makes the decision (the husband is autocratic). These two decisions are important in this particular context for two reasons: the stove is generally a durable household item, but husbands and wives may treat it as a good that disproportionately benefits the wife.

4.2 *Regression Model*

In the BDM experiment, we ask subjects to bid for the improved cookstove using the money they earned from the manual work. Because the BDM design is incentive compatible, subjects are expected to reveal their true preferences through their maximum WTP for the cookstove. However, their WTP may be bounded by the amount of money they earn from the manual work, which was set at 150 ETB. Our key empirical model is therefore a tobit model, which considers the censored nature of the data. The model is briefly presented as follows:

$$WTP_i^* = \boldsymbol{d}_i\boldsymbol{\beta} + \boldsymbol{x}_i\boldsymbol{\gamma} + u_i \tag{14}$$

where $i = 1, ..., N; \boldsymbol{d}_i$ is a $1 \times p$ vector of our key explanatory variable of interest - decision making autonomy or autocracy; $\boldsymbol{x}_i$ is a $1 \times k_1$ vector of other control variables; $\boldsymbol{\beta}$ and $\boldsymbol{\gamma}$ are vectors of parameters of interest, and u_i is a random error term. WTP_i^* is not observable to the researcher; instead the researcher observes

$$WTP_i = \begin{cases} a & WTP_i^* < a \\ WTP_i^* & a \leq WTP_i^* \leq b \\ b & WTP_i^* > b \end{cases} \tag{15}$$

In order to take account of all the information in the dependent variable, WTP_i one should fit the model with the tobit estimator, which uses the maximum likelihood framework. The regression can be estimated in standard packages such as STATA using the *tobit* command, which also allows marginal effects to be computed in a straightforward manner.

5 Results

5.1 *Baseline Characteristics*

Table 1 presents summary statistics from the baseline survey both at the spouse level and the household levels. First, means and standard deviations are reported in Columns 1 (Wives) and 2 (Husbands). Column 3 presents statistical tests on mean differences between the two samples. From Panel A, wives on average are almost 3 years younger, and have less political participation (27%) and involvement in off-farm work (30%), while about 56% of husbands report political participation, and 68% are involved in off-farm work. Fuelwood collection seems to be predominantly the wives' task, with about 82% of wives involved in collection, while only 27% of husbands are involved in fuelwood collection. From Panel B, we observe that, on average, households spend about 0.44 hours in collecting 1 kg of fuelwood, and spend a total of about 48.8 hours to collect fuelwood every month. Households in the study area on average collect about 234.4 kg of fuelwood per month. These descriptive statistics reveal the significant reliance of rural households on biomass fuelwood and the substantial burden that women in developing countries carry to meet the cooking needs of the household.

Table 1 about here

Table 2 shows descriptive statistics on decision-making autonomy of wives in purchase of their own material items. We can see that about 47% of wives perceived themselves as having a low level of autonomy to make decisions regarding purchases of their own material items. On the other hand, around 45.5% of husbands consistently perceived their dominance (autocracy) in purchase decisions

of their wife's material items, i.e., they make the final decision on purchase of their wife's material items. Table A.1 in the appendix presents descriptive statistics on autonomy in decision-making regarding purchase of household durables, showing dominance of husbands in decision-making. These descriptive statistics imply that women in the study area lack autonomy in decision-making and support the hypothesis that the men are usually the default heads of households who control the households' cash accounts. Overall, the gender-specific summary statistics presented are in line with existing evidence in developing countries on gender differences (e.g., Anderson and Baland, 2002; Hoddinott and Haddad, 1995; Miller and Mobarak, 2013; Pitt and Khandker, 1998). Women work more at home and less for wage income, have low political participation, and lack autonomy regarding major household decisions.

Table 2 about here

5.2 *Experimental Results*

Mean WTP by wives, husbands and couples during purchase decisions conducted individually and jointly are reported in Table 3. Results show that wives who make the purchase decision individually are generally willing to pay ETB 35.67 (60%) more than husbands who make the decision individually. This difference is statistically significant at the one percent level in a two-sample comparison t-test. Wives who make the stove purchase decision individually are also willing to pay ETB 27.33 (40%) more than wives who make the decision with their husbands. Husbands who make the purchase decision jointly with their wives are willing to pay ETB 8.33 (14%) more than husbands who made the decision individually. However, this difference is not statistically significant at conventional levels. These results provide the first evidence in support of *prediction* 1. There is strong preference difference between wives and husbands (wives willing to pay substantially more than husbands) for the improved cookstove and a clear spousal influence in household-level decisions.

Table 3 about here

We further explore the difference in WTP between wives and husbands by taking into account the difference in intra-household decision making power of wives. Table 4 presents mean comparison tests between the sample of wives, husbands, and couples depending on wives' decision-making power on purchase of their material items. Results in Panel A suggest that wives who have high autonomy and make the stove purchase decision individually are willing to pay ETB 141.43, while those with low autonomy who make the stove purchase decision individually are willing to pay only ETB 61.44. This translates into about 130% more WTP by autonomous wives. WTP for the stove declines by only 14% when autonomous wives make the stove purchase decision jointly with their husbands. However, for wives with a low level of autonomy, WTP declines by about 35% when they make the stove purchase decision jointly with their husbands. These findings provide a

clear support for *prediction* 2 that a wife reveals low WTP for the improved stove if she has low decision-making autonomy.

Panel B of Table 4 presents WTP of husbands based on their level of autocracy. Results reveal that there is no statistically significant difference in WTP between husbands who make the stove purchase decision individually and those who make the decision jointly. Providing supportive evidence for *prediction* 3, on average, husbands who are autocratic regarding the purchase of their wife's material items are willing to pay ETB 45.89, only around one-third of the full cost of the improved stove (ETB 150) when making the stove purchase decision individually. Non-autocratic husbands on the other hand are willing to pay on average ETB 106.67, which translates into 132% more than autocratic husbands. Taken together, the results provide suggestive evidence on the possible role of women's decision-making autonomy in adoption decisions of important household technologies, such as improved cookstoves.

Table 4 about here

Does empowering women improve their decision-making power within the household? In order to shed light on this question, we let randomly selected wives, husbands and couples work for cash to earn money and participate in the stove purchase experiment. We let both wives and husbands decide on the use of both individually and jointly earned income from the work. An important innovation of our experiment is that we assigned randomly selected wives and husbands in the sample of couples and allowed them to make a purchase decision individually using the money the couples jointly earned. This treatment allows us to determine to what extent wives feel empowered to make the purchase decision using the household's resources.

Experimental results for this set of the BDM game presented in Table 5 provide useful insights. Wives who are fully entitled to earnings (they work and earn individually and make the stove purchase decision individually) are willing to pay 20.04 Birr or 25% more than wives who use household (joint) income from the experiment. The difference is statistically significant at the one percent level. This clearly indicates that many wives lack the autonomy to make a purchase decision - even on a durable item, such as improved stoves that benefit the entire household - using the household's resources. Husbands who make the stove purchase decision individually using the joint income earned from the manual work are also willing to pay 6.04 Birr or 10% more than husbands who make the purchase decision using individually earned income. However this effect is not statistically significant at conventional levels. It is therefore safe to conclude that there is no significant difference in husbands' willingness to pay between individual and household (joint) earnings. Husbands do not seem to differentiate between these two income sources. The results of this part of the experiment have important implications on the role of empowering women in improving their decision-making power within the household.

Table 5 about here

5.3 *Econometric Results*

In this section, we investigate the causal impact of our treatments on willingness-to-pay for the improved stoves. We also explore the relationship between the reported decision-making power of spouses and WTP by wives, husbands and couples. Given that we asked subjects to bid for the stoves using the money they earned from the manual work, their WTP may be bounded at 150 ETB, the amount they earned. We therefore estimate our regression for WTP using a tobit estimator. Marginal effects from tobit regression results are reported in Table 6. Column [1] reports marginal effects from a WTP regression by the wives sample and Column [2], by the husbands sample. The variable Autonomy/Autocracy in Column [1] measures the wife's reported level of autonomy in making decisions regarding purchase of her material items. In Column [2], the variable captures reported autocracy of husbands in purchase of the wife's own material items. Column [3] reports WTP by the pooled sample, in which the gender of the participant is interacted with autocracy of husbands and with our treatments, i.e., whether the stove purchase decision was made individually and whether it was made using individually earned income. In all regressions, we control for individual characteristics, household characteristics and village fixed effects.

Results in Column [1] suggest that wives' autonomy in decision-making when purchasing their material items has a strong positive correlation with their willingness to pay for the improved stove.[10] This effect is statistically significant at the one percent level. Consistent with the descriptive results presented in the preceding sub-section, compared to wives who make the stove purchase decision together with their husbands, wives who make the purchase decision individually are willing to pay about 16.50 ETB more for the stove. This implies 24% more, as the average WTP of wives who made the stove purchase decision jointly with their husbands is about 68.83 ETB. The results also reveal that wives who participated in the manual work individually and made the stove purchase decision individually are also willing pay 10.90 birr (20%) more than those who earned the money together with their husbands but made the stove purchase decision individually using the income the couple earned. Given that these treatments were assigned randomly, it is possible to infer a causal relationship between them and WTP for the improved cookstove, a representative household durable that benefits all household members.

Results in Column [2] of table 6 on the other hand show how WTP for the improved stove declines with autocracy in household decision-making by husbands. Moving from being a non-autocrat to moderately autocrat husband in decisions for the purchase of the wife's personal items reduces WTP for the stove by about 26.64 birr. The coefficient is statistically significant at the one

[10] Because the reported level of decision-making autonomy/autocracy by wives and husbands respectively is likely to be endogenous, we refrain from making a causal statement on WTP.

percent level. The reported marginal effects also suggest that both husbands who were randomly assigned to earn alone and make the stove purchase decision alone, and those who were assigned to make the stove purchase decision individually using the money the couple earned, are willing to pay less for the stove. However, neither of these effects are statistically significant at conventional levels.

Results from the pooled sample with interactions of the key variables of interest, reported in Column [3] of table 6, also confirm the findings in Columns [1] and [2]: autonomous wives are willing to pay more than non-autonomous wives; wives who make the stove purchase decision individually are willing to pay more than wives who make the decision together with their husbands; wives who made the stove purchase decision using individually earned income are willing to pay more than wives who made the stove purchase decision using the money the couple earned; autocratic husbands are willing to pay less than non-autocratic husbands; husbands who made the stove purchase decision individually are willing to pay less than husbands who make the stove purchase decision together with their wives; and husbands who made the stove purchase decision using individually earned income are willing to pay less than husbands who made the stove purchase decision using money earned by the couple.

The regression results, together with the mean comparison tests presented in the preceding subsection, have significant implications for adoption and diffusion of improved household technologies and empowerment of women in developing countries. First, the consistent finding that wives are willing to pay more than husbands for the improved cookstove clearly indicates that intra-household differences in division of labor and decision-making power should be taken into account while promoting improved cookstoves. This implies that the conventional approach of communicating with household heads - who are men by default - in cookstove technology campaigns won't result in socially optimal outcomes. Second and most importantly, decision-making autonomy matters and women lack the autonomy to make the decision that maximizes their (and possibly children's) welfare. Thus, providing them with income earning opportunities, such as the public work we created for this project, will very likely empower them.

Table 6 about here

5.4 *Robustness Checks*

We investigate robustness of our results using alternative definitions of intra-household bargaining power and alternative regressions. First, we re-construct the decision-making power (autonomy/autocracy) variable using the response to the question regarding decision-making on purchase of household durables. Following the definition of the autonomy variable in decision-making on the wife's material items, we construct the autonomy variable in decision-making on household

durables as a continuous variable, where 3 stands for complete autocracy by husbands and 1 for non-autocracy (i.e., the wife autonomously makes the decision). Table B.1 in the appendix shows that 49.5% of wives lack the autonomy to decide on household durables and only 26% feel that they have complete autonomy to make such decisions. These descriptive statistics are quite similar to the descriptive statistics on autonomy of wives in purchase of their own material items presented in Table 2.

We then investigate WTP for improved stoves based on the level of decision-making power on purchase of household durables. Mean WTP comparison results presented in Table B.2 (Panel A) in the appendix suggest that wives who have high autonomy and make the stove purchase decision individually are willing to pay more than twice what autocratic husbands who make the stove purchase decision individually (Panel B) are willing to pay. The results in the joint purchase decision of improved stoves are also similar to the results we found using wives' decision-making power on purchase of their own material items. Wives who have more autonomy in decision-making for household durables are significantly willing to pay more than wives who lack autonomy.

Second, we re-estimate the tobit regression using decision making autonomy for household durables. Tables B.3 in the appendix presents the regression results. The results are consistent with the ones we documented in the preceding section: wives who are autonomous in making decisions regarding purchase of household durables are willing to pay much more than husbands who are autocratic, and wives who make the stove purchase decision individually are willing to pay more than those who make the stove purchase decision together with their husbands.

Finally, we investigate whether decision-making power determines how quickly the improved stove is put in use. We conducted a follow-up survey on the households who participated in the stove purchase experiment 15 months after the stoves were acquired. We collected detailed information on stove use, fuelwood collection, fuelwood consumption and time allocation. Table B.4 in the appendix reports OLS regression results on the correlates of stove use measured by the number of months since the stove was put to use. Results suggest that neither decision-making power nor the treatments have any impact on how quickly the stove is put to use once the household acquires it. This supports our hypothesis that decision-making power, rather than inability to understand the stove's benefits, is the most important factor that hinders wives from purchasing the stove. Table B.4 also provides other useful insights on the correlates of the improved stove use. For example, better-educated households and those with a large number of windows are very likely to have used the stove for a longer period of time, while those with larger number of adult females are less likely.

6 Conclusions

This paper uses a field experiment to analyze the effects of differences in preferences and intra-household decision-making power on willingness to pay for a new household durable. The experiment was conducted using randomly recruited wives, husbands and couples from the Tigray region of Ethiopia. We invited subjects to participate in a public works project in order to earn income, which they were given the option to spend on the purchase of improved cookstoves. The stoves are a new generation of improved stoves called the "mirte stove" and have been proven to reduce fuel consumption by 50% and indoor air pollution by about 90%. Thus, they have a large potential for improving the wellbeing of all members of the household, but most importantly that of women and children. Our experimental design and empirical strategy therefore allow us to tease out the role of both preference difference and decision-making power between women and men within the household, which is the key contribution of our paper.

We find strong evidence that differences in both preferences and intra-household bargaining power drive WTP for the improved cookstove. Wives who make the stove purchase decision individually in general are willing to pay 60% more for the improved stove than are husbands who make the decision individually. Wives who make the decision individually are willing to pay 40% more than those who make the decision together with their husbands. We also find that wives who are randomly chosen to make the stove decision individually using the income the couples earned are willing to pay much less than wives who make the decision using the money they earned alone. We don't find a statistically significant difference between husbands who make the decision individually and jointly. Wives who have high autonomy in decisions regarding the purchase of their own material items are willing to pay more than twice that of husbands who are autocratic (one who does not allow his wife to decide on purchase of her own material items). A follow-up survey conducted 15 months after the stoves were offered shows that decision-making power does not have any impact on how quickly the improved stove is put to use. This supports our hypothesis that, if wives do not purchase the stove, it is very likely because of lack of autonomy rather than lack of interest in the stove. Our results remain robust to alternative definitions of decision-making power and alternative specifications.

The results here suggest that preference differences, mainly driven by division of labor in the household and women's lack of decision-making power, have significant impacts on investment decisions on household durables that benefit all members of the household. Our results are consistent with previous studies (Anderson and Baland, 2002; Miller and Mobarak, 2013; Schaner, 2015) conducted in different set-ups and show that preference differences by couples lead to sub-optimal household decisions. Our results have policy implications that extend to many other technologies that can provide benefit to the entire household and improve welfare in poor communities. Very

often, policymakers and other stakeholders, such as NGOs, face constraints on how to optimally distribute modern technologies. Our findings indicate that adoption can be increased significantly if the existing differences in division of labor and decision-making power within the household are taken into consideration. While empowering women is a long-term and relatively complex development outcome, the results suggest that simple and easy-to-design income-generating opportunities entitle women to their own earnings, improve their decision-making power and benefit women themselves and other vulnerable household members, such as children.

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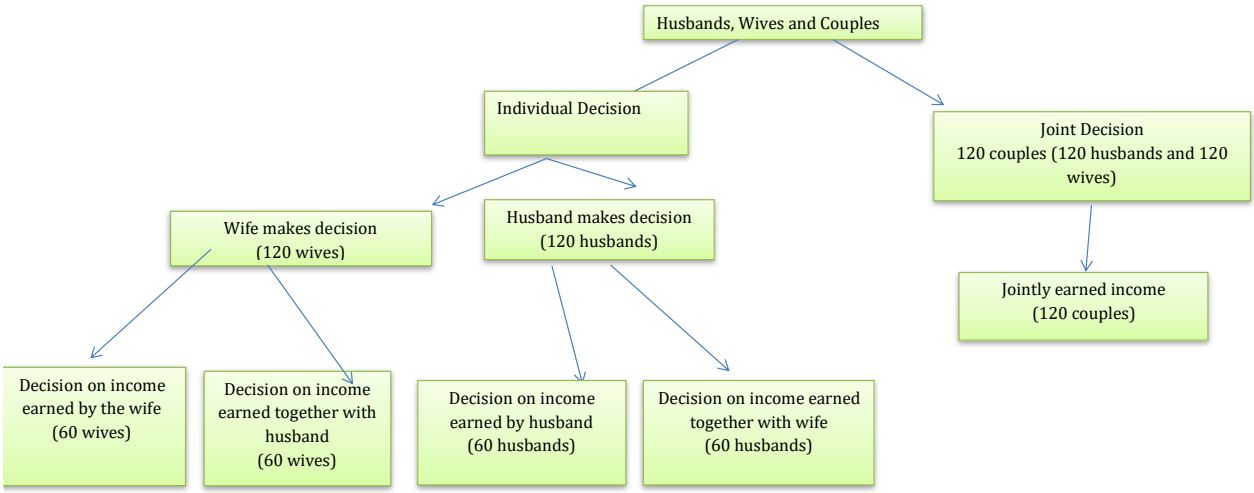

Fig 1: Diagram of Experimental Design

Table 1: Descriptive Statistics at Baseline

	[Wives]		[Husbands]		[Mean Diff.]	
	Mean	SD	Mean	SD	Diff.	SE
Panel A:Individual Characteristics						
Age	45.16	12.96	48.14	13.41	-2.98**	1.39
Years of schooling	1.61	1.68	1.34	2.19	0.27	0.21
Member of the ruling party (1=yes, 0=no)	0.27	0.45	0.56	0.50	-0.28***	0.05
Participates in fuelwood collection (1=yes, 0=no)	0.82	0.38	0.27	0.45	0.55***	0.04
Time spent on fuelwood collection/month (in hours)	32.50	27.88	1.48	2.97	31.03***	2.09
Off-farm income activities (1=yes, 0=no)	0.30	0.46	0.68	0.47	-0.38***	0.05
Indiv. stove purchase decision (1=yes, 0=no)	120		120			
Joint stove purchase decision (1=yes, 0=no)	60		60	60		
Indiv. stove purchase decision - indiv. income (1=yes, 0=no)	60		60	60		
Indiv. stove purchase decision - joint income (1=yes, 0=no)	60		60	60		
Observations	180		180		360	
Panel B: Household Characteristics						
Mean hours spent in collecting 1 kg of fuelwood (shadow price)	0.44	0.43				
Household monthly time spent in fuelwood collection (in hours)	48.81	41.73				
Household monthly fuelwood collection (in kg)	234.40	181.78				
Household livestock ownership (TLU)	4.93	4.12				
Household wealth in 1000 Ethiopian Birr	34.96	39.26				
Household land size (in Timad)	3.05	2.21				
Number of trees the household owns	12.04	33.47				
Number of adult males (age >15)	0.63	0.98				
Number of adult females (age >15)	0.64	0.97				
Number of male youth (age 7-15)	0.69	0.97				
Number of female youth (age 7-15)	0.94	1.10				
Number of children (age < 7)	0.86	0.99				
Household size	5.76	1.77				
Owns a separate kitchen (1=yes, 0=no)	0.51	0.50				
Observations	300					

Notes: Columns [1] & [2] of panel A of this table presents summary statistics from the experimental sample collected before the experiment and in individual surveys conducted separately with husbands and wives based on their own reports. Column [3] reports statistical test results on mean differences between the two samples. Panel B of the table reports household-level summary statistics from the experimental sample prior to the experiment. ***, ** and * denote significance at the 1, 5 and 10% levels, respectively.

Table 2: Decision-making autonomy (autocracy)

Panel A: Wives		
Wives' autonomy in purchase of own material items	Freq.	Percent
Low level of autonomy	85	47.22
Moderate level of autonomy	45	25.00
High level of autonomy	50	27.78
Total	180	100.00
Panel B: Husbands		
Husbands' autocracy in purchase of wives' material items		
High dominance (autocrat)	82	45.56
Moderate	62	34.44
Low dominance (non-autocrat)	36	20.00
Total	180	100.00

Notes: Panel A of this table shows descriptive statistics on reported decision-making autotomy of wives in purchase of their own material items collected before the experiment. Panel B shows descriptive statistics on reported autocracy of husbands on purchase of wife's material items survey data collected before the experiment.

Table 3: WTP: wives, husbands, and couples in individual and joint decisions

	[1]		[2]		[3]	
	[Wives]		[Husbands]		[Mean Diff.]	
Decision type	Mean	SD(SE)	Mean	SD(SE)	Mean	(SE)
Individual decision	96.17	40.72	60.5	34.77	35.67***	(4.89)
Joint decision	68.83	43.66	68.83	43.66		
Mean difference	27.33***	(6.59)	-8.33	(6.00)		
Observations	180		180	360		

Notes: Column [1] of this table shows mean WTP of wives when they earn and make stove purchase decision individually and jointly with their husbands, and a formal statistical test of mean differences between the two. Column [2] shows mean WTP of husbands when they earn and make stove purchase decision individually and jointly with their wives, and a formal statistical test of mean differences between the two. Column [3] reports statistical test results on mean differences between WTP of wives and husbands under individual purchase decision. ***, ** and * denote significance at the 1, 5 and 10% levels, respectively.

Table 4: Autonomy (autocracy) in decision-making and WTP by wives and husbands

	[1]		[2]		[3]	
	[Indiv.]		[Joint]		[Diff.]	
	Mean	SD(SE)	Mean	SD(SE)	Diff,	SD(SE)
Panel A: Wives						
Low level of autonomy	61.44	20.24	40.00	10.68	21.44***	(4.21)
Moderate level of autonomy	114.04	23.83	66.32	40.03	47.72***	(9.55)
High level of autonomy	141.43	15.56	122.00	34.48	19.43**	(7.02)
Mean diff: low and high autonomy	-79.99***	(3.98)	-82.00***	(7.25)		
Mean diff: low and moderate autonomy	-52.60***	(5.03)	-26.32**	(8.19)		
Mean diff: moderate and high autonomy	-27.39***	(5.04)	-55.68***	(13.02)		
Observations	120		60		180	
Panel B: Husbands						
Non-autocrat	106.67	23.73	122	34.48	-15.33	9.68
Moderate	56.98	32.39	66.32	40.03	-9.33	9.60
Autocrat	45.89	23.86	40.00	10.68	5.89	4.90
Mean diff: non-autocrat and autocrat	60.77***	(6.1)	82***	(7.25)		
Mean diff: non-autocrat and moderate	49.69***	(7.95)	55.68***	(13.02)		
Mean diff: moderate and autocrat	11.08*	(5.65)	26.32***	(8.19)		
Observations	120		60		180	

Notes: Panel A of this table shows WTP of wives for the improved stove based on their level of autonomy regarding purchase of their material items, during individual and joint stove purchase decisions respectively, and a formal statistical test of mean differences between the two. Panel B shows WTP of husbands based on their level of autocracy regarding purchase of wives' material items during individual and joint decisions respectively, and a formal statistical test of mean differences between the two. ***, ** and * denote significance at the 1, 5 and 10% levels, respectively.

Table 5: Mean WTP of wives and husbands using individual or joint income

	[1]		[2]		[3]	
	[Wives]		[Husbands]		[Mean Diff.]	
Income type	Mean	SD(SE)	Mean	SD(SE)	Mean	SD
Individual earning	100.42**	38.38	59.25	35.62	41.17***	(6.76)
Joint earning	80.38	44.60	65.29	39.20	15.08**	(5.42)
Mean Difference	20.04**	(6.74)	6.04	(6.02)		
Observations	180		180			360

Notes: Column [1] of this table shows mean WTP of wives when they make the stove purchase decision using income earned individually and jointly respectively and a formal statistical test of the difference between the two. Column [2] shows mean WTP of husbands when they make the stove purchase decision using income earned individually and jointly respectively and a formal statistical test of the difference between the two. Column [3] reports statistical test results on mean differences between WTP of wives and husbands using individually and jointly earned income. ***, ** and * denote significance at the 1, 5 and 10% levels, respectively.

Table 6: Decision-making autonomy and WTP for improved stoves

	[1]		[2]		[3]	
	[Wives]		[Husbands]		[Pooled]	
	Coeff.	SE	Coeff.	SE	Coeff.	SE
Autonomy/Autocracy	27.208***	1.881	-26.639***	2.778	29.820***	2.054
Individual decision	16.498***	3.125	-4.127	4.287	17.431***	3.755
Earned individually	8.956***	3.300	-1.873	4.267	8.888**	3.886
Husband					-4.345	4.933
Autocracy*Husband					-54.807***	2.998
Individual decision*Husband					-22.087***	5.251
Earned individually*Husband					-9.937*	5.351
Controls	Yes		Yes		Yes	
Village fixed effects	Yes		Yes		Yes	
Observations	180		180		360	

Notes: Columns [1]-[3] show marginal effects from tobit regressions for wives only, husbands only and pooled samples respectively of WTP for improved cookstoves. ***, ** and * denote significance at the 1, 5 and 10% levels, respectively.

Decision-making within the Household: The Role of Autonomy and Differences in Preferences

Supporting Information for Online Publication *

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1 Appendix A: Photo of the Improved Cookstove

Pic.pdf

2 Appendix B: Robustness Checks

Table B.1: Decision-making autonomy (autocracy)

Panel A: Wives		
Wives' autonomy in purchase durables	Freq.	Percent
Low level of autonomy	89	49.45
Moderate level of autonomy	44	24.44
High level of autonomy	47	26.11
Total	180	100.00
Panel B: Husbands		
Husbands' autocracy in purchase of durables		
High dominance (autocrat)	91	50.56
Moderate	52	28.89
Low dominance (non-autocrat)	37	20.55
Total	180	100.00

Notes: Panel A of this table shows descriptive statistics on reported decision-making autotomy of wives in purchase of household durables collected before the experiment. Panel B shows descriptive statistics on reported autocracy of husbands on purchase of household durables collected before the experiment.

Table B.2: Autonomy (autocracy) in decision-making and WTP by wives and husbands

	[1]		[2]		[3]	
	[Indiv.]		[Joint]		[Diff.]	
	Mean	SD(SE)	Mean	SD(SE)	Diff,	SD(SE)
Panel A: Wives						
Low level of autonomy	66.83	28.61	40.00	10.68	26.83***	(5.79)
Moderate level of autonomy	115.96	25.30	63.89	39.73	52.07***	(9.79)
High level of autonomy	139.19	17.08	121.25	33.44	17.94**	(7.33)
Mean diff: low and high autonomy	-72.37***	(5.58)	-81.25***	(7.04)		
Mean diff: low and moderate autonomy	-49.14***	(6.46)	-23.89***	(8.15)		
Mean diff: moderate and high autonomy	-23.23***	(5.64)	-57.36***	(12.68)		
Observations	120		60		180	
Panel B: Husbands						
Non-autocrat	107.87	24.83	121.25	33.44	-13.87	(9.57)
Moderate	53.09	29.49	63.88	39.73	10.80	(9.71)
Autocrat	49.23	26.97	40.00	10.68	9.23*	(5.47)
Mean diff: non-autocrat and autocrat	58.15***	(6.65)	81.25***	(7.04)		
Mean diff: non-autocrat and moderate	54.29***	(7.22)	57.36***	(12.68)		
Mean diff: moderate and autocrat	3.86	(5.9)	23.89**	(8.15)		
Observations	120		60		180	

Notes: Panel A of this table shows WTP of wives for the improved stove based on their level of autonomy regarding purchase household durables, during individual and joint stove purchase decisions respectively, and a formal statistical test of mean differences between the two. Panel B shows WTP of husbands based on their level of autocracy regarding purchase of household durables during individual and joint decisions respectively, and a formal statistical test of mean differences between the two. ***, ** and * denote significance at the 1, 5 and 10% levels, respectively.

Table B.3: Decision-making power and WTP for improved stoves

[4]	[1]		[2]		[3]	
	[Wives]		[Husbands]		[Pooled]	
	Coeff.	SE	Coeff.	SE	Coeff.	SE
Autonomy/Autocracy	23.898***	2.003	-24.917***	2.563	26.901***	2.117
Individual decision	17.100***	3.414	-1.605	4.302	18.285***	3.917
Earned individually	9.063**	3.568	-2.637	4.258	9.581**	4.028
Husbands					-3.422	5.134
Autocracy*Husbands					-50.462***	3.027
Individual Decision*Husbands					-20.782***	5.484
Earned Individually*Husbands					-11.607**	5.557
Controls	Yes		Yes		Yes	
Village fixed effects	Yes		Yes		Yes	
Observations	180		180		360	

Notes: Columns [1]-[3] show marginal effects from tobit regressions for wives only, husbands only and pooled samples respectively of WTP for improved cookstoves. ***, ** and * denote significance at the 1, 5 and 10% levels, respectively.

Table B.4: Decision-making Power and Stove Use: OLS results

	[1]	
	Coeff.	SE
Wife's autonomy in purchase of her personal items	0.769	0.895
Individual decision	1.497	1.434
Earned individually	0.908	1.875
Age	0.027	0.026
Proportion of time wife allocates for fuelwood collection	0.009	0.587
Number of livestock in tropical livestock units	-0.058	0.093
Wife's years of schooling	0.563*	0.263
Wife participates in off-farm work	0.623	1.296
Number of adult males in the household	0.717	0.427
Number of youth males in the household	0.640	0.561
Number of adult females in the household	-0.534*	0.211
Number of youth females in the household	-0.042	0.297
Number of children in the household	0.866	0.549
Number of windows	0.826**	0.224
Separate kitchen	0.134	0.931
Wealth in birr (value/1000)	0.017	0.011
Household land size	-0.251	0.171
Number of trees	0.034	0.308
Intercept	0.256	1.751
Village fixed effects	Yes	
Observations	180	
R-squared	0.32	

Notes: Column [1] of this table shows OLS regression results on the correlates of stove use 15 months after the stove purchase experiment. Standard errors are clustered at the village level. ***, ** and * denote significance at the 1, 5 and 10% levels, respectively.

Appendix C: Survey and Experimental Instructions

Step 1: Baseline survey

Before we started the survey, the village cadres introduced the enumerators to the subjects to be interviewed. The cadres used general statements that the survey team came from Mekelle University for a study in their village. Following the introduction of the cadres, the enumerators used the following introductory statement in the local language, Tigrigna:

"*Good morning/good afternoon. We are sent by Mekelle University to study the socio-economic conditions of households in Tigrai. Your household and village have been selected randomly to be part of the study. The study involves asking husbands and wives survey questions on their and their households' socio-economic conditions. We will ask questions twice: today and two weeks from today. Today we will ask survey questions at your place for a maximum of 2 hours. It is important that both the husband and the wife participate in today's survey. After completing today's interview, either the husband or the wife, or both, will be randomly selected to further participate in the next phase of the study, which involves participation in paid labor work (weeding) at the farm land of the farmers' training center for a maximum of four hours and two more hours for a similar study. The study we'll conduct in two-week's time demands the randomly selected husband/wife/both to be at the farmers' training center at 7AM/9AM. Are you willing to participate in today's survey?*

[If yes, we begin the survey]

[If no, thank the respondent and ask if we can interview them any time before the next phase of the study.

[If yes, we ask them for a suitable date and time for the interview]

After completing the survey, we made the random draw for the next period of the study and asked the selected husband/wife/both if they are willing to participate in the next period of the study as well.

[If yes, we tell them the time and date that they should arrive at the farmers' training center]

[If no, we ask why he/she/they is/are not willing to participate and replace them with another randomly selected respondent.]

Step 2: Stove Purchase Experiment

Stage 1: Weeding activities and earning income

Upon arrival at the place of the experiment (the farmers' training center), in cooperation with the administrators of the farmers' training center, we informed subjects who were randomly selected to come without their spouse that they would weed for four hours in the center's plots, while those who came with their spouse would each weed for two hours. It was required for both spouses to work for these hours. After completing the weeding activity, we also told them that they would stay for 2 more hours for a study about cooking stoves. At the end of the study, joint spouses would be paid a total of 150 ETB and those who came without their spouse would also be paid ETB150 as compensation for all the time they spent in weeding and in the experiment. We also told them that it was not possible to choose only one of the two activities (either weeding or participating in the experiment). If they were not willing to participate in the experiment, we did not allow them to work in the weeding activity only and earn money, and vice versa. No payment would be given if they did not participate in both activities.

Stage 2: Demonstration of the attributes of the improved stove

After completing the weeding and after refreshments had been provided, we gathered all the subjects in one place and told them that they would stay with us for 2 more hours for a study about an improved cookstove. Before we started the actual study, we told the subjects that we would give them a demonstration of the attributes of the new cooking stove. In the demonstration, the experimenter explained the fuel saving, smoke reduction, time saving, life span and other attributes of the new cooking stove. The experimenter used the following statements.

"The stove that you all see here is called 'Mirte'. It is made of cement concrete and has an estimated life span of 15 years. It reduces fuel consumption by half. To make it clear, the traditional stove which you are using now consumes 10 wood sticks (shilen - a wood type common in the area) to bake 20 pieces of 'injera' [bread]. *You can bake the same number of 'injera' using only 5 wood sticks with this new stove. Another important feature of this stove is that you can cook 'wot'* [stew] *using the same fuel which you use to bake injera. This will save your time and energy. The stove will also reduce the smoke by half. Such reduction in smoke has the advantage of reducing health problems associated with smoke."*

Subjects were also trained how to assemble and disassemble the new cookstove.

Stage 3: Becker-DeGroot-Marschak (BDM) bidding experiment

After completing the demonstration of the stove, we divided the subjects into five groups and placed them in different places that were far apart. For each group, an experimenter explained about the Becker-DeGroot-Marschak (BDM) bidding game which was used to make the subjects reveal their preference for the new, energy efficient stove. We used the following statements to explain the experiment;

"*We explained to you earlier about the new attributes of the improved stove and its benefits. We are interested in knowing how much you are willing to pay for this new improved stove. You can use the 150 ETB you have earned to buy the improved stove. There is no obligation to buy the improved stove. We will ask you to tell us the maximum price you are willing to pay for the improved stove.*

At the end, all groups will gather together and one subject amongst you will be randomly selected to choose a ball from a bucket containing different small balls representing each possible price. Inside each ball, we put a small slip of paper. Different prices are written on each slip (bucket, sample slip papers and balls were shown). If the price you tell me is greater than the price chosen randomly, you will have the improved stove and pay us the price chosen. You will keep the difference between the total money you earn and the price drawn. However, if the price you tell me is less than the price chosen, you will get your money but you will not have the stove.

You might wonder why we ask you to give a bid for the stove instead of just asking you to pay a price. The reason is that, we would like to understand how valuable such improved stoves are to you. We would therefore ask you to think carefully about the most you would be willing to pay for the stove.

Therefore, we ask you to tell us exactly the maximum price you are willing to pay; no more, no less. If the price you tell us is greater than your actual willingness to pay, you will be forced to pay it if that price is chosen. If the price you tell us is lower than your actual willingness to pay, then if a lower price is drawn and you find this price cheap, you will not have the stove even if you want to have it. Once the price is drawn, you are not allowed to change your price. The information you give us will determine whether you will buy the improved stove or not.

We will give you color copies of currency notes representing currency, and we will give you envelopes where you can put your bid price. (Copies of currency notes adding up to 665 were

given to each subject: 4 pieces of 100 ETB paper currency; 4 pieces of 50 ETB paper currency; 4 of pieces of 10 ETB paper currency; 4 of pieces of 5 ETB paper currency; and 5 of pieces of 1 ETB paper currency). You are not allowed to talk or see others' price and you should also hide your bids from being seen by others. Once you decide how much you want to pay for it, put the amount of paper currency notes that you would like to pay in the envelope and seal it. We will come to your seats to collect the envelope. You are also not allowed to talk each other and ask questions in public. If you have questions, raise your hand and I will come and talk to you privately and quietly."

Before the subjects started the actual bidding for the improved cookstove, we practiced the BDM game using pencils. The following statements were used for this session:

"We will give you tokens representing coins and an envelope to put your bids in. We will give you an extra ETB 5 to practice the experiment procedure by buying improved pencils. You are not obliged to buy the pencil. You can use the ETB 5 for whatever you want. Now we will ask you to tell us the maximum price you are willing to pay for this pencil. You will put tokens in the envelope and seal it. A subject amongst you will randomly choose a ball from the bucket containing different small balls (like the above balls) representing each possible price. If the randomly drawn price is less than the amount you want to pay, you will get the pencil and you will pay money equal to the chosen price. But if the price is greater than the amount you want to pay, we will keep the pencil and you keep your money. We will do this once with real money. Do you have questions?"

After collecting each subject's bid price, we gathered all the subjects again in one place to choose a price randomly. The random prices were: 30, 45, 60, 75, 90,105, 120, 135 and 150.