2019

Examining The Role Of Intra-Household Bargaining In The Adoption Of Green Technology

Antara Anand

EXAMINING THE ROLE OF INTRA-HOUSEHOLD BARGAINING IN THE ADOPTION OF GREEN TECHNOLOGY

by

ANTARA ANAND

SUBMITTED TO SCRIPPS COLLEGE IN PARTIAL FULFILLMENT OF THE DEGREE OF BACHELOR OF ARTS

PROFESSOR BOSE
PROFESSOR GRANT

DECEMBER 14, 2018

Table of contents:

ABSTRACT

This paper investigates factors that affect gender-based differences in intra-household bargaining power that are reflected in consumption decisions regarding the adoption of green technology. Using data from the Indian Human Development Survey-II and a probit regression analysis, I find that increasing the level of a woman's education (a proxy for increasing bargaining power) increases the likelihood of her household adopting LPG, the cleanest fuel option available. I also create an experimental design to serve as a next step for future research and target data collection on individual-level factors and environmental outcomes. The setup is for a potential intervention that assesses whether there are gender-based differences in the propensity for men and women to purchase improved cookstoves, given increased access to credit as a means to increase bargaining power in the household.

ACKNOWLEDGEMENTS

I would like to thank my thesis readers, Nayana Bose and Laura Grant, whose patience and guidance have been invaluable to me during this process and in the classes I have taken with them along the way. I am also indebted to Professor Menna Bizuneh for always supporting and challenging me in my capacity as a researcher and student. I feel lucky to have had so many role models to look up to during my four years here.

I would also like to extend my deepest love and gratitude to my friends and community in Claremont. Thank you for giving the strength and emotional support to feel capable enough to complete this project. Morgan, thank you for being the wind beneath my wings every step of the way – I look to you for inspiration, humor, and STATA wisdom, now and long into the future. A special thanks to Romanshi – the Rom to my Mot Cap, the Pitbull to my dale – I am so grateful to have you near me, both when returning to old homes and creating new ones. I would also like to thank Kavanaugh Livingston and Rachel Mahmud – this thesis would never have been a reality without your guidance and friendship during my time in Washington, DC.

Lastly, thank you to my family across the United States and in India. I am endlessly grateful for this education, and for all the opportunities to learn and grow in ways I never could have anticipated. Thank you for your commitment to helping me explore this big wide world on my own.

1. INTRODUCTION

Engagement with climate mitigation and adaptation rests in the hands of actors at many differing levels of power and access to finance. This includes policymakers at the federal, state, and local levels; NGOs, and members of the household. The actors on the receiving end of policy interventions could adopt green technology at the industrial or the household level. In this paper, I will center discussion around the strategies that have been employed to combat climate change risks at the household level in rural regions of developing countries. I focus in particular on the role played by women in the adoption of improved, environmentally beneficial technology. More specifically, I aim to explore whether women or men in developing countries choose to invest in greener technologies when their bargaining power within the household is improved through increasing their access to credit.

Climate change arguably presents one of the largest threats to the stability of global institutions and society in the coming century, exacerbating a number of issues central to the broader development agenda as outlined by the Millennium Development Goals (MDGs). These include (but are not limited to) the eradication of poverty, ensuring gender equality for women and girls, and ensuring environmental sustainability. The IPCC Fifth Assessment Report (AR5) determined that at 1.5°C of global warming, risks to health, livelihoods, food security, access to water and sanitation, migration, and economic growth that are a direct result of climate variability and extreme weather events are projected to increase (IPCC, 2018).[1] The report also notes that climate change is likely to increase the risk of displacement, particularly populations that lack the resources to adequately plan for and deal with migration – namely, low-income

[1] The IPCC is an international scientific body whose legitimacy is built on its emphasis on conservative estimates of climate outcomes, has ascertained that there is little doubt that anthropogenic climate change (induced by human activity) is underway. The IPCC's most recent report outlined the impacts of 1.5°C of global warming.

developing countries. In addition to this, low-income developing countries face increased risks of ill health and magnification of drivers of conflict, such as poverty and economic shocks. The report also notes that climate change impacts are expected to slow down economic growth, thus hindering poverty alleviation efforts, prolonging existing poverty traps, and creating new ones in developing countries. (IPCC AR5, 2018).

As noted in previous research, the populations who are exposed to increased risks of the most negative outcomes (as mentioned above) are those who are least equipped to cope effectively and in a timely manner – namely, those in developing countries and women (Smit et al., 2001; Adger et al., 2003). Thus, there is a need for concerted efforts on behalf of the public and private sectors on an international scale to address the threats posed by anthropogenic climate change (i.e., climate change induced by human activity) to these vulnerable populations. International multilateral organizations that provide funds and serve as facilitators of funding assess the most efficient ways that public and private capital can be allocated to engage in climate change mitigation and adaptation in developing countries.[2,3]

Funding for initiatives and policy proposals that address climate change come from many sources, comprised of public, private, and market-based mechanisms. The ways in which the range of mechanisms under these three umbrellas are organized is referred to as the global climate finance architecture or regime. Actors within this framework include governments,

---

[2] *Climate mitigation* change is defined by the United Nations Framework Convention on Climate Change (UNFCCC) as "human intervention to reduce the sources or enhance the sinks of greenhouse gases" (UNFCCC 2010). Examples would include increasing efficiency of fossil fuels during combustion, shifting energy reliance towards solar energy or wind power (reducing sources), and increasing afforestation efforts (increasing 'sinks' of carbon that remove carbon dioxide from the atmosphere).

[3] *Climate adaptation* is understood as "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (UNFCCC 2010). With an eye towards implantation of development policy, Rodenberg (2009) also notes that adaptation can take place at different levels of society and be influenced by different groups of vulnerable actors, not just international policymakers and federal governments.

private corporations (e.g. groups of experienced companies and financial intermediaries), international quasi-government institutions (UN agencies, multilateral development banks), and market- (e.g. carbon markets) and non-market mechanisms (e.g. subsidies). One example of many is the Climate Investment Funds (CIF), jointly established between the World Bank and regional multilateral development banks, has pledged approximately $6.5 billion towards investments focused on "energy efficiency, low-carbon and renewable energy carriers, pilot forest investments and new approaches to building climate resilience in vulnerable countries" (UNDP, 2011). One of the proposed strategies to tackle climate change and make vulnerable communities safer from future risk is encouraging the adoption of technologies that are cleaner and carry more environmental benefits. Thus, there is a need to ensure that this capital is being put towards policy interventions that have the potential to create the most economically and environmentally beneficial returns.

Women are often at the nexus of vulnerability to climate shock impacts and using their traditional roles in household management to mitigate those very impacts. Research shows that the benefits of adopting green technology could be unevenly concentrated on members of the household, particularly on women in the household – however, there is more work to be done in formalizing a general theory of adoption and use (Jeuland & Pattanayak, 2012). Recognizing this, policy briefs and analytical reports from multilateral organizations have begun to recommend focusing climate change financing mechanisms on promoting global climate benefits while simultaneously addressing sustainable development goals. For instance, a UNDP report on climate change financing states that incorporating gender issues into all aspects of climate change financing will "maximize the effectiveness and efficacy of climate change responses" (UNDP, 2011). A UNDP training module on gender and energy notes that women face differing problems to men with regards to energy production and utilization of energy services that are linked to traditional gender roles related to cooking, cleaning, and income generation (UNDP, 2013). As noted by Williams (2016),

> "Women must face and deal with the adverse challenges of climate change with fewer personal and social resources than their male counterparts. Yet, women are critical actors in managing and maintaining their households, the community, the ecosystems and natural resources."

To gain more of an understanding of how funds can be allocated most efficiently within a household to encourage the adoption of green technology, I will look at how the effect of intra-household bargaining power differentials between men and women can be leveraged to encourage adoption of cleaner household technologies.[4] With this, I hope to further and understanding of whether when given access to credit, women choose to invest in greener technologies disproportionately to men.

This paper studies factors that affect intra-household bargaining relationships that are reflected in consumption decisions that result in improved household outcomes, specifically with regards to the adoption of green technology. To do so, I use a probit model to assess the determinants of the adoption of a clean cooking fuel (LPG) in India. To supplement this econometric analysis and provide scope for future research, I will create an experimental design that can be used to test this theoretical model in a setting that measures whether a targeted increase in access to credit (and thereby increasing a member's bargaining power within the household) has an effect on the adoption of improved cookstove technology in India based on the gender of the recipient..

---

[4] Here, household-level interventions aimed at reducing greenhouse gas (GHG) emissions and creating environmental benefits can broadly be classified into four categories: improved cookstoves (ICs), off-grid energy, reforestation (or alternatively, reducing deforestation), and improved agricultural technologies (including livestock).

2. LITERATURE REVIEW

2.1 The role of gender in household bargaining power and spending patterns

Keeping in mind the role of the household as an actor in engaging in climate change mitigation, I will examine different models of intra-household resource allocation – that is, the allocation of rights, responsibilities, and resources among members within a household – and their subsequent policy implications with regards to shifting patterns of consumption towards greener technologies. As Doss (1996) notes, households are the center of much of the economic decision making that goes on in an economy. The intra-household allocation of resources is characterized by both cooperation and conflict. Given a set of possible outcomes, household members (for simplicity, here the members are assumed to be the male and female adults in the household) have different sets of preferences for those outcomes. The outcome that is realized is thus dependent on each member's relative *bargaining power*. Though dependent upon a range of factors, bargaining power can be said to largely be defined by the strength of the member's fall-back position, defined by Agarwal (1997) as "the outside options which determine how well-off she/he would be if cooperation failed." Thus, the better a member's outside options, the stronger their fall-back position, and the more bargaining power they have within the household.

Historically, researchers have conceptualized households through unitary models of the family (Becker, 1965). These models assume that households operate as a single consistent entity, where "household members seek to maximize utility on the basis of a set of common preferences represented by an aggregate utility function, and a common budget constraint" (Agarwal, 1997).

This unitary model of household allocation implies that, in terms of policy interventions, it would be enough to provide a cash transfer to a household irrespective of the identity of the target/recipient and the desired outcome would be achieved. This framework fails to recognize that targeting interventions of cash transfers or increased credit access to a particular member of the household would increase their fall-back position, raise their bargaining power, and allow them to express their differentiated preference more clearly through consumption (here considered the household outcome).

Consequently, newer economic research has disaggregated preferences within the household to create a collective household model that acknowledges: that often income is not pooled; that demographic characteristics such as age, gender, and caste can influence the preferences of individuals within households; and that depending on differences in preferences, bargaining power, and information flows, cooperation can occur and render the unitary household model an inappropriate for analysis (Doss, 1996; Hoddinott & Haddad, 1995; Thomas, 1990; Thomas, 1993; Iversen et al., 2006; Ashraf, 2009; Duflo, 2003; Quisumbing and Maluccio, 2003). Adding context to these concerns within the framework of development issues, anthropological and economic literature suggests that collective household models are more appropriate for households in developing countries, where households do not pool incomes and where husbands and wives might receive differing income streams (both earned and unearned) that would lead them to be responsible for different household expenses (Mammen & Paxson, 2000).

Given that economic analysis is gaining a propensity to disaggregate member preferences within households, and that many micro-credit initiatives directed at women operate on the belief that women invest in goods that increase household welfare, it is increasingly important to understand the empirical claims that giving women access to credit is economically efficient. That being said, programs that extend cash transfers and micro-credit to women implicitly acknowledge the role that women play in the household as agents of economic change (Duflo, 2012). A large body of empirical literature (discussed below) has looked at whether intra-household allocation is, in fact, affected by the identity (in this case, gender) of the recipient of income.

There are two major components to interventions that aim to influence household dynamics: proxies for bargaining power and proxies for household outcomes. As outlined by Agarwal (1997), factors that influence the bargaining power of a person within a rural household are primarily comprised of "ownership of and control over assets, especially arable land; access to employment and other income-earning means; access to communal resources such as village commons and forests; access to traditional social support systems such as of patronage, kinship, caste groupings, etc.; support from NGOs; support from the State; social perceptions about needs, contributions and other determinants of deservedness; and social norms." Following from this, proxies for bargaining power include used in experimental studies earned income, unearned income (cash transfers), maternal education at low levels, labor force participation of women, asset ownership (where assets can include land, savings, agricultural equipment), consumer durables, businesses, and financial assets (Thomas, 1990; Doss, 2006; Doss, 2013).

Household outcome proxies largely comprise of children's educational outcomes, anthropometric measurements of children's health, budget shares spent on food, budget shares spent on alcohol and cigarettes, budget shares spent on household repairs, and expenditure on healthcare. All of the household outcome proxies measured above can be broadly said to capture changes in consumption – i.e., they serve as a measurement of the household's well-being. Consumption is preferred to income as a proxy for well-being because budget shares and expenditure are bound to fluctuate less than income itself, since households tend to smooth consumption over time. Additionally, consumption better reflects the expression of preference of individual members in a household more accurately.

Studies indicate that, relative to men, income and asset ownership in the hands of women is associated with improvements in child health and larger expenditure shares of nutrition, health, and housing (Thomas, 1990; Thomas, 1993). Doss (2006) uses a comprehensive measure of asset ownership that encompasses farmland, savings, and business activity to demonstrate that increasing women's asset ownership increases budget share comprised by food and education (Doss, 2006). Results from Hoddinott and Haddad's 1995 study on household behavior in Côte d'Ivoire suggest that, using a collective model of the household where bargaining between members occurs, increasing the wives' share of income results in a greater proportion of household expenditure on food, while simultaneously reducing budget share spent on cigarettes and alcohol (Hoddinott & Haddad, 1995). Similarly, also in Côte d'Ivoire, Duflo and Udry (2004) find that rainfall shocks that increase the crop yields of crops cultivated by women tend to shift expenditures towards food consumption, whereas there is no effect of food consumption with shock-related output increases from crops cultivated by men. This again suggests that women tend to divert funds towards consumption that benefits the entire family/household. [5]

Some studies develop the collective bargaining model further by recognizing the informational asymmetries that often occur within spousal relationships in households in developing countries, and accounting for this imbalance within their experimental setups. For instance, Iversen et al. (2006) find that though couples do *not* maximize surplus, the identity of the member responsible for allocation matters, and that a greater proportion of potential surplus

[5] The literature relies on an "inferential approach" that assumes that due to a significant change in a certain outcome resulting from an increase in women's bargaining power, it is safe to infer that the outcome achieved is indeed the preferred one (Thomas, 1990).

was realized when women were in charge of the common income account. Ashraf (2009) tests the effects of informational asymmetries between male and female household heads in the Philippines by randomizing the level of communication between spouses. The study finds that conditions of asymmetric information interact with existing household roles and divisions of labor with regards to money management.

Though it is tempting to assume that mothers are more altruistic than fathers, it has been suggested that there might be economic reasons for mothers' preferences that are expressed as increased investment in children. For instance, given the differentials between men and women in age at marriage and life expectancy, one possible reason for this preferential outcome could be that women invest more in their children's education because they are more likely to rely on them into old age than their husbands (Quisumbing & Maluccio, 2003).

2.2 Household-level developments in green technology

Having reviewed the literature on household bargaining models, I will now turn to a more detailed discussion of the household-level green technologies that are under the umbrella of improved household outcomes. Here, the consumption (adoption) of green technology within a household is thought of as the household outcome. Understanding the different green technology options available and the different benefits that can be conferred upon a household can inform the structure of climate mitigation interventions, as well as informing the structure of experiments aimed at data collection. In this section, I provide a condensed overview of developments in four household-level green technologies: off-grid rural electrification, reforestation, agricultural technologies, and improved cookstoves (ICs). Among the four, my focus is on improved cookstoves, given that ICs will be incorporated into the experimental design presented in this paper.

Off-grid energy sources comprise of those that operate independently of the national electricity grid. Though still circumstance- and location-dependent, off-grid energy sources at the localized level are increasingly being considered as a viable potential means to electrify rural households. Off-grid energy solutions represent a somewhat optimal solution in terms of their ability to proliferate electricity provision with relation to a given project's required investment, efficiency and quality of service (Yadoo & Cruickshank, 2012). In addition, small-scale biomass combustion for rural household energy use has the potential to reduce greenhouse gas (GHG) emissions (Creutzig et al., 2015). However, it must be noted that some critics have posited that the potential increased reliance on biofuels might actually increase GHG emissions by encouraging the growth of crops for fuel.

Reducing tropical deforestation in developing countries has the potential to significantly reduce the cost of the global portfolio of climate change mitigation strategies, particularly through the implementation of carbon payments programs (Seymour & Busch, 2016). Additionally, household-level research in Uganda has shown that incentivizing forest-owning households to change their behavior so as to reduce the amount of deforestation they engaged in had a significant impact on slowing the decline of forest cover in the villages, as well as generating program benefits that were 2.4 times as large as the program costs, making the intervention cost-effective as well (Jayachandran et al., 2017).

Improvements in agricultural technologies tend to address either the role of livestock or crop production. The benefits received by livestock interventions include "reductions in greenhouse gas emissions, increases in productivity because of time saved, reductions in deforestation, improvements in children and women's health as well as reductions in public expenditures within the health sector," (Gill et al., 2009). With regard to crop production, studies show that factors that influence the household uptake of climate adaptation strategies include access to credit, access to information and education, government support by way of policy and subsidies, education, and wealth/income (Bryan et al., 2009; Igoden et al., 1990; Lin, 1991; Knowler & Bradshaw, 2007).

2.2.1 Improved cookstoves (ICs)

Studies have shown that domestic cookstoves hold significant potential as a point of improvement in reducing greenhouse gas (GHG) emissions (Smith et al., 2000; Bruce et al., 2000). For instance, Johnson et al. (2009) estimated the CO_2-e (carbon dioxide equivalent) savings for 603 homes in Michoacán, Mexico, to find that the cost of CO_2-e savings as a result of the adoption of the IC was US$8 per tCO_2-e, which is approximately 18 times less expensive than solar power.[6] This study, as well as others, suggests that the relative cost of US$8 per CO_2-e abatement, in conjunction with their significant health benefits, that ICs are a viable solution to pursue as a relatively low-cost Black Carbon mitigation option (Johnson et al, 2009; Kar et al., 2012).

A potential issue with cookstoves might lie with the way in which these technologies are marketed towards consumers. The focus on mitigating health risks and costs rather than potential environmental benefits when marketing to households might speak to a larger disconnect between the adoption of broader collective benefits of adopting improved technologies and the strategies employed to influence household decision-making or leverage existing power

[6] For any quantity and type of greenhouse gas, CO2-e signifies the amount of CO2 that would have the equivalent impact on global warming.

dynamics within the household. Additionally, some research shows that in Bangladesh, relying on the communication of health benefits of ICs was not the most effective way to encourage adoption, since many women in rural Bangladesh do not perceive indoor air pollution as a significant health hazard.

Jeuland and Pattanayak (2012) conduct a cost-benefit analysis of cookstove adoption at the household level to assess potential contributing factors to poor uptake of IC technology. By modeling private costs and benefits and then social costs and benefits, they show that households switching from traditional stoves to improved stoves yield net private benefits in at least half of the simulations. These improved technologies included improved wood-burning, improved charcoal-burning, or electric stoves, LPG, and kerosene stoves, with LPG and kerosene stoves yielding the highest welfare gains by magnitude. Additionally, Jeuland and Pattanayak (2012) add the value of net value of carbon benefits to the private benefits they calculated to the household, and find that (using the most conservative assumptions regarding emissions savings) carbon subsidies are justified to promote adoption, thereby offsetting adoption costs that would otherwise deter adoption. They also acknowledge that their study excludes "aesthetic benefits and disamenities" that occur with different cooking options (Jeuland & Pattanayak, 2012). These benefits, along with others (including health benefits), have the potential to be disproportionately concentrated on women, given that women are usually responsible for cooking and food preparation under traditional gender roles, thus allowing for women to have an increased preference for adopting ICs over men. This, in conjunction with the potential for increased bargaining power from increased access to credit from a policy intervention, would theoretically make the adoption of ICs a useful specification for the study of a household's consumption of green technology relative to women's bargaining power.

3. MODEL

I have chosen to narrow the focus of this paper to the use of two proxies for bargaining power: the empirical analysis uses women's education as a proxy for bargaining power, and the experimental design uses access to credit as a proxy for bargaining power. In both cases, the adoption (consumption) of improved household technology as a proxy for household outcomes. The experimental design outlined in this section will focus on women's access to credit in India as a proxy for bargaining power, and adoption of improved cookstove (IC) technology by a given household as a proxy for the improved household outcome. While much of the literature has focused so far on outcomes related to educational attainment and nutrition, this paper expands the scope of household utility maximization models by incorporating the adoption of climate mitigating household technologies into the umbrella of improved household outcomes by using consumption of those goods as a proxy.

3.1 Theoretical model

The theoretical model that I employ draws upon the work of Hoddinott & Haddad (1995) in their study of the influence of female income share on household expenditure using a utility maximization model. Hoddinott & Haddad (1995) use a Nash equilibrium model to show that as income share of one utility-maximizing member in the household rises, it is clearly reflected in the pattern of household expenditure because the share of household income spent on that individual's preferred set of goods will rise. The theory suggests that if both the man and woman in the household derive different utilities from green technology consumption, they would realize different outcomes in the pursuit of utility maximization.

Thus, when one member's bargaining power in the household increases, they have more power for their preferences to be realized and reflected in household consumption decisions over the other member's. The experimental design in this paper can be used to test this theory. By increasing either the man or woman's bargaining power through access to credit from microfinance programs, we could test whether one has an increased propensity to purchase green technology for the household over the other in the pursuit of utility maximization.[7] Given the literature that shows that women's set of preferred outcomes is likely to be more beneficial for the household, I hypothesize that when green technology is included as a possible item of consumption, women's set of preferred outcomes will reflect the outcome that is more beneficial to the household – i.e., the adoption of green technology.

3.2 Empirical model

3.2.1 Data

I conduct a regression analysis of the factors that influence the use of three different commonly used fuels in India. The data are a part of the Indian Human Development Survey (IHDS).[8] The IHDS was conducted twice; the initial round was in 2005 (IHDS-I) and a second round was carried out in 2011-2012 (IHDS-II) that largely consisted of re-interviewing households from the initial survey. The IHDS is nationally representative, multi-topic survey of 42,125 households in villages as well as urban neighborhoods across India. Both surveys cover all states and union territories in India with the exception of the Andaman & Nicobar and Lakshadweep islands. Data from the survey was gathered through two one-hour interviews in each household covered topics concerning health, education, employment, economic status, marriage, gender relations, social capital, and more. The data form this survey are cross-sectional and consist of measurements for individual observations (persons, households, districts, states,

[7] A more detailed explanation of this theory is included in Appendix A2 for the interested reader.
[8] The Indian Human Development Survey can be found at: https://ihds.umd.edu/

etc.) at a given point in time. For this analysis, I only use data from IHDS-II. More specifically, I use data from parts DS2 (Household) and DS3 (Eligible Women)[9] of this survey.[10,11] The IHDS surveys are particularly useful for helping analyze human development indicators across a range of social and economic dimensions – for instance, in this paper I analyze consumption (an economic outcome) by considering the roles of education, gender relations, community context, and economic resources.

Recently, the negative health impacts of traditional biomass stove (*chulha*) use in India have been realized by the general public and the government.[12] Charcoal is one of the most commonly used fuels for biomass stoves in India, and is the only type of biomass fuel included in the IHDS-II survey. LPG has been shown to be the cleanest of the three fuel options, addressing both the issue of indoor air pollution and ambient (outdoor) air pollution simultaneously. Though kerosene is considered to still be cleaner than charcoal and other biomass, it is still has significantly negative health and environmental impacts that are not shared by LPG usage. As a result, the Indian government has invested heavily in LPG subsidy programs primarily targeting poor and middle-income households. The country has seen a significant increase in LPG connections, and has plans to further expand the program. Thus, I use LPG connections in India as a proxy for improve cookstove technology, as LPG stoves are cleaner than *chulhas* and kerosene stoves.

[9] Here, an 'eligible woman' is described as an ever-married woman aged 15-49. DS3 has data from a questionnaire where an eligible woman in the household is the respondent.
[10] Data from DS3 were used wherever possible for consistency of responses, and data from DS2 were used if data from DS3 were not available.
[11] Sample weights for the household were assigned to observations in this analysis to account for differences in geographical population distribution.
[12] A *chulha* is a small earthen or brick stove that uses wood, charcoal, animal dung, or crop residue (biomass). *Chulha* use has been compared to cigarette smoking in terms of its negative individual and public health impacts.

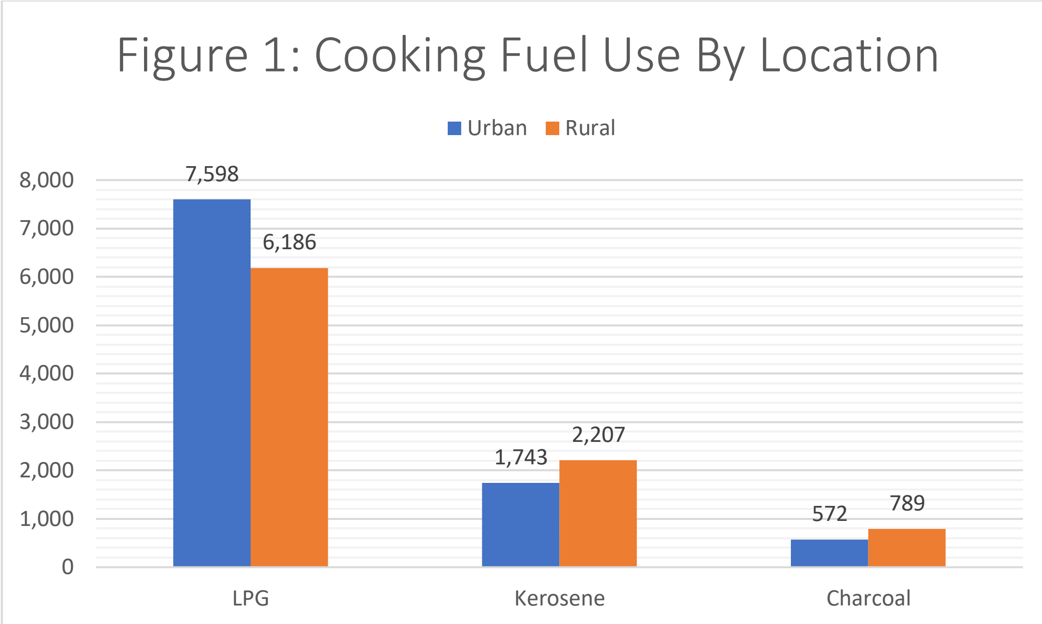


Figure 1 reflects this switch to cleaner fuels – LPG is by far the most used fuel in this sample in both urban and rural areas, which likely speaks to the success of the fuel subsidy program in encouraging people in both areas to move towards cleaner fuels. This is likely the result of intelligent social marketing on behalf of the programs, as well linking participation in these programs to financial inclusion through access to banking facilities. However, the graphs illustrate a lingering reliance on kerosene and charcoal among rural households, which suggests some difference in fuel usage characteristics based on location. This is further explored in the regression analysis of factors affecting LPG use later in this paper.

Table 2 (see Appendix) shows that when households do have to collect wood fuel for charcoal, over half of the women who responded have to collect it at least once a week. This shows that women do have to engage in the process of fuel collection frequently enough that it is an established part of their household routines.

Figure 2: Cooking Fuel Use By Main Purpose

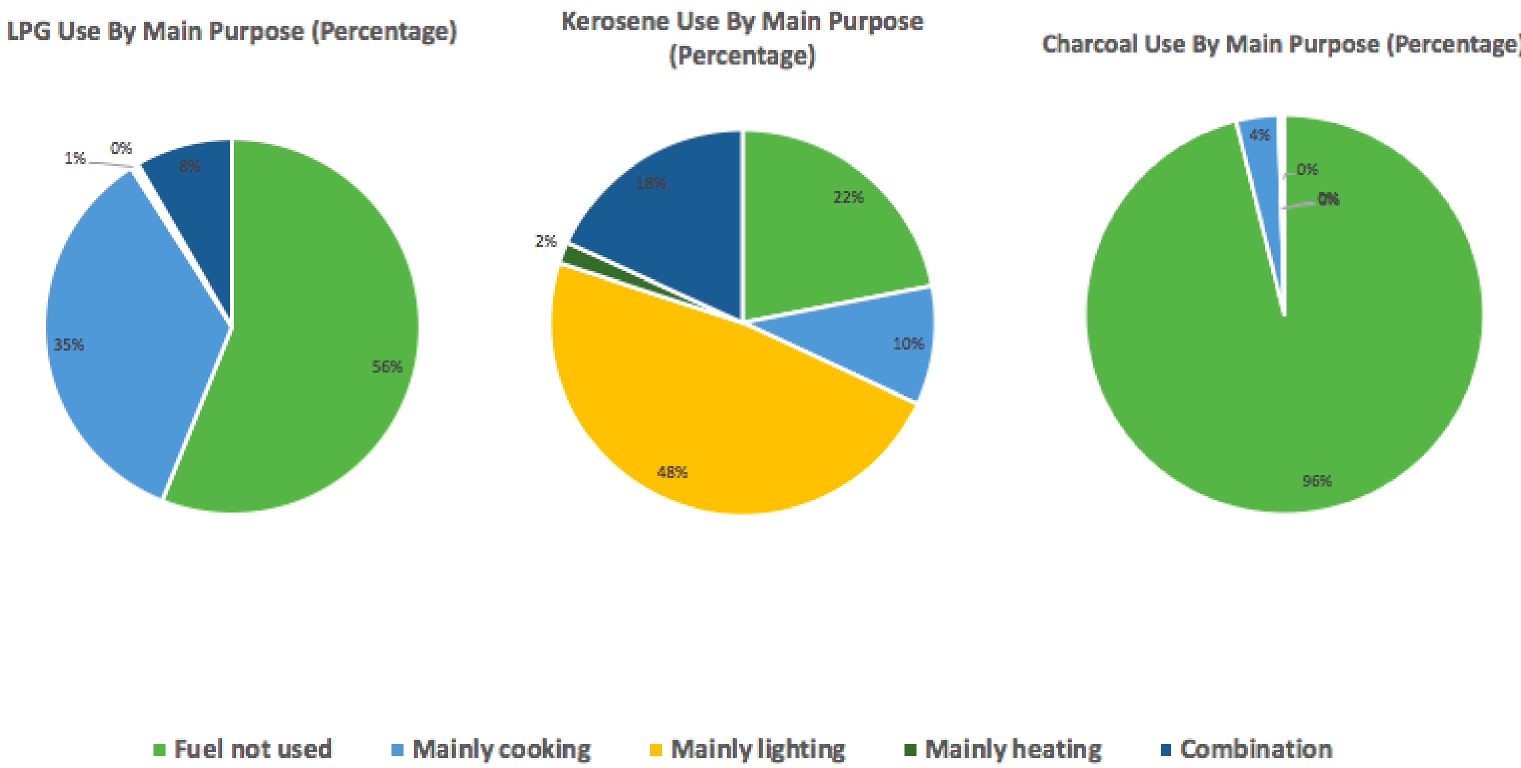


Figure 2 is illustrative of the different uses of each fuel within the pooled sample. Among households that do use LPG, it is reported that its main use is for cooking, followed by a combination of energy-consuming activities. Kerosene, unlike LPG, is largely used for lighting. One possible explanation for this could be that households who have access to the LPG subsidy program might have switched from charcoal directly to LPG, thereby leapfrogging over the 'middle step' of using kerosene. At the time of the public subsidy deployment, some households have presumably been using kerosene for a long time and have found the most suitable and efficient ways for their families to make the most use out of a given fuel – kerosene and LPG would be suited for this diverse set of needs. However, since the intervention focused on switching to LPG as a cooking fuel, it is possible that households that switched from *chulhas* to ICs primarily use LPG for cooking instead of charcoal. These households still rely on kerosene for other energy needs, likely because they have not had enough time to integrate LPG into other energy consuming activities in their lives, and because of a lack of access to electricity. Additionally, most households report not using charcoal at all, but those that do report using it primarily for cooking. This could be supported by the fact that kerosene and charcoal are imperfect substitutes in terms of how they meet different energy needs.

3.2.2 Model

I investigate what factors might have a significant effect on increasing the likelihood of the adoption of LPG for a given household, controlling for demographic, geographic, and socio-economic factors. I ran a probit regression with a dependent variable that captures LPG usage for cooking, and women's access to education as my independent variable of interest, the results of which are displayed in Table 3. I ran the same regressions using a linear probability model (LPM) as well, and the results are reported in Table 4. The directions in which the coefficients move is the same as in the probit model, and the coefficients for the independent variables are of similar magnitude. I chose to run a probit model instead of the LPM because my outcome of interest is coded as a binary variable ranging from 0 to 1. The probit model is thus better fitted for the dependent dummy variable and predicts the probability of the adoption of LPG for cooking.[13] The model was calculated with robust standard errors to correct for heteroskedasticity.

$$Pr(LPGcook) = \Phi(\beta_0 + \beta_1 Educ + \beta_2 Educ*Urban + \beta_3 Lincome + \beta_4 Lincome*Urban + \beta_5 Women + \beta_6 Women*Urban + \beta_7 Men + \beta_8 Age + \beta_9 Hindu + \beta_{10} Urban + \mu) \quad \mathbf{(1)}$$

I used the dependent variable *LPGcook*, which equals 1 if the respondent reports that the main use of LPG in their household is for the purpose of cooking, and 0 if otherwise. The main

[13] The results of the regression using a linear probability model (LPM) are displayed in Table 4 (Appendix 2).

independent variable of interest, *Educ*, is a proxy for bargaining power in the household. *Educ* captures the highest level of education attained by an adult woman (over 21 years old) in the household. I chose this variable over variables that described the education level of the respondent or mother-in-law (only two of the women in the household) because the households that report having between 0 and 3 women living in them comprise 97 percent of the sample, with 7.60 percent of the sample reporting that 3 women live in the household. I hypothesize that the coefficient on *Educ* will be positive and significant.

Demographic controls used in this regression include the log of total household income (*Lincome)*, the number of adult men and women in the household over 21 years of age (*Women* and *Men*), and religion (coded as *Hindu* = 1 if the respondent identifies the head of the household as Hindu, and 0 if otherwise). The log of *Income* was used if values for *Income* were greater than or equal to 0. This was to account for the wide range in orders of magnitude for observations within this variable. Additionally, I chose to limit the characterization of religion to Hindi and non-Hindu, despite the fact that both categories comprise heterogenous groups of religious identity. I made this choice for two reasons: first, the vast majority of the sample reports that the head of the household is Hindu (81.62 percent). Moreover, in some places in India, identifying as Hindu translates into higher social capital and bargaining power, and different cultural norms.

I chose to use a probit model with robust standard errors. I report the marginal effects from the probit estimations instead of the estimated coefficients, for ease of interpretation. Three empirical models are estimated, one with the pooled sample controlling for urban/rural characteristics, and two that were disaggregated by urban/rural characteristics to investigate the effects of women's education in areas where social norms are likely to be different and influence bargaining power.

<u>3.2.3 Results and Limitations</u>

The results of this model are presented in Table 3. The variables *Educ*, *Lincome*, and *Women* were estimated along with the interaction terms for each of them with *Urban*. As a result, the coefficients in Column 1 show the results of those three variables in the rural subsample.

From Column 1, the independent variable of interest, *Educ*, is significant in rural households and carries the anticipated positive sign. According to these results, the level of education of the adult woman in a rural household with the highest level of education is a positive predictor of the household's choice to use LPG primarily for cooking. That is, an increase in education by 1 grade level for the most-educated woman in a rural household, increases the likelihood that the household uses the cleaner fuel alternative by 3.66 percent, significant at the 1 percent level. The results in Columns 2 and 3 support this hypothesis as well. In urban households, an increase in education by 1 grade level for the most-educated woman in the household increases the likelihood that the household uses the cleaner fuel alternative by 4.61 percent. This coefficient is smaller than for rural households. Moreover, the coefficient on the difference between the urban and rural effects is also significant, showing that the effect of increasing women's education (and subsequently, bargaining power) on LPG use is magnified in rural areas when compared to urban households. This suggests that perhaps due to prevailing social norms, the marginal effect of a woman having more bargaining power in terms of more education is greater in areas where it is less common for women to have an education.

This supports my hypothesis that increasing a woman's bargaining power within the household does increase the likelihood that the improved household outcome will be achieved, specifically using the adoption of LPG (the cleanest option, the other two being charcoal and kerosene) as the proxy for the improved household outcome.

Additionally, the control variables *Lincome, Age, Women* and *Men* are statistically significant. Like *Educ*, *Lincome* is interacted with *Urban* to give *Lincome*Urban*. The coefficients in Column 1 indicate that an increase in income corresponds to a 3.49 percent increase in the likelihood of a rural household adopting LPG as its primary cooking fuel. Similarly, the coefficients in column 3 indicate that an increase in income corresponds to a 7.40 percent increase in the likelihood of an urban household adopting LPG as its primary cooking fuel. However, the difference between these two is not significant. This could perhaps be due to social and cultural factors having more of an influence in households making the decision to use LPG or not, and goes against some literature on the income-energy ladder (Reddy, 2004).

Surprisingly, having a higher number of women in the household significantly decreases the probability of using LPG as a cooking fuel by approximately 1 percent in rural households, by 3.6 percent in urban areas, and by 0.7 percent overall. The difference between the effect of this variable in urban and rural households is not significant. Conversely, having more adult men in the house significantly increases the probability of using LPG by 1.37 percent overall. Having a Hindu-identifying head of household significantly decreases the probability of using LPG as the primary cooking fuel in the household by 4.78 percent overall.

Finally, the differences in magnitude of LPG adoption between urban and rural areas is illustrated by the coefficient on the variable *Urban*. Living in an urban area increases the likelihood of adopting LPG as the primary cooking fuel by 50.1 percent, significant at the 1 percent level. This supports the initial hypothesis and previous literature on the subject. The magnitude of the coefficient confirms my initial motivation for disaggregating the sample to see whether the independent variable of interest and other control variables have different effects/the same effects of differing magnitudes in both settings.

Within this analysis, there are limitations to the model I have presented. First, the empirical model in this paper largely relies on self-reported data, which is subject to a bias. The model itself would have better reflected preferences of fuel choices had an ordered probit model been used as is frequent in the literature (Reddy, 2004), however I did not have enough observations from subsamples using charcoal and kerosene to be able to yield analysis of significant power. Additionally, the proxies chosen for improved household outcomes are far from perfect. It is difficult to gather data directly about improved environmental outcomes. For this survey I used the adoption of the cleaner fuel (LPG) as a proxy for the improved outcome without actually quantifying the benefit to the household, since I assumed (based off of the literature) that an improved outcome would follow form the switch from biomass to LPG. Additionally, if I had access to a better proxy that measured the actual environmental benefit, it would have been worthwhile to use a fixed effects model using the IHDS-I and IHDS-II that could track household outcomes over time, since many of the IHDS-II in 2011-2012 households were ones that were re-interviewed from the IHDS-I in 2005. This, in conjunction with a more specific proxy for women's empowerment, could yield more robust insights about causal relationships between women's bargaining power and the adoption of green technology. Some of these concerns are addressed in through the creation of the experimental design.

4. EXPERIMENTAL DESIGN

4.1. Motivation

As pointed out by Zimmerman (2012), most studies that seek to identify instances of gender discrimination in the allocation of household outcomes such as consumption, health, or expenditures are constrained by the unavailability of data. Household consumption and expenditure data is usually only available at the household level, rather than at the individual level. Furthermore, bargaining power as a variable is unobservable – these studies must also use proxies for bargaining power, in addition to those used for preferences. As noted by Agarwal (1997), income can often serve as an endogenous factor in outcome differentials, obscuring the causality between exogenous increases in earned income and bargaining power in the household. Randomized control trials (RCTs), where participants are randomly assigned to control or treatment groups, are one way to overcome this issue and reveal the intricacies of decision-making processes within households more clearly (Doss, 2013).

These issues can and have been addressed in a few ways. The problem of endogeneity has been addressed in experiments by using a 'natural experiment' framework, where a policy change or exogenous change to income outside of the control of the household creates natural control and treatment groups (Duflo, 2003; Qian, 2008). Kusago and Barham (2001) directly surveyed household members on how they would spend an extra $40 on different expenditure categories, and created a measure of preference heterogeneity to include within their model. Similarly, RCTs are another method of circumventing the problem of endogeneity to some extent. Many conditional cash transfer programs have utilized the design of RCTs to test their efficacy.

To address the data and endogeneity constraints within my own empirical model, I incorporate a theoretical experimental design based on previous research in intra-household allocation to move beyond these limitations.

The experiment would aim to test whether a targeted increase in access to credit (i.e., the increase in access to credit is directed either towards the man or the woman in the household) results in a significant difference in the rates of ICs adoption between men and women in rural areas in India. The hypothesis the experiment operates on is based on the theoretical model outlined above. I hypothesize that given increased access to credit, women would disproportionately increase household budget expenditure on ICs relative to men. Increased access to credit has been chosen as the specific intervention to address credit market inefficiencies given the choice of technology.

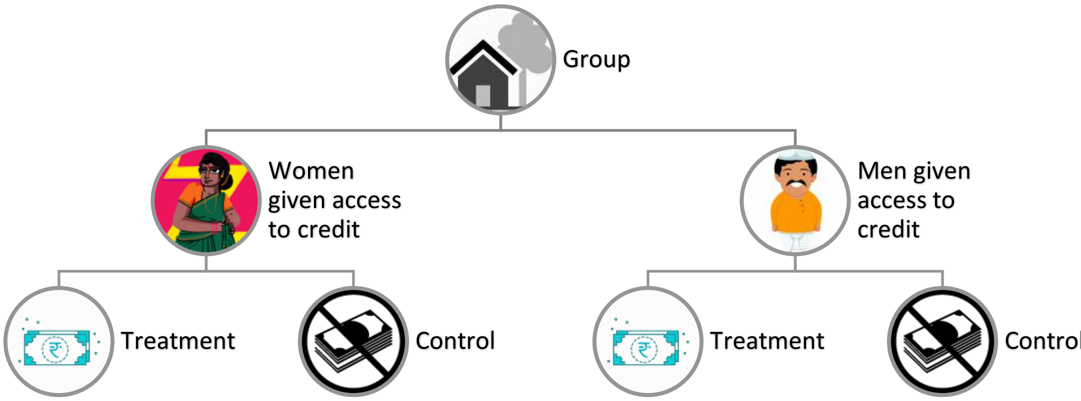
ICs were chosen specifically because of the asymmetrical distribution of benefits of adoption to women, thus creating a preference differential that could be realized as a result of increased bargaining power (Jeuland & Pattanayak, 2012). Subsequently, as Jack (2011) notes, access to credit is needed most when the upfront cost of technology adoption is highest – this is by and large true for the financing of stoves. Previous studies have largely used education, income or asset ownership as proxies for increasing women's bargaining power. Another such proxy is increasing women's access to credit, which could have similar effects to that of increased earned income. This is a particularly salient proxy given the high up-front costs of ICs, which would require most consumers (particularly rural ones) to have access to consumer finance to make the purchase. Microfinance organizations are well-positioned to address the constraints that women face in borrowing from commercial banks, such as lack of access to collateral, lack of asset ownership, social norms, lack of information, and other institutional and legal barriers. Though there is a lack of academic consensus on whether microfinance does 'empower' women, it has been shown to have a positive impact on income and serves as a useful tool for the promotion of new technologies (UN, 2009). Microfinance organizations are able to address the constraints women face more specifically through group-lending programs.

4.2 Specification

The experimental set up here would thus follow the RCT design, wherein a sample of households would be randomly sorted into two groups with similar socioeconomic characteristics and culturally-based influencing factors (such as income, education levels, religion, and caste – which would be disaggregated into high caste and lower caste communities). The nature of the intervention would be a 2x2 design as follows: one group would be subject to an intervention where women are given increased access to credit (1), and the other would be subject to an intervention where men are given increased access to credit (2) in the form of a loan. Within groups (1) and (2), each group would be further stratified into a treatment and control group, based on our subgroups of interest – i.e. gender. So, in group (1) there would be two randomly assigned groups of households: one group where women are given increased access to credit (treatment group 1) and another group where women are not given increased access to credit (control group 1). Similarly in group (2), two groups would exist – one where men are given access to credit (treatment group 2) and another where men are not given access to credit (control group 2).

Additionally, to ensure that the option of adopting green technology is incorporated into the household's budgeting process, the experiment would be linked to a menu of consumption options. Both treatment and control groups would receive a menu of options to choose from, which would include the improved cookstove as a possible component of budget allocation. The menu of options would be catered to the economic (income, education) and socio-cultural (religion, caste) characteristics of the community, as high-caste, highly educated rural households would likely have different potential baskets of consumption than low-caste, low-income rural households. This would help ensure that the increased access in credit is directed towards incentivizing the green technology, and not influencing consumption in general.

Figure 5: 2x2 experimental setup



The next point of concern is the level of randomization in the study. Randomization is necessary to ensure that there is no contamination across groups as a result of treatment. In this experimental design, I would need to ensure that the risk of treatment groups communicating with one another about having received the increased access to credit is minimal, as this would affect how both treatment and control groups would respond to the intervention. The next question to address would be at what level the groups could be randomized so as to generate a credible test.

The sample size and level at which the sample is randomized is important both for analytical and practical reasons. Treatment and subsequent data collection through interviews is expensive, thus the sample size needs to be optimized. Furthermore from a statistical standpoint, the significance of the true effect of treatment (measured through averages in the treatment and control group) depend both on the magnitude of the true effect, the sample size, and the homogeneity of the population.[14] Ideally, on average, the sample size would be large enough that observable and unobservable characteristics of the treatment and control populations are the same.

In this experiment, the treatment level is at the household – one person in each household receives the intervention, so no two individuals within the same household would be recipients of the increased credit flow. Randomization could occur at:

1. The household/group level, where households in the same village are randomly selected to form treatment and control groups within the same village.
2. The village level, where a certain number of households are randomly selected within each village to receive treatment across villages in the same sub-district (village cluster).[15] Here, the intensity of treatment can be varied across villages (i.e. the number of treatment households can be increased or decreased across villages). Other strategies include assigning all villages partial treatment (where 50% of households receive treatment) or assign full treatment to some (say 50%) villages.
3. The sub-district level, where a certain number of villages in a sub-district are randomly selected to have all the households as recipients of the treatment while all the households in the other villages in the sub-district are randomly chosen to be the control group.

As the scope of randomization widens, a trade-off begins to appear. The smaller the scope, the easier it is to collect reliable data and information through interviews – however, keeping the scope of the experiment small runs the risk of cross-contamination from informational spillovers. For instance, if the intervention is randomized at the household level,

[14] Here, the true effect tested would be the increase in women's propensity to spend on cleaner cooking technologies.

[15] In India, the hierarchy of government administration is organized (in order of decreasing geographical scope) at the following levels: national, state, district, sub-district (village clusters), and village. Here, a district

non-recipient households in the same village might find out and be dissatisfied, thereby reiterating the practical constraints of the experimental setup. To mitigate this potential dissatisfaction, recipients should either be chosen arbitrarily or randomly, or some combination of the two. Another potential concern is cross-contamination through crossovers (movement to treatment or control groups). This is less of a concern since it would be difficult for members of recipient households to move into non-recipient households or vice versa, and it would also be difficult for entire families to move to or from recipient villages, depending on the level of randomization.

The power test also needs to be taken into account when selecting sample size and the level of randomization. As demonstrated by Thornton (2011), if the experiment is randomized at the individual/household level, a large minimum detectable effect (MDE) of 0.5 is achievable with either a) a minimum of 144 responses with under 50% treatment and full compliance or b) a minimum of 576 observations with 50% compliance. Moving away from individual randomization results in a loss in precision from an increase in MDE.

Taking into consideration both practical and statistical concerns regarding randomization and its limits, I would recommend that the intervention be randomized at the village level (level 2) so as to provide flexibility in treatment intensity/administration; achieve a balance within the trade-off between ease of data collection and risk of spillover cross-contamination; and maintain realistic expectations about budgetary limitations.

5. CONCLUSION

The primary goal of this paper is to incorporate the rigorous body of empirical research on household bargaining models into the architecture of climate change financing. International political and development agendas are beginning to emphasize the need for access to clean and affordable energy not merely as an afterthought in project planning, but at the heart of any reasonable sustainable development initiative moving forward, particularly given the pressing need for climate change mitigation in light of the recent IPCC report. This is evidenced not only by the inclusion of 'Affordable and Clean Energy' as Goal 7 of the United Nations Sustainable Development Goals, but also by the focus of recent policy brief aiming to integrate issues of gender and clean energy access into the broader global development agenda. (UN, 2015; UNDP, 2011; UNDP, 2013).

Many households in developing countries face the barrier of high up-front costs standing between them and the adoption of green technologies that have the potential to confer improved environmental outcomes to the community at large, as well as improved health and livelihood outcomes within the household itself. Though the jury is still out on its efficacy, microfinance is often used as a means to bridge that funding gap – more specifically, microcredit poses one possible avenue to facilitate the adoption of these technologies.

There seems to be a missing link between empirical literature on improving household outcomes and policy initiatives that recognize that women in developing countries are simultaneously on the receiving end of the burden of climate change and in the best position to improve environmental outcomes at the household level. With this paper, I aim to both motivate the need for more robust empirical research linking the two with my own economic analysis, as well as provide the first steps for an empirical design that could provide the basis of an experimental design to collect data that would help test this theory in the real world, and gather data on the realized outcomes of increasing women's access to credit.

These limitations in the data and empirical model in this paper can be addressed through the collection of survey data from the experimental design outlined above. Avenues for future research could expand on this experimental design to test for improved outcomes with other green household technologies, such as reforestation initiatives, off-grid solar energy, and agricultural technology improvements. This might be especially pertinent for technologies where improved household outcomes and environmental benefits are easier to measure and analyze. Moreover, I aim to have challenged ideas of women in developing countries as a vulnerable populations with limited means and agency, as well as assumptions that these same women are, by virtue of being on the receiving end of the adverse outcomes of climate change, able to secure the desirable outcome of adopting greener technology within their households as a part of their rational consumption choices.

Policy that aims to finance the adoption of green technology for households must ground itself in an evidence-based understanding of the complex dynamics that shape large consumption decisions, and the gathering of that evidence must flow from economic theory. In providing this theoretical and empirical background to my experimental design, it is my hope to gain a more expansive empirical understanding of women’s role in climate change mitigation strategies.

BIBLIOGRAPHY:

Adger, W.N., Huq, S., Brown, K., Conway, D., Hulme, M., 2003. Adaptation to climate change in the developing world. Progress in Development Studies 3, 179–195. https://doi.org/10.1191/1464993403ps060oa

Agarwal, B., 1997. "'Bargaining'" and Gender Relations: Within and Beyond the Household. Feminist Economics 3, 1–51. https://doi.org/10.1080/135457097338799

Ashraf, N., 2009. Spousal Control and Intra-Household Decision Making: An Experimental Study in the Philippines. American Economic Review 99, 1245–1277. https://doi.org/10.1257/aer.99.4.1245

Becker, Gary S. 1965. "A Theory of the Allocation of Time." *Economic Journal* 75: 493–517.

Bruce, N., Perez-Padilla, Albalak, R., 2000. Indoor air pollution in developing countries: a major environmental and public health challenge. Bulletin of the World Health Organization 78 (9), 1078–1092.

Bryan, E., Deressa, T.T., Gbetibouo, G.A., Ringler, C., 2009. Adaptation to climate change in Ethiopia and South Africa: options and constraints. Environmental Science & Policy 12, 413–426. https://doi.org/10.1016/j.envsci.2008.11.002

Creutzig, F., Ravindranath, N.H., Berndes, G., Bolwig, S., Bright, R., Cherubini, F., Chum, H., Corbera, E., Delucchi, M., Faaij, A., Fargione, J., Haberl, H., Heath, G., Lucon, O., Plevin, R., Popp, A., Robledo-Abad, C., Rose, S., Smith, P., Stromman, A., Suh, S., Masera, O., 2015. Bioenergy and climate change mitigation: an assessment. GCB Bioenergy 7, 916–944. https://doi.org/10.1111/gcbb.12205

Doss, C.R., 1996. Testing among models of intrahousehold resource allocation. World Development 24, 1597–1609. https://doi.org/10.1016/0305-750X(96)00063-0

Doss, Cheryl R. 2006. "The Effects of Intrahousehold Property Ownership on Expenditure Patterns in Ghana," *Journal of African Economies* 15 (1): 149-80.

Doss, C., 2013. Intrahousehold Bargaining and Resource Allocation in Developing Countries. The World Bank Research Observer 28, 52–78. https://doi.org/10.1093/wbro/lkt001. Working Paper.

Duflo, E., 2003. Grandmothers and Granddaughters: Old-Age Pensions and Intrahousehold Allocation in South Africa. The World Bank Economic Review 17, 1–25. https://doi.org/10.1093/wber/lhg013

Duflo, E., 2012. Women Empowerment and Economic Development. Journal of Economic Literature 50, 1051–1079. https://doi.org/10.1257/jel.50.4.1051

Duflo, E., Udry, C., n.d. Intrahousehold Resource Allocation in Cˆote d'Ivoire: Social Norms, Separate Accounts and Consumption Choices 49.

Glossary of climate change acronyms and terms [WWW Document], n.d. [WWW Document]. UNFCCC. URL https://unfccc.int/process-and-meetings/the-convention/glossary-of-climate-change-acronyms-and-terms (accessed 10.19.18).

Gurgand, M., Thornton, R., n.d. Power calculation for randomized experiments. J-PAL advanced course, Cape Town July 2011.

Hoddinott, J., Haddad, L., 1995. Does Female Income Share Influence Household Expenditures? Evidence From Côte D'ivoire. Oxford Bulletin of Economics and Statistics 57, 77–96. https://doi.org/10.1111/j.1468-0084.1995.tb00028.x

Igoden, C., Ohoji, P., Ekpare, J., 1990. Factors associated with the adoption of recommended practices for maize production in the Lake Basin of Nigeria. Agricultural Administration and Extension 29 (2), 149–156.

Intergovernmental Panel on Climate Change (IPCC), 2007a, 'Summary for Policymakers' in Solomon, S. et al., Climate Change 2007: The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. Available at < http://www.ipcc.ch/publications_ and_data/publications_ipcc_fourth_assessment_report_wg1_report_the_physical_science_basis.htm >.

Iversen, V., Jackson, C., Kebede, B., Munro, A., Verschoor, A., 2006. What's Love Got to Do with It? An Experimental Test of Household Models in East Uganda. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.1080594

IPCC, 2014: *Climate Change 2014: Synthesis Report*. *Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

Jack (2011) "Constraints on the adoption of agricultural technologies in developing countries." White paper, Agricultural Technology Adoption Initiative, J-PAL (MIT) and CEGA (UC Berkeley).

Jayachandran, S., de Laat, J., Lambin, E.F., Stanton, C.Y., Audy, R., Thomas, N.E., 2017. Cash for carbon: A randomized trial of payments for ecosystem services to reduce deforestation. Science 357, 267–273. https://doi.org/10.1126/science.aan0568

Jeuland, M.A., Pattanayak, S.K., 2012. Benefits and Costs of Improved Cookstoves: Assessing the Implications of Variability in Health, Forest and Climate Impacts. PLoS ONE 7, e30338. https://doi.org/10.1371/journal.pone.0030338

Johnson, M., Edwards, R., Ghilardi, A., Berrueta, V., Gillen, D., Frenk, C.A., Masera, O., 2009. Quantification of Carbon Savings from Improved Biomass Cookstove Projects. Environmental Science & Technology 43, 2456–2462. https://doi.org/10.1021/es801564u

Kar, A., Rehman, I.H., Burney, J., Puppala, S.P., Suresh, R., Singh, L., Singh, V.K., Ahmed, T., Ramanathan, N., Ramanathan, V., 2012. Real-Time Assessment of Black Carbon Pollution in Indian Households Due to Traditional and Improved Biomass Cookstoves. Environmental Science & Technology 46, 2993–3000. https://doi.org/10.1021/es203388g

Knowler, D., Bradshaw, B., 2007. Farmers' adoption of conservation agriculture: a review and synthesis of recent research. Food Policy 32 (1), 25–48

Kusago, Takayoshi and Bradford L. Barham. 2001. "Preference Heterogeneity, Power, and Intrahousehold Decision-Making in Rural Malaysia," *World Development* 29 (7): 1237-56.

Lee, K., Miguel, E., Wolfram, C., n.d. Experimental Evidence on the Economics of Rural Electrification 45.

Lin, J., 1991. Education and innovation adoption in agriculture: evidence from hybrid rice in China. American Journal of Agricultural Economics 73 (3), 713–723.

Maluccio, J.A., R. Quisumbing, A., n.d. Resources at Marriage and Intrahousehold Allocation: Evidence from Bangladesh, Ethiopia, Indonesia, and South Africa.

Mammen, K., Paxson, C., n.d. Women's Work and Economic Development 32.

Organization for Economic Cooperation and Development (OECD), 2015. Climate change and gender: economic empowerment of women through climate mitigation and adaptation? https://www.oecd.org/dac/gender-development/46975138.pdf. Working Paper.

Qian, Nancy. 2008." Missing Women and the Price of Tea in China: The Effect of Sex-Specific Earnings on Sex Imbalance," *The Quarterly Journal of Economics* 123 (3): 1251-85.

Reddy, B. Sudhakara, June 16-19. Economic And Social Dimensions Of Household Energy Use: A Case Study Of India. Proceedings of IV Biennial International Workshop "Advances in Energy Studies". Unicamp, Campinas, SP, Brazil. 469–477.

Rodenberg, Birte: Climate change adaptation from a gender perspective : a cross-cutting analysis of development-policy instruments / Birte Rodenberg. DIE Research Project "Climate Change and Development" – Bonn : DIE, 2009. – (Discussion Paper / Deutsches Institut für Entwicklungspolitik ; 24) ISBN 978-3-88985-474-2

Seymour, F., Busch, J., 2016. Why forests? Why now?: the science, economics, and politics of tropical forests and climate change. Center for Global Development, Washington DC.

Smit, B. *et al*. 2001: Adaptation to climate change in the context of sustainable development and equity. In McCarthy, J.J., Canziani, O., Leary, N.A., Dokken, D.J. and White, K.S., editors, *Climate change 2001: impacts, adaptation and vulnerability*. IPCC Working Group II. Cambridge: Cambridge University Press, 877–912.

Smith, K.R., Uma, R., Kishore, V.V.N., 2000. Greenhouse Gases from Small-scale Combustion Devices in Developing Countries. United States Environmental Protection Agency, Washington, DC.

Thomas. D. (1990). Intra-household Resource Allocation: An Inferential Approach. Journal of Human Resources. VoL 25. pp. 636-64.

Thomas, 1993. The Distribution of Income and Expenditure within the Household. Annales d'Économie et de Statistique 109. https://doi.org/10.2307/20075898

United Nations (2015) 'Sustainable development goals' [online], United Nations Sustainable Development Knowledge Platform [accessed 7 December 2018].

United Nations Development Programme (UNDP) (2011) Ensuring gender equity in climate change financing [pdf], New York: UNDP [accessed 10 October 2018].

United Nations Development Programme (UNDP) (2011) Training module 4: Gender and energy [pdf], Gender and Climate Change: Capacity development series, Asia and the Pacific. New York: UNDP [accessed 10 October 2018].

Vereinte Nationen (Ed.), 2009. Women's control over economic resources and access to financial resources, including microfinance, World survey on the role of women in development. United Nations, New York, NY.

Williams, M. (2016). Gender and climate change financing. New York: Routledge.

Yadoo, A., Cruickshank, H., 2012. The role for low carbon electrification technologies in poverty reduction and climate change strategies: A focus on renewable energy mini-grids with case studies in Nepal, Peru and Kenya. Energy Policy 42, 591–602. https://doi.org/10.1016/j.enpol.2011.12.029

Zimmermann, L., 2012. Reconsidering Gender Bias in Intrahousehold Allocation in India. Journal of Development Studies 48, 151–163. https://doi.org/10.1080/00220388.2011.629652

Appendix
A1: Tables

Table 1: Highest female adult education level in household

Highest female adult education	Freq. (Pooled)	Percent	Freq. (Rural)	Percent (Rural)	Freq. (Urban)	Percent (Urban)
None	14,949	37.82	12,352	45.85	2,596	20.64
1st class	169	0.43	150	0.56	20	0.16
2nd class	537	1.36	415	1.54	122	0.97
3rd class	845	2.14	635	2.36	210	1.67
4th class	1,138	2.88	846	3.14	292	2.32
5th class	3,207	8.12	2,345	8.70	863	6.86
6th class	1,035	2.62	705	2.62	330	2.62
7th class	2,001	5.06	1,284	4.77	717	5.70
8th class	2,851	7.21	1,928	7.16	923	7.34
9th class	2,662	6.74	1,636	6.07	1,027	8.16
Secondary (10th class)	3,513	8.89	1,842	6.84	1,671	13.28
11th class	516	1.3	305	1.13	211	1.68
High secondary (12th class)	2,677	6.77	1,367	5.07	1,310	10.41
Bachelor's	2,210	5.59	754	2.80	1,456	11.57
Above bachelor's	1,212	3.07	378	1.40	835	6.63
Total	39,523	100	26,941	100	12,582	100

Note: The sample sizes for urban and rural subsamples are lower than the full sample used in the regression. This is because the IHDS-II is a survey, and restricting based on different variables results in observations being dropped due to some questions being left unanswered by respondents.

Table 2: Frequency of fuel collection (adult women)

FuelFreq	Freq.	Percent
Daily	2,724	22.28
Weekly	6,825	55.82
Monthly	1,728	14.13
Quarterly	584	4.78
Yearly	365	2.99
Total	12,226	100

Note: The sample size is lower than the full sample used in the regression. This is because the IHDS-II is a survey, and restricting based on different variables results in observations being dropped due to some questions being left unanswered by respondents.

Table 3: Determinants of LPG Use (Probit Model)

	Rural Interacted (1)	Urban Effect (2)	Urban (3)	Pooled Sample (4)
Educ	0.0366***			0.0261***
	(0.00106)			(0.000637)
*Educ*Urban*		-0.0203***	0.0461***	
		(0.00138)	(0.002512)	
Lincome	0.0349***			0.0256***
	(0.00459)			(0.002220)
*Lincome*Urban*		-0.00861	0.07403***	
		(0.00650)	(0.01324)	
Women	-0.0102*			-0.00671*
	(0.00616)			(0.004040)
*Women*Urban*		-0.00265	-0.03627**	
		(0.00798)	(0.01652)	
Men	0.0137***	0.0137***	0.0137***	0.0128***
	(0.00393)	(0.00393)	(0.00393)	(0.00341)
Age	0.00331***	0.00331***	0.00331***	0.00269***
	(0.00033)	(0.00033)	(0.00033)	(0.000264)
Hindu	-0.0478***	-0.0478***	-0.0478***	-0.0423***
	(0.00844)	(0.00844)	(0.00844)	(0.00706)
Urban	0.501***	0.501***	0.501***	0.253***
	(0.06580)	(0.06580)	(0.06580)	(0.0066)
Pseudo R^2	0.1917	0.1917	0.1917	0.1917
Observations	39,430	39,430	39,430	39,430

Note: Probit estimations. The reported coefficients in columns (1) and (2) are marginal effects. Standard errors in parenthesis. (***, **, *) indicates statistical significance at the (1, 5, 1) level. Dependent variable = 1 if LPG fuel is used primarily for cooking. Coefficients in (1) denote effect of the interacted independent variables on the dependent variable for the rural population (i.e., where *Urban*==0). Coefficients in (2) denote the isolated effect of the interaction term, i.e. the difference in the effect on the dependent variable between the urban and rural subsamples for interacted variables. Coefficients in (3) denote the effect of the interacted independent variables on the dependent variable for the urban population (i.e., where *Urban*==1). Column (4) shows the effect of the independent variable on the full sample, and is estimated by running the probit model without the interaction terms.

Table 4: Determinants of LPG Use (Linear Probability Model)

	Rural Interacted (1)	Urban Effect (2)	Urban (3)	Pooled Sample (4)
Educ	0.0313***			0.0332***
	(0.00086)			(0.000599)
*Educ*Urban*	-0.0140***	-0.0203***	0.0173***	
	(0.00126)	(0.00138)	(0.000925)	
Lincome	0.0254***			0.0399***
	(0.00244)			(0.002360)
*Lincome*Urban*	0.00286	-0.00861	0.02831***	
	(0.00540)	(0.00650)	(0.004847)	
Women	-0.0066			-0.0208***
	(0.00500)			(0.004150)
*Women*Urban*	-0.00603	-0.00265	-0.01263**	
	(0.00733)	(0.00798)	(0.00592)	
Men	0.0122***	0.0122***	0.0122***	0.0122***
	(0.00341)	(0.00341)	(0.00341)	(0.00341)
Age	0.00284***	0.00284***	0.00284***	0.00284***
	(0.00026)	(0.00026)	(0.00026)	(0.00026)
Hindu	-0.0418***	-0.0418***	-0.0418***	-0.0418***
	(0.00705)	(0.00705)	(0.00705)	(0.00705)
Urban	0.322***	0.322***	0.322***	-0.195***
	(0.05980)	(0.05980)	(0.05980)	-0.0249
Constant	-0.218***	-0.218***	-0.218***	-0.218***
R^2	0.23	0.23	0.23	0.23
Observations	39,430	39,430	39,430	39,430

Note: LPM estimations. The reported coefficients in columns (1) and (2) are marginal effects. Standard errors in parenthesis. (***, **, *) indicates statistical significance at the (1, 5, 1) level. Dependent variable = 1 if LPG fuel is used primarily for cooking. Coefficients in (1) denote effect of the interacted independent variables on the dependent variable for the rural population (i.e., where *Urban*==0). Coefficients in (2) denote the isolated effect of the interaction term, i.e. the difference in the effect on the dependent variable between the urban and rural subsamples for interacted variables. Coefficients in (3) denote the effect of the interacted independent variables on the dependent variable for the urban population (i.e., where *Urban*==1). Column (4) shows the effect of the independent variable on the full sample, and is estimated by running the LPM without the interaction terms.

A2: Summary statistics

Variable name	Description	Mean	Std. Dev.	Min	Max
LPGcook	1 if respondent reports that the main use of LPG in household is cooking, 0 if otherwise	0.3490	0.4766	0	1
LPGfuel	1 if household uses LPG for any purpose, 0 if otherwise (DS2)	0.4397	0.4964	0	1
Educ	Highest education level attained by an adult woman in household (DS3)	5.486	5.1780	0	16
Income	Total household income (DS3)	125301	20300	100	11400000
LIncome	Log of household income	11.23	1.0011	4.605	16
Women	No. of adult women in HH (DS3)	1.602	0.8166	0	9
Men	No. of adult men in HH (DS3)	1.513	0.9103	0	9
Age	Age measured in years	22.72	10.323	1	62
Hindu	1 if head of household's religion is Hindu, 0 if otherwise (DS2)	0.8207	0.3836	0	1
Urban	1 if urban household, 0 if rural household (DS3)	0.3208	0.4668	0	1

A3: Theoretical model

Assume that there exists a multi-member household where decisions on expenditure are made by two utility-maximizing members, the man (*m*) and woman (*w*). Hoddinott & Haddad (1995) use a Nash equilibrium model to show that as income share of one member in the household rises, it is clearly reflected in the pattern of household expenditure because the share of household income spent on that individual's preferred set of goods will rise.

$$\max U^W (gt, \sim gt^{m}, \sim gt^{f}) \text{ subject to } \rho * (\sim gt^{m}, gt) \leq y_f$$

Similarly,

$$\max U^M (gt, \sim gt^{f}, \sim gt^{m}) \text{ subject to } \rho * (\sim gt^{f}, gt) \leq y_m$$

Where

U^W is the utility of the woman in the household
U^M is the utility of the man in the household
gt is the purchase of green technology
$\sim gt^{m}$ is a vector of the purchase of non-green technology goods made from the man's income. The woman takes as a given when making decisions to maximize her utility.
$\sim gt^{f}$ is a vector of the purchase of non-green technology goods made from the woman's income
ρ is the associated vector of prices associated with non-green technology goods
y_f is the woman's earned income
y_m is the man's income.

While Hoddinott & Haddad (1995) use a vector of purchases and their corresponding prices to compute preference, I am assuming a simpler model that only takes into account the preferences of men and women with regard to the purchase of green technology. If both *m* and *w* derive different utilities from green technology consumption, they would realize different outcomes in the pursuit of utility maximization. Thus, when one member's bargaining power in the household increases, they have more power for their preferences to be realized and reflected in household consumption decisions over the other member's. The experimental design in this paper can be used to test this theory. By increasing either *m* or *w*'s bargaining power through access to credit from microfinance programs, we could test whether one has an increased propensity to purchase green technology for the household over the other in the pursuit of utility maximization.