"Stop the killer in the Kitchen": Do women's intrahousehold bargaining power trigger clean fuel adoption? Evidence from Senegal

By:

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ABSTRACT

Fuel switching models to understand the high dependency of Sub Saharan African households on traditional fuels have been blind beneath and above the household level, undermining the role played by intra-household (women's) bargaining and the household's embeddedness in its external environment (informal institutions). As a result, there is still a lack of understanding of the region's high dependency on solid fuels. Using the case of Senegal, this paper suggests that intra-household bargaining and informal institutions in which households are embedded in, also affect the adoption and the transition from traditional to clean fuels. It bridges the knowledge gap on those issues by assessing not just the solely one way effect of women's bargaining power on clean fuel adoption but also the reverse effect of the type of fuel used on the bargaining power of the women. Using a Simultaneous Equation Model, We found in line with the literature that while some socio-economic characteristics matter in the adoption of clean fuel (age, household size, land and house ownership, wealth, earnings, religion, region, type of residence, education); woman's intrahousehold bargaining power(measured using a Latent Trait Model) and clean fuel uptake also simultaneously interact. In fact, while an increase of woman's intrahousehold bargaining power leads to an increase of clean fuel adoption, households using a clean fuel are the ones with woman having a high level of bargaining power./.

Key Words: intra-household bargaining, informal institutions, clean fuel, adoption

JEL: D13, J13, C13, C70

1. INTRODUCTION

1.1. Background and motivation

Considering the growing pressure on natural resources catalyzed by the rapid population growth in urban and rural areas, climate change has become a pressing issue in the developing world. Indeed, even if there is no binding target in term of greenhouse gas emissions reduction, developing countries might avoid passing through the same polluted stages of developed economies, by leapfrog environmentally with a shift from the use of intensive to low carbon energy technologies. However, according to the International Energy Agency (2014), almost 03 billion of people in developing countries, mostly in Sub Saharan Africa (75%) and South East Asia, still rely on solid fuels (animal dung, wood, charcoal, crop residues, etc.) to meet their domestic energy needs, creating a room for higher global warming through the smoke that emanates from stoves fueled by these solids. Indeed, the primary constituent of this smoke is what scientists call "black carbon" which warms the planet. Black carbon absorbs the sunlight directly in the air and releases the trapped energy as heat, warming the air. (The Hindu, 2015). Many leading scientists believe black carbon to be the most potent warming agent after CO2.

In Sub-Saharan African countries, 76% of the population in rural areas uses firewood as fuels for cooking and heating, generating a great amount of pollution through the release of black carbon and CO2 (IEA 2006). Consequently, 730 million tons of traditional biomass is burned in developing countries, producing more than 1 billion tons of carbon dioxide per year (WHO 2006). It is also worth mentioning that around 1000 mg of particles is released per m^3 of solid fuel, equivalent to the smoke of 02 packets of cigarettes per day (Todd J.J., 2003).

Indoor Air Pollution as the main consequence of this extensive use of wood fired stoves by households is listed as the 4th most important risk factor for disease worldwide, (lung cancer, acute lower respiratory infection, pulmonary disease, etc.), responsible for about 4.3 million deaths per year, primarily women and children (2014 WHO report). If nothing is done, the International Energy Agency forecasts that in 2030, Indoor Air Pollution will be the most important source of deaths in the developing world, outpacing Malaria and Aids.

On top of that, this dependency on smokier fuel by households leads to the tremendous increase of deforestation rate, with an extensive loss of biodiversity but also the creation of tropospheric or ground level ozone. If the importance and benefits of ozone in the upper atmosphere is a good thing as it absorbs ultraviolet rays and help preventing disease such as cancer, it doesn't

hold at the ground level. In fact, it substantially affects agriculture, one of the main sources of income in Sub Saharan Africa, by lowering crop yields of farmers with substantive harmful consequences for their livelihoods.

Aware of this urgent situation, the United Nations Millennium Project aimed to halve the number of households using traditional biomass for cooking by 2015, involving about 1.3 billion people switching to cleaner fuels. In the post 2015 Sustainable Development Goals Agenda, this aim has been reiterated under the Goal number 7 by endeavoring to ensure universal access to affordable, reliable and modern energy services for all by 2030. Also, the Global Alliance of Clean Cooking stove is willing to foster the adoption of clean stoves in 100 million households by 2020. Hence, it is more than a necessity to improve our understanding of the household's decision making process underpinning fuel switching in order to support policies to make this transition happens.

1.2. Research context

The dominant approach to understand households' energy behavior in developing countries has long been focused on the energy ladder theory, considering fuel switching from inferior (dung, wood, charcoal) to more efficient ones (Kerosene, Gas, LPG, electricity) as a linear process solely constrained by economic factors (cost, prices); acting as hurdles to the upwards movement on the ladder. (Akabah, 1990; Dovie et al., 2004). Strong criticisms have been directed towards this theory with some authors considering it much more a myth than a reality (Van der Kroon B. et al, 2013).

Indeed, alternative findings reveal that rather than being a leap, energy transition to modern fuel by households is more an incremental process, with the phenomenon of fuel stacking and multiple fuel use. Empirical investigations show that even households with larger income tend to revert to the use of traditional fuels, after adopting modern one (Hiemstra and Hovorka, 2008). Also, some poor households, even when having access to modern fuel continue using traditional cookstoves. Others don't even adopt clean fuels when freely offered (Miller and Mushfiq, 2013).Thereby, the idea of wood as the fuel of the poor has been removed, paving the way to another strand of the literature investigating non economic impediments of fuel switching (Masera et al., 2000; Mekonnen et al., 2008). Thus, social and cultural norms have been recognized as important determinants of switching to cleaner fuels (Arnold et al., 2006; Martins, 2005). Specifically, gender and social capital have been pointed as important determinants of

households' energy behavior (Holger, 2011; McMichael, 2007; Adrianzén, 2009), contributing to the acknowledgement of the role of informal institutions on modern fuel uptake.

Thereby, Sonntag (2009), by criticizing the stated assumption of households considered as a single rational economic individual, suggests that intra household bargaining is likely to affect household energy consumption decisions but didn't elaborate the idea. This implies that gender and mostly relative women's intrahousehold bargaining power are other key variables that have to be considered when trying to understand clean fuel uptake.

This research aims to further the discourse on the high dependency of Sub Saharan African households on traditional biomass by shedding new light on the role played by intrahousehold inequalities or uneven intrahousehold bargaining power between women and men as other important determinants of clean fuel adoption. As women are highly involved on household energy use in developing countries and especially in Sub Saharan Africa (fetching fuel for cooking and heating), it also assesses the reverse effect, often undermined; of the type of fuel used on woman's bargaining power. The broad literature on household's technology adoption would be reviewed first before moving to the specific one on clean fuel.

2. LITERATURE REVIEW

2.1. Literature review on the determinants of technology adoption

The traditional literature of technology adoption at the household level firstly focused on socio-economic constraints before recognizing alternative factors such as institutions (formal and informal) at the forefront. These factors have all been incorporated in the Model of Adoption of Technology in Households (MATH) by Brown and Venkatesh (2006) disentangled on household's beliefs (Attitudinal, normative and control) and life cycle variables (age, income, gender and marital status). More recently, with the growing acceptance of the non unitary model of households, the effect of intrahousehold interactions on technology adoption has been addressed.

2.1.1. Socio-economic determinants

Drawing upon the neoclassical rational theory, it has been assumed that a household will decide to adopt a new technology if the expected discounted utility of adoption outweighs the costs. Thus, if the direct and indirect costs of the technology are high, it is more likely that the

household will not adopt the technology as reported in the "control beliefs" of the MATH. Consequently, an increase of the technology's price will obviously diminish the welfare gain, creating a selecting and screening out effect. Dupas (2009) considering the uptake of bednets also shows that liquidity constraints are a major impediment of their adoption. Aikens et al. (1975) with their economic constraint model reveal different economic factors (resource endowments, income and access to capital) as major determinants of technology adoption. Uncertainty and risk aversion, referred to the "fear of technological advance" under the "Control of beliefs" determinants in the MATH have also been pointed out as important impediments of technology adoption with risk perception often associated with the socio economic status of households. To support this idea, Giné and Klonner (2006) reveal the low probability of poor households to adopt risky technology relatively to richer one.

As more social determinants of technology adoption, the level of human capital (referred as the "requisite knowledge" in the MATH framework) has been revealed as an important factor of technology adoption through two main channels: the increase of income by relaxing credit constraint and the improvement of information access, conformably with the innovation diffusion model of Rogers (1995). Besides, education could also improve the understanding of complex innovation and enhance learning ability (Rosenweig and Schutlz, 1989; Foster and Rosenweig, 2010). Several empirical evidences confirmed the role of education on the adoption of new technology (Kremer and Miguel, 2007; Lleras-Muney and Lichtenberg, 2002; etc.). Considering the supply side perspective, it has been proven that a lack of suitable infrastructure may hinder technology adoption by households (Suri, 2009). Household life cycle variables namely age, marital status and the number of children have also been underlined in the extended MATH framework as important variable of technology adoption as well as social influences (friends and family, secondary sources, etc.). The latter, incorporated in the concept of normative beliefs in the MATH are embedded in the broader concept of institutions.

2.1.2. Formal and informal institutional determinants of technology adoption

The recent literature of economic development has widely acknowledged the role of institutions as ultimate sources of economic growth. (Acemoglu et al., 2001). Defined as "humanly devised constraints that shape human interactions", institutions as formal and informal rules of the games reduce uncertainty and transactions costs among economic agents, conducive to economic growth (North, 1990). If too much emphasis has been put on formal institutions, especially the rule of law and the protection of property rights, there are far from being the solely constraints of

human behavior. Norms, values, beliefs, trust and social capital also matter as recognized in the informal institutional literature. The seminal paper of Max Weber (1976) argues that there is a relationship between religious affiliation and economic development as he found that countries with a high proportion of protestant citizens were more economically successful than others. Also, by decreasing the cost of transactions and increasing the level of cooperation, trust leads to the enhancement of economic growth (La Porta et al, 1997; Knack and Keefer, 1997). Furthermore, social capital as a proxy of informal institutions has been identified as a main source of economic development. (Woolcock, 1998; Christoforou, 2013)

With the recognition of technology adoption as a key driver for economic growth, empirical investigations on the relationship between institutions and technology uptake have also been addressed in the literature. At the macro level, it has been proven that countries with better institutional quality are the one with faster rates of technology adoption (Fabio Manca, 2009). At the micro level, Infante and Smirnova (2009) show that when the rule of law is strong, the adoption of environmental friendly technology tends to be more frequent. Also, Jeannin (2012) argues that households with property rights have a higher probability to adopt new (energy and agricultural) technology. The same result has been confirmed by Goldstein and Udry (2002; 2008) and Feder et al. (1985).

So far, institutional barriers to technology adoption have been focused on formal institutions, overlooking informal one. Nevertheless, traditions, religious and social norms could impede technology adoption (Jeannin, 2012; Munshi and Myaux, 2006; Duesenberry and Stemble, 1949, Slowinkowski and Jarratt, 1997). Recently, the role of social capital, consistent with the innovation diffusion model of Rogers (1995) has been acknowledged. Indeed, by enhancing collection action and social learning, assuming individuals' behavior and opinions are influenced by their network; social capital might foster the process of technology adoption. Thus, Isham (2000) found a positive relationship between tribally-based social affiliations and adoption of improved fertilizers in Tanzania. Katungi et al. (2006) and Lee (2011) found similar results. Bandiera and Rasul (2006) also pointed out the role of social networks and peer effect on technology adoption. Using membership to group as a proxy of social capital, Sulo et al (2012) found it significant in the uptake of agricultural innovation in Kenya. Magnan et al. (2013) underlined a gender difference on networks affecting technology adoption. Venkatesh and Morris (2000) extended the Technology Acceptance Model of Davis (1989) by adding a gender dimension which has been found significant for technology adoption. This paves the way to the literature on difference in preference between men and women regarding household's technology adoption, discussed in the following section.

2.1.3. Intrahousehold bargaining and technology adoption

The empirical rejection of the unitary model in both developed and developing countries where household's preferences are assumed to be identical leads to the conclusion that some sort of bargaining process exists within the household. (See Manser and Brown, 1981; Lundberg and Pollak, 1993; McElroy M. and Horney M., 1981, Strauss and Thomas, 1995; Haddad et al, 1997). So far, the intra-household literature has been interested on the way individual heterogeneous preferences, specifically women's preference relatively to their partner affect production and consumption decisions (Duflo and Udry 2004; Quisumbing and Maluccio 2003; McPeak and Doss 2006, Haddad et al., 1997). As preferences are unobserved, power has been used in the intrahousehold literature to represent preferences with the underlying assumption that the higher a woman's bargaining power is inside the household, the better she is able to influence the intrahousehold decision making process and the allocation of resources.

Thereby, if a gender bias has been found on fertility, food, health and children's education decisions, with an increase of woman's bargaining power in the house affecting each of these outcomes (Rubalcava et al, 2004; Schimdt et al, 2012;); there is still a scarce literature on the effect of intrahousehold bargaining on technology adoption. Volman and Van-Eck (2001) found that males are more likely to adopt new technology that women. Jeannin(2012) also reported that health-related technology adoption is likely to vary with partners' bargaining power. Zhou and Xu (2007) revealed the existence of a substantial gender-bias on educational technology adoption. On the contrary, Doss and Morris (2001) found gender neutrality on improved maize adoption in Ghana. Overall, among the paucity of the literature on intrahousehold bargaining and technology adoption, there is enough evidence of the existence of a gender bias on technology adoption (See e.g. Appleton, 1995).

2.2. Determinants of modern fuel adoption: what has been done?

2.2.1. Socio-economic determinants of modern fuel uptake

Firstly dominated by the energy ladder theory, the determinants of fuel transition has recently been focused on non economic factors after acknowledging that income and price are not the solely determinants of the move up the ladder (A. Mekonnen, 2009). Willing to understand the socio-demographic determinants of household energy behavior, Shimoda (2007) and Sardianou (2008) found that the number and the age of people in the household matter. Related, Hosier and Dowd (1987) found that larger households are more likely to adopt cleaner fuel. Ouedraogo B.

(2006) found a significant relationship between household ownership and the likelihood of using firewood, with tenants having a higher probability of using non solid fuel in Burkina Faso. This finding has been confirmed by Pundo and Fraser (2006) in rural Kenya.

2.2.2. Informal institutions and clean fuel adoption

Informal institutions, namely norms and cultural factors constraining household behavior have also been pointed out as important factors for fuel switching (Masera et al, 2000; Barnes et al., 1996; Foley, G, 1995; Israel D., 2002). Heltberg (2005) found a significant difference between indigenous and non indigenous ethnic groups in term of fuel portfolios in urban Guatemala. Religion has also been found relevant for fuel transition with Muslim less likely to use modern fuel (Rao and Reddy, 2007).

2.2.3. Intrahousehold bargaining and modern fuel uptake

Taking the non unitary model perspective and considering that men and women perceive climate risk differently (Stallen and Thomas, 1988), Beltramo T. et al. (2014) use an experimental approach in Uganda and found that women's bargaining power, proxied by the additional assets they owned , increase the willingness to pay for non traditionnal cookstoves by 10%. Miller and Mobarak (2013) found that men are more likely to refuse to pay for clean cookstoves and Meredith et al. (2013) underlined men and women's inequality on the decision sharing rule in the household as a key impediment of clean fuel adoption. Mohapatra et al. (2014) using an adoption-empowerment system of equation, namely a probit-ordered probit model in a representative cross national survey in rural Indias found that women's intrahousehold bargaining power could increase Improved Cook Stove. Kishore et al. (2012) using a causal identification strategy on two nationally representative datasets found similar results in rural India with low women's intrahousehold status associated with a low uptake of clean fuel.

2.3. Research gap(s)

Drawing upon the non unitary model, the existing literature on technology adoption in general acknowledges the role of informal institutions and intrahousehold inequalities as important determinants. Nonetheless,

(i) The one way effect of intrahousehold inequalities or bargaining power on the uptake of climate change mitigation technology such as clean fuel is still understudied.

Moreover, women being the most involved parties on household energy use, they bear the main responsibility for supplying, fetching and collecting firewood for cooking and heating. Drought, uncertain rainfall and deforestation make these tasks more time-consuming, threaten women's livelihoods and prevent them to engage themselves on learning and income generating activities or to participate in the life of their community. Thereby, there is also a clear connection, better, a reverse effect between the type of fuel used at the household level and intrahousehold inequalities (relative women's bargaining power) that previous research on the subject tend to undermine. This research aims to fill this gap by also assessing:

(ii) The reverse effect of the type of fuel adopted on the level of intrahousehold inequalities.

Also, as intra-household decision-making is far from being a static phenomenon but a dynamic process (See Malhotra et al, 2002; Kabeer, 2001), evolving with the change of social norms and beliefs (gendered informal institutions), there is a connection between informal institutions and power relationship within the house. For example, societies where women have few existing opportunities, with social norms hindering their participation in the labor market or other ownership rights would not be able to participate or have less to say in the household's decision making process which would expect to be under the husband's control (Olmstead 1998). Therefore, this research will also:

(iii) Contribute to the empirical assessment of the effect of different features of informal institutions on woman's bargaining power. It adds to the literature of determinants and consequences of technology adoption and bargaining power at the household level.

2.4. Research questions

The overarching aim of this paper is the improvement of our understanding of "why the dependency on traditional fuel in Sub Saharan Africa/ Senegal is still high?" Specifically, the following questions will be answered:

(a) What are the core determinants of modern fuel in Senegal?

(b) To what extent informal institutions and women's bargaining power matter?

(c) What is the consequence of the type of fuel adopted on women's bargaining power?

(d) How do gendered informal institutions (husband rights, wife beating justification, perception of Female Genital Mutilation) as well as social capital, religion and ethnicity affect women's bargaining power?

The answers of these questions start with the definition of succinct conceptual and analytical frameworks prior to the empirical estimation.

3. FRAMEWORK OF ANALYSIS

3.1. Conceptual framework

Following Mohapatra et al. (2014), we consider a cooperative household with two decision making homo oeconomicus, the husband (m) and his wife (f) with a single private good (x) and a single public good(s) . Here we assume that air is the public good consumed by agents or its inverse, Indoor Air Pollution or Smoke which brings a disutility for both of them.

The preferences towards those two goods are also assumed to be different since men and women tend to bear differently the burden or cost of fuel collection and use.

Therefore, considering ψ_i as the disutility function (strictly increasing and strictly convex) (Basu, 2006) of the individual i stemming from the consumption of the public good s, the global (quasi-linear) utility functions of the woman and the man are defined as follow:

$$u_f = -\psi_f(s) + x \quad \textit{(1)}$$

$$u_m = -\psi_m(s) + x \quad \textit{(2)}$$

We also assume that the marginal women's disutility from smoke is at least equal to the marginal men's disutility from the same public good. ($\psi'_f(s) \geq \psi'_m(s)$).

The total household utility function could then be written as follow:

$U = \pi(\lambda)\, u_f + (1 - \pi(\lambda))\, u_m$ **(3)** Which could be rewritten as:

$U = \pi(\lambda)\left(-\psi_f(s) + x\right) + (1 - \pi(\lambda))(-\psi_m(s) + x)$ **(4)**

Where $\pi(\lambda) \in [0,1]$ is defined as the weight assigned to the women which itself depends on the level of authority of the woman in the household (λ); which is contingent to a set of individual, household and institutional characteristics.

For sake of simplicity, we consider a unitary price and considering $\Gamma(s)$ as a technology that could be bought by the household to curb the level of smoke; the budget constraint of the household is given as:

$w = x + \Gamma(s)$ **(5)**

w being the wealth of the household.

The properties of Γ are as follow:

i) $\Gamma'(-s) > 0$ or $\Gamma'(-s) < 0$

ii) $\Gamma'(s) > 0$ or $\Gamma''(s) < 0$

That means that the technology Γ is convex and increases with the level of smoke reduction.

In other words, the value of the technology increases with the level of smoke it helps to cut down.

Thereby, by replacing the budget constraint in the Total utility function of the household;

We end up with the following equation:

$$U = \pi(\lambda)\left(-\psi_f(s) + w - \Gamma(s)\right) + (1 - \pi(\lambda))(-\psi_m(s) + w - \Gamma(s)) \quad \textbf{(7)}$$

The variant parameter here being s, the First Order Condition here is given by the derivative of U regarding s.

Thereby:

$$\frac{\partial U}{\partial \lambda} = 0 \iff = FOC(\lambda, s)$$

$$\frac{\partial U}{\partial \lambda} = 0 \iff \pi(\lambda)\,\psi'_f(s) + (1 - \pi(\lambda))\,\psi'_m(s) + \Gamma'(s)$$

Here we are interested at looking at how the adoption of fuel varies with the level of women's empowerment. Thereby, we ought to derive the following expression:

$$\frac{\partial s}{\partial \lambda} = -\frac{\frac{\partial FOC}{\partial \lambda}}{\frac{\partial FOC}{\partial s}} = -\frac{\pi'(\lambda)(\psi'_f(s*) - \psi'_m(s*))}{\pi(\lambda)\psi''_f(s*) + (1-\pi(\lambda))\psi''_m(s*) + \Gamma''(s*)}$$

Thereby, considering the assumptions made previously,

$$-\frac{1}{\pi(\lambda)\psi''_f(s*) + (1-\pi(\lambda))\psi''_m(s*) + \Gamma''(s*)} > 0$$

As Γ is concave in s with $\Gamma''(s) < 0$ and $\pi(\lambda)\psi''_f(s*) + (1 - \pi(\lambda))\psi''_m(s*) = 0$

Thereby, for $\frac{\partial s}{\partial \lambda}$ ***to be greater*** than $\mathbf{0}, \boldsymbol{\pi'(\lambda)}$ should be greater than 0 and

$\boldsymbol{\psi'_f(s*) - \psi'_m(s*)}$ should also be greater than 0.

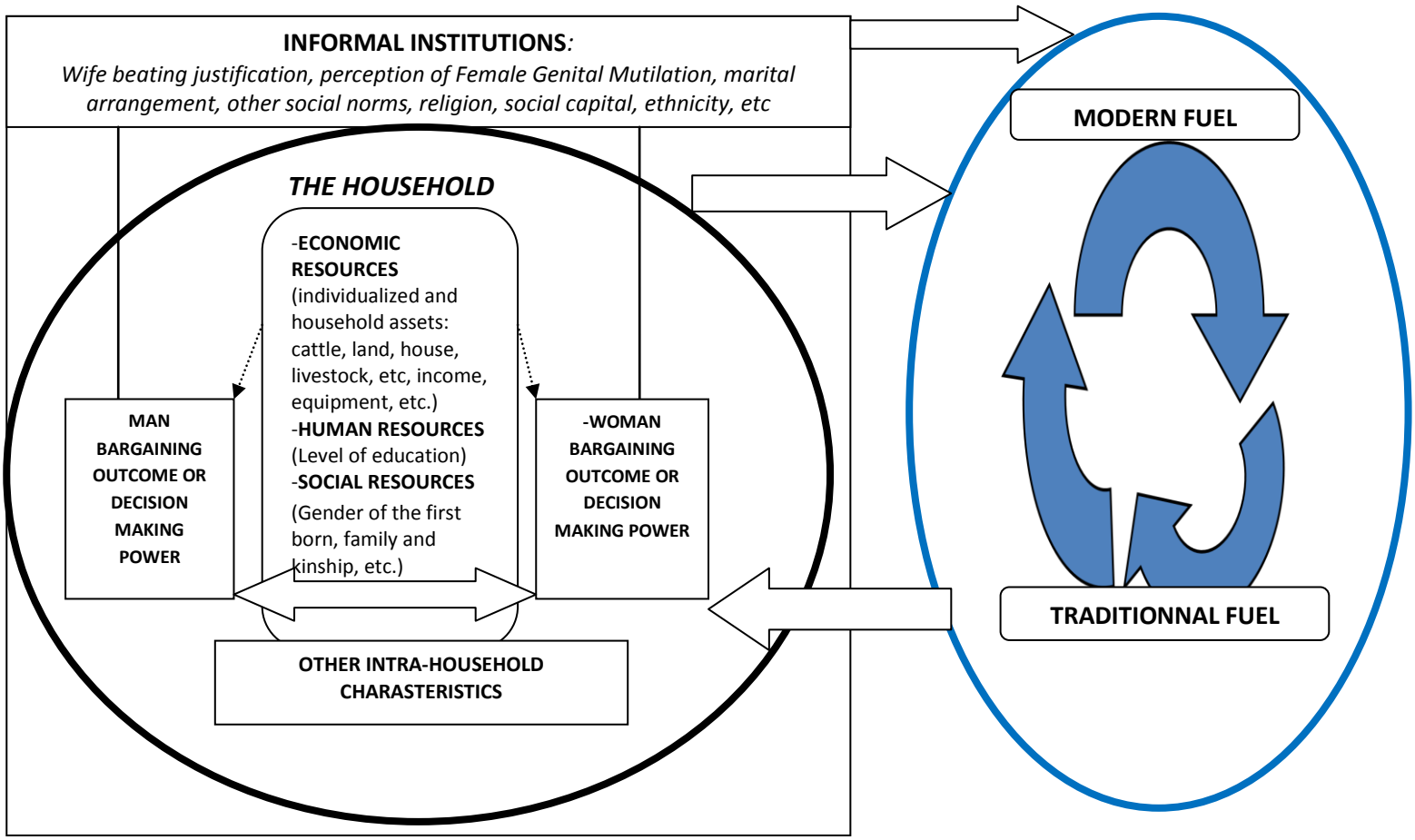
However, we have already assumed that the Utility weight of the woman $\pi(\lambda)$ increases with her level of empowerment within the household which is λ.

This implies that $\frac{\partial_{\pi(\lambda)}}{\partial \lambda} = \pi'(\lambda) > 0$.

$\frac{\partial s}{\partial \lambda} > 0 \; if \; \pi'(\lambda) > 0$ and $\psi'_f(s*) - \psi'_m(s*) > 0$

The remaining condition for $\frac{\partial s}{\partial \lambda} > 0$ is $\psi'_f(s*) - \psi'_m(s*) > 0$ implying that the Women's disutility from smoke inhalation has to be greater than the men's ones. In other words, an increase of household clean fuel uptake would happen by increasing women's intrahousehold bargaining power if the preferences of women for smoke mitigation are stronger than the one of men. Therefore, this assumption needs to be bear in mind when building our empirical framework of estimation.

3.2. Towards an analytical framework of intrahousehold bargaining, informal institutions and modern fuel transition



Source: Author

The analytical framework above shows how informal institutions, by pre-conditionnaly setting the boundaries of women's and men's interactions, affects and modify their respective economic, human and social resources and thus, the intra-household bargaining (Bilisuma Bushie,

2011; Care, 2006). Hence, woman's bargaining outcome, together with informal institutions may affect fuel adoption as well as the in and out movement from traditional to clean fuel. On the other hand, the type of fuel used by household has a reverse effect on intrahousehold bargaining and children's health.

4. Data

In order to fulfill our analysis, a necessity to have a data set with complete information on intrahousehold bargaining power measures, informal institutions and fuel uptake proxies are of a great importance. Fortunately, the newly advertised 2014 DHS data sets from Senegal has been used and a thorough description of the database is provided in the following sub section.

4.1. Sources

We use the most recent waves of the gender disaggregated National Demographic and Health Survey of Senegal with a questionnaire specifically dedicated to women, making the direct and indirect measures of woman's bargaining power easier.

Launched since 1984 by the USAID, the Demographic and Health Survey (DHS) are household surveys with large representative samples at national and sub national levels covering a variety of topics, mostly in health and demography. The DHS also put a specific emphasis on 15-49 years old women, asking them questions related to their health and the one of their children. There is also a questionnaire dedicated to men.

For the purpose of our analysis, an unweighted sample of monogamous couples (married or living together) has been selected. The reason of non restricting our sample to just couples who are married is to avoid having a selection bias in the analysis as couples with the most disagreement in decision making are more likely to split. As for now, our Analysis will be based on the 2014 cross section with 5558 15-49 years old married women.

4.2. Variables

4.2.1. The measurement of clean /modern fuel uptake

The type of fuel used will be a binary variable taken the value 1 if the household uses a modern fuel (LPG, electricity and kerosene) and 0 otherwise (dung, wood, charcoal, crop residues)

4.2.2. The measurement of intrahousehold bargaining power

The empirical measurement of the Bargaining power inside the household is a daunting and challenging task (Varadharajan, 2003; Agarwal, 1997; Kabeer, 2001, Malhotra et al., 2002) for two main reasons: fistly, the suitable definition of a measure of power that acts as a determinant of

the outcome of interest is difficult. Secondly, the underlying factors used to compute the bargaining power measure happen to be part of the variables that also influence the outcome of interest, leading to the common econometric problem of endogeneity.

There are two existing types of measures of bargaining power inside the household: direct or self reported measures of empowerment and indirect. The direct proxy of bargaining power mostly referred to the effective participation of the husband or the wife in the decision making inside the household (Agarwal, 1997) assuming that a woman or a man has a stronger bargaining power or agency if she/he is participating more to the decision making inside the household.

The indirect measures are mostly the determinants of the bargaining power itself and encompasse variables such as access and control over resources (Land, Credit, etc.) and the difference in the level of income and education between the husband and the wife.

4.2.2.1. The indirect measure of intrahousehold bargaining power

Indirect measures of woman's bargaining power comprise the Mother's level education (Handa,1996; Thomas, 1994) and age; assets brought to marriage by the woman; Woman's share of (unearned) income (Thomas, 1990; Schultz,1990); assets[1] accumulated during the marriage (Beegle et al., 2001) as well as woman's relative family and background status . Handa (1996) using maternal education as a proxy of bargaining power reveals its significant effect on children's schooling decision while Thomas(1994) using a similar proxy finds a significant effect on children's health outcomes. Quisumbing and Malucio (2003) found similar result by using assets brought to mariage as a proxy of bargaining power.

4.2.2.2. The direct measure of intrahousehold bargaining power

4.2.2.2.1 Variables used for the direct measurement of bargaining power

Instead of considering the determinants of empowerment to proxy the level of woman's bargaining power, direct or self reported measures could be used. These measures generally refer to decision making in several areas of life to proxy empowerment. (See Ahmed, 2006; Ghuman, 2003).

Generally, in the DHS survey since 2000/ 2001, a specific section on ' decision making inside the household' has been introduced and the different questions that are being asked to both the husband and the wife are the following : (i) *Woman say on health expenditure* (ii) *woman say on*

[1] Assets here referred to the house occupied by the household, other house or building, farm land ,livestock, vehicles, household appliances, savings, jewelry, furnitures, etc.

large/major household purchases or daily household needs (iii) *woman say on family/relatives visits*. (iv) *Woman say on the way the money is spent*.

Five categories of answers are usually considered: The husband decides, the wife decides, husband and wide jointly decide, someone else and wife jointly decide and someone else decides. Thereby, a woman is considered to be empowered where she unilaterally or jointly makes the decision making. The value 1 is therefore granted in the newly dichotomous measure of Woman's intrahousehold bargaining power. Otherwise, the value 0 is given and in that case, the woman is said to be disempowered or with a lack of agency. Following (Varadharajan, 2003), we would use the response given by the wife as it has been shown that the response given by the spouse (husband) could over or under represent the true level of the woman's bargaining power inside the household. An overview of the section on intrahousehold decision making as presented in the questionnaire could be seen in Annex 1.

However, in a very recent literature on the measurememt of women's empowerment, It has been suggested as a way forward to come up with a more 'contextualised' set of domains where the involvement in the decision making process should be assesses, rather than using preestablished ones that doesn't necessary reflect the different domains women think they has to be empowered.(See Peterman et al., 2015; Bishop et al., 2014, Carter et al. 2014). In fact, the canonical domains (decision in large household purchases , children's health, visits to family or relative, etc.) may not be the one that women think they need to have agency on. Therefore, the ' quantitative' section on decision making questions should be complemented by a qualitative ones where a woman could previously give a narative on the domain she values a lot in life or where she thinks she needs to be empowered before asking her questions on her involvement in the decision making process within the household in those domains.

While most of the authors by considering each component of direct and indirect measures of bargaining power separately, show a substantial discrepancy on the effect of this power on the outcomes of interest, some authors proceed to the aggregation of those variables into a composite index using a variety of statistical techniques.

4.2.2.2.2 Computation of the Women's bargaining power index

Due to the multidimensionnality (economic, socio-cultural, familial, legal, politiical and psychological) of the concept of power, most of the authors tend to make a summary of each of the component of direct and indirect indicators of power through on composite index. A

commun way of getting an aggregate measure of Bargaining Power is to perform a factor analysis (Filmer and Pritchett, 2001; Sahn and Stifel, 2002); as using just a single measure of power could yield incorrect estimates (the omitted variables bias).

By using a factor analysis to resume individual indirect measures of bargaining power , Varadharajan (2003) founds that his index has a positive effect on children's schooling and health. Koissy-Kpein (2013) using a composite index of women's empowerment also finds its significant and positive effect on children's schooling outcomes. However, the use of a factor analysis could only be justified when having quanttative direct or indirect measure of empowerment. When the variables aiming to capture the level of empowerment are dichotomous (as this tends to be the case with women decision making questions), the use of a Latent Trait Model is more appropriate. Varanasi (2009) and Seebens (2006) use a Latent Trait Model (LTM) to construct a latent measure of bargaining power based on binary response of household decision making questions. This model is succinctly presented in Annex B.

It is however worth mentionning that there is not a "one-size fits all" approach in terms of the measurement of bargaining power. In this study, we used the direct measure of bargaining power and indirect single indicators of power as well as the direct and indirect indices in order to capture the effect of intrahousehold bargaining power on clean fuel uptake.

4.2.3. The measurement of informal institutions

Informal institutions will be a mixture of continuous and qualitative variables. Gendered social norms will be measured as a computed index based on wife beating justification questions. These are: i) beating justified if wife goes out without telling husband, ii) beating justified if wife neglects the children. iii) beating justified if wife argues with husband iv) beating justified if wife refuses to have sex with husband v) wife justified asking husband to use condom if he has a STI . Ethnicity, region, religion will be used as qualitative variables to proxy traditions and cultural norms which are more likely to influence both the clean fuel uptake and the decision making power at the household level

5. Empirical Strategy

This section presents the empirical strategy used to assess simultaneity effect of the effect of women's bargaining power on the probability that her household adopts a clean fuel. According

to data availability, three types of methods are generally used to model technology adoption in developing countries: time series studies with the pattern of adoption measured as a logistic-shaped function, panel data and probit models based on cross sectional studies (Besley and Case, 1993).The latter will be implemented as we are in the possession of two cross sectional waves. The adoption of modern fuel will be modeled as follow:

$$Type\ of\ fuel\ used = f(Woman\ Bargaining\ power\ , etchnicity, religion, education, household\ welath, other\ control\ variables\ )$$

In line with the literature, ethnicity and religion are the two main features of informal institutions likely to affect clean fuel adoption. Also, plausible control factors are the type of residence, However, the woman decision making index is reversely affected by the type of fuel used but also by gendered informal institutions/social norms, mainly wife beating justification, religion and ethnicity but also by individual (age, education, assets owned, Whether yes or no the woman has a son) and household level bargaining (Difference in age and level of education, difference in earnings). This leads to the second relation below:

$$WomenBargpower = f(type\ of\ fuel\ used, Individual\ source\ of\ bargaining\ power, Household\ source\ of\ bargaining\ power, informal\ institutionnal\ source\ of\ bargaining\ power, other\ control\ variables)$$

As we suggested using both the single indicators of decision making power and the aggregate measure (the index obtained with the Latent Trait Model), we will successively estimate a bivariate probit model and a Simultaneous Equation Generalized Probit model. These two models are described in the following sections.

5.1 A latent Simultaneous Equation Probit model

As a first step, we would consider each of the decision making variables as proxy of women's decision making power before summing them into an index. We would therefore estimate a latent simultaneous equation model in the latent variables y_1^* and y_2^* respectively representing the bargaining power decision making variable in each of the different domains and the clean fuel uptake variable. The model is as follow:

$$y_1^* = \alpha_1 y_2^* + \beta'_1 x_2^* + \varepsilon_1,\ y_1 = 1(y_1^* > 0) \quad (1)$$

$$y_2^* = \alpha_2 y_1^* + \beta'_2 x_2^* + \varepsilon_2,\ y_2 = 1(y_2^* > 0) \quad (2)$$

It is worth mentioning that in each of the equations (1) and (2) , rather than having the observed binary variables which would lead to an unidentified model, we have the underlying latent structural variables. The model above could therefore be consistently estimated by a two step methods described by Amemiya (1979) and Maddala (1983).

5.2. A Simultaneous generalized probit model

As shown above, the relationship between clean fuel uptake and woman's intrahousehold bargaining power is a recursive one where informal institutions tends to influence both of them.

By considering an aggregate measure of woman's bargaining power given by the index computed using the Latent Trait Model approach, this variable is a continuous measure rather than a dichotomous ones as It was the case in the Bivariate Probit model presented above. The decision of uptaking a clean fuel is a dichotomous one taken the value 1 if a modern fuel is adopted and 0 otherwise. The simultaneity (or reciprocal causation) of the relationship between Woman's intrahousehold bargaining power and clean fuel uptake is analyzed using a two-stage probit least squares (2SPLS) method (Maddala, 1983).

In the presence of simultaneity, standard estimation methods result in biased and inconsistent estimates. A two-stage estimation approach provides the necessary corrections of the standard errors of estimates. However, two-stage methods (such as 2SLS) typically use continuous endogenous variables across equations. While they are useful for examining the relationship between two continuous variables, their application is limited when a continuous and a dichotomous variable are hypothesized to simultaneously determine each other. In such instances, the 2SPLS is used to account for the simultaneity of the processes. This model is therefore used for studying the association between clean fuel uptake and Woman's intrahousehold bargaining power where informal institutions are considered as being exogenous determinants of each of those variables.

To illustrate the econometric method used, a two-equation model is defined:

$$y_1^* = \alpha_1 y_2^* + \beta_1' x_1 + u_1$$

$$y_2^* = \alpha_2 y_1^* + \beta_2' x_2 + u_2$$

Here it is worth mentioning that the set of covariates x_1 and x_2 could both contained common exogenous variables where y_1^* represents the continuous women's bargaining power variables and y_2 the binary clean fuel adoption variable.

Also, $\alpha_1 \neq 0$ and $\alpha_2 \neq 0$ meaning that the error terms are contemporaneously correlated.

If both outcomes are observed, i.e. $y_1 = y_1^*$ and $y_2 = y_2^*$, then the usual simultaneous equations model applies. The 2SLS approach can be used to estimate the model, as both outcomes are continuous. However, if one outcome is observed, while the other is defined as a latent variable as it is the case here where the level of women's empowerment is a continuous observable variable and clean fuel uptake a dichotomous variable,

$y_1 = y_1^*$ and

$y_2 = y_2^*$ *if* $y_2^* > 0$ *and* $y_2 = 0$ *otherwise*

then the 2SPLS approach could be used to estimate the model (See Keshk, 2003).

6. Results

6.1 Descriptive statistics

The table A1 in the annex presents descriptive statistics of our key variable of interests. Overall about 90 % of Senegalese households, irrespective of their place or region residence rely of unclean fuel as their main source of cooking. Also, women in couples in Senegal have less say or decision making power on large household purchases (18.5%), on visit to family and friends (20.6%), on What to do with money husband earns (14.3%) and on their own health (19%). The only domain where they tend to have more say is on their own earnings where they decide at almost 92%. Overall, looking at the women's bargaining power index, they are less empowered with an average mean of 0.005 on a scale going from -0.47 to 1.74.

Also, women tend to be pretty much younger than their husband/ partner in Senegal with a difference of age of about 12 years with women being on average 31 years old. However there is almost no difference in terms of years of education between the wife and her partner/ husband and just 4.3% of women have declared to earn more than their partner, implying that the gender wage gap is still high in the country. In terms of women's asset ownership, just 15% of women have declared to own a land jointly or separately and just 14 % of them have declared to own a

house. 45% of women in our sample have said to have an occupation and the primary school tends to be the highest level education for women (19%). Without no surprise, the dominant religion is Muslim (96%) and the population ethnicity are the Poular (33%).

6.2 Econometric results

We first proceed to the estimation of a Latent Simultaneous Probit Model by considering each of our four women's decision making variable as dependent variable. The table B1 in the annex then shows that the positive effect of clean fuel adoption on women's bargaining power hold for all the different women's decision making variables. Also, in line with the literature of woman's economic empowerment, socio economic variables such as the age of the woman tends to also matter with older married woman more likely to have a greater woman's bargaining power in the household. Besides Women's land ownership and women earning more than their husband tend to have a greater bargaining power. Also, the fact of living in some regions tend to lessen the bargaining power of women (Kaolak) while other tend to enhance it (Ziguinchor and Sedhiou) underlying the role of informal institutions here.

On the other hand, a higher level of Woman's intrahousehold decision making tends to enhance the likelihood of using a clean fuel. However, our results are also consistent with the energy ladder theory with richer households more likely to use a clean fuel. Again, in consistence with the literature, the size of the households tends to matter with greater households less likely to use a clean fuel. Besides, households living in rural areas are more likely to use a traditional fuel compare to those living in urban areas. In terms of informal institutions, households practicing animism are less likely to use a clan fuel.

Moving forward, instead of considering each of the dummy decision making variables separately, as proxies of women's intrahousehold bargaining power, we've estimated a simultaneous generalized probit model with our computed Woman's bargaining power index as our outcome variable. The results here are quite similar with the previous ones. In fact, clean fuel adoption, Women's age and Women's land ownership are positively related to Women's intrahousehold bargaining power. However, new insights have been revealed. Women having spent more years in the educational system tend to have a greater bargaining power as well as women owning a house. Reversely and still similar to previous results, Households with Women with a high level of bargaining power and household wealth are more likely to uptake a clean fuel. Also, the uptake of traditional fuel is more likely to happen in the rural area rather than in the urban areas.

However, these results need to be interpreted with some caveats, specified in the following below.

7. Discussions/potential caveats

It is worth mentioning that this paper using Senegal as a case study is a preliminary research that we are willing to extend regionally and temporally; by performing our analysis using a panel data analysis including all the Sub Saharan African countries from 2000[2] onwards. That would allow us to take in account the unobserved heterogeneity spatially and to have a better measure of the informal institutions' proxy which is more likely to vary across the countries that inside each country.

Also, we have restrained our analysis to the static setting which could be misleading considering the fact that women's empowerment is far from being a static but a dynamic phenomenon. Also, the fact of just performing our analysis on a static setting doesn't allow us to explain the transition behavior of households from one fuel to another and to assess how this dynamic fuel switching behavior is affected by the change of informal institutions and women's empowerment. Our forthcoming research will focus on these issues by exploiting previous DHS household datasets.

Moreover, our theoretical framework only considers the case of cooperation between the husband and the wife. An extension to this framework in the case where there is no cooperation between those two agents should also be explored and adapt empirically to see whether the results vary.

Besides, we have made the assumption that the women, main respondent of the questionnaire is the one effectively involved in household energy use (cooking and heating), overlooking the situation where this one hire a domestic worker who is in fact the one using the fuel. By restraining our sample to rural areas where the use of domestic worker is not so common, the results obtained here could be more realistic as there is not a clear DHS question asking the woman if she is the one effectively involved in the cooking or heating process.

Furthermore; with the widespread practice of polygamy in Senegal, this research hasn't explicitly taken in account this aspect which could have an impact on the intrahousehold bargaining power of the woman. Thereby, introducing the type of marriage as informal institutions could sharpen

[2] Corresponding to the year information on Women's empowerment has started to be collected.

the results by getting them closer to the Senegalese context and reality. This also means that the conceptual framework used here with just the husband and 'one' wife should be amended.

Last but not the least, the sign of the coefficient rather than the value of the coefficient in itself needs to be interpreted here as this is a non linear model. Marginal effects would be computed in the forthcoming version of the paper.

8. Policy implications

This research aims to show that, controlling for other socio economic factors, there is a significant and simultaneous effect between women's bargaining power and the adoption of climate mitigation technologies: here clean fuel uptake using the case of Senegal. Therefore, policies aiming to enhance clean fuel uptake, 'stopping the killer in the kitchen' should focus on enhancing women's empowerment through for instance, Cash Transfer Program specifically targeting women but also education's laws keeping pregnant girls to school or ease their return to education after delivery. Indeed, harnessing the knowledge and experience of women can make natural resource management and climate change adaptation and mitigation strategies more successful. On the other hand, policies aiming to enhance women's intrahousehold bargaining power should also proceed by scaling up programs and projects to lower the uptake of traditional fuel as that would free women from the additional burden of fetching fuel.

Also, the UNECA and the African Union Commission validated late 2014 in Kigali, Rwanda, a study on "Gender Mainstreaming in implementation of Bioenergy Development in Africa". We suggest that a deep research taking stock on this preliminary study has to be undertaken where case studies from countries representative of each SROs could be performed. This could therefore be the topic of the forthcoming 2016 African Women Report with the suggested title "Moving up the ladder of Energy Value Chain for Africa's structural transformation: Where are the Women?"

9. Conclusion

The overarching goal of this research was to shed new light on how intrahousehold inequalities, (proxied here by the level of women's bargaining power) might affect the adoption of a specific climate change mitigation technologies, (here clean fuel) with a focus on Senegalese households. To the best of our knowledge, this research is the first to assess the simultaneity or the reverse

causality between informal institutions, Women's intrahousehold bargaining power and clean fuel uptake.

We found in line with the literature that while some socio-economic characteristics matter in the adoption of clean fuel (age, household size, land and house ownership, wealth, earnings, religion, region, type of residence, education); woman's intrahousehold bargaining power and clean fuel uptake also simultaneously interact. In fact, while an increase of Woman's intrahousehold bargaining power leads to an increase of clean fuel adoption, households using a clean fuel are the ones with woman having a high level of bargaining power. Thereby, policy aiming to enhance clean fuel uptake would also contribute to the enhancement of women's empowerment. Reversely, households with women more empowered would therefore be more likely to uptake clean fuel, curbing the harmful health and environmental effects of traditional ones.

Overall, this research shows that empower women is an effective responses to climate change, as that would foster the adoption of clean technologies which in turn would lower, rather than exacerbate intrahousehold inequalities between women and men.

However, this research is not at the final stage. We are intending to further our analysis to all Sub Saharan African countries by also introducing a time dimension to move from a static to a dynamic setting using repeated cross sectional data analysis techniques. Also, we are thinking of performing a panel data analysis aiming to compare Sub Saharan Africa and South East Asia as the two developing countries' regions with the higher incidence of traditional fuel use./

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ANNEX A: DESCRIPTIVE STATISTICS

Table A1: Frequency of distribution of household decision making (entire sample)

WHO MAKES DECISION ON	Wife Does Not	Wife Does	Number of Observations
On the woman's own earnings	7.9%	92.10 %	2569
Large Household purchases	81.54%	18.46%	5558
Visit to Family and friends	79.44%	20.56%	5558
What to do with money husband earns	85.72%	14.28%	5455
On the woman's own health care expenditure	80.95 %	19.05 %	5558

Source: Our own computations, DHS 2014, Senegal.

Table A2: Descriptive Statistics of the other variable of interests

Variables	Number of Observations	Mean	Std. Dev.
Woman's bargaining power index			
Composite woman's bargaining power index	5558	0.005 (median=-0.47, Max=1.74)	0.74
Clean fuel adoption			
Use of a clean cooking fuel by the household (LPG, Natural Gas, Electricity, LPG, Biogas, Kerosene)			
Individual sources/ determinants of Woman's bargaining power			
Wife's age	5558	31	8.58
Wife number of years of Education	5558	1.79	3.30
Wife Highest educational attainment_primary	5558	0.19	0.39
Wife Highest educational	5558	0.091	0.28

attainment_secondary			
Wife Highest educational attainment_tertiary	5558	0.00	0.09
Ownership of land (jointly or separately)	5558	0.15	0.35
Wife owns of a house (jointly or separately)	5558	0.14	0.35
Wife is having an occupation	5558	0.48	0.499
Number of sons living in the household	5558	1.32	1.28
Wife's exposure to Media	5558	1.45 (0=less exposure; 2= high exposure)	0.75
Individual sources/ determinants of Woman's bargaining power			
Age difference	5558	11.8	8.5
Years of education Difference	5032	0.02	3.5
Household wealth	5558	2.47 (Max=5, Min=1)	1.31
Household has a land-line/ telephone	5558	0.046	0.209
Wife earns more than the husband	2569	0.0428	0.202
Informal institutional sources/ determinants of Woman's bargaining power			
Ethnicity-Poular	5558	0.33	0.32
Ethnicity- Serer	5558	0.11	0.29
Ethnicity-Mandingue	5558	0.09	0.20
Ethnicity-Diola	5558	0.04	0.20
Ethnicity-Soningue	5558	0.024	0.15
Ethnicity-Not a Senegalese	5558	0.028	0.16

Ethnicity-Other	5558	0.00	0.09
Region-Dakar	5558	0.051	0.22
Religion-Muslim	5558	0.96	0.09
Religion-Christian	5558	0.007	0.09
Wife beating justification index	5558	0.1435 (Min= -0.91; Max=1.23)	0.83
Other household characteristics			
Number of living children	5558	3	2.4
Age of the head of the household	5558	52	14
Type of residence-Rural	5558	0.67	0.47
Female Household head	5558	0.22	0.42
Household has electricity	5558	0.46	0.49

Source: *Our own computation based on the Senegal 2014 DHS data*

Table A3: Correlation matrix of the decision making variables

	Women decision in her own expenditure on her own healthcare	*Women decision in large household purchase*	*Women decision in family relatives. visit*	*Women decision on how the money earned by the husband should be spent*
Women decision in her own expenditure on her own healthcare	1			
Women decision in large household purchase	0.6926	1		
Women decision in family relatives. visit	0.4877	0.5358	1	
Women decision on how the money earned by the husband should be spent	0.4230	0.4265	**0.2981**	1

Source: *Our own computation based on the Senegal 2014 DHS data*

ANNEX B: ECONOMETRIC RESULTS

Table B1: Results of the Latent Simultaneaous Probit Equation Model

DEPENDENT VARIABLE 1 (Different proxies of Bargaining power)	WOMEN'S SAY IN EXPENDITURE ON HER OWN HEALTHCARE	WOMEN'S SAY IN LARGE HOUSEHOLD PURCHASE	WOMEN SAY IN FAMILY RELATIVES. VISIT	WOMEN SAY ON HOW THE MONEY EARNED BY THE HUSBAND SHOULD BE SPENT
Clean fuel adoption	1.34*** [0.091]	1.37*** [0.087]	1.33*** [0.072]	1.47*** [0.072]
Women's age	0.030*** [0.030]	0.025*** [0.030]	0.012*** [0.003]	-0.0027 [0.0041]
Women's years of education	-0.000 [0.009]	-0.000 [0.009]	0.009 [0.009]	-0.0037 [0.0097]
Woman's Land Ownership	0.315*** [0.075]	0.408*** [0.070]	0.24*** [0.08]	0.51*** [0.08]
Women's earn more than the husband	0.853*** [0.13]	0.74*** [0.12]	0.28** [0.11]	0.71*** [0.14]
Region_Ziguinchor	0.407*** [0.162]	0.514*** [0.140]	0.25 [0.16]	0.19 [0.16]
Region_Kaolak	-0.41*** [0.15]	-0.23 [0.15]	-0.77*** [0.15]	0.14 [0.16]
Region_Sedhiou	0.309* [0.16]	0.42*** [0.16]	0.12 [0.15]	0.30* [0.16]

DEPENDENT VARIABLE 2 **(Clean fuel Uptake)**	**Variable i-WOMEN'S SAY IN EXPENDITURE ON HER OWN HEALTHCARE)**	**Variable i-WOMEN'S SAY IN LARGE HOUSEHOLD PURCHASE**	**Variable i-WOMEN SAY IN FAMILY RELATIVES. VISIT**	**Variable i-WOMEN SAY ON HOW THE MONEY EARNED BY THE HUSBAND SHOULD BE SPENT**
Women's say in Variable i (cf column)	1.51*** [0.068]	1.47*** [0.084]	1.63*** [0.081]	1.67*** [0.097]
Household wealth index	0.754*** [0.056]	0.76*** [0.055]	0.63*** [0.047]	0.85*** [0.055]
Household size	-0.035*** [0.017]	-0.032* [0.017]	-0.023 [0.018]	-0.011 [0.018]
Household lives in rural area	-0.23*** [0.08]	-0.21*** [0.09]	-0.27** [0.08]	-0.19** [0.096]
Religion_animism		-7.25*** [0.20]	-8.74*** [0.00]	-6.7*** [0.19]

Source: *Our own computation based on the Senegal 2014 DHS data*

Table B2: Results of the Simultaneous Generalized Probit model

DEPENDENT VARIABLE 1 **(WOMEN'S BARGAINING POWER INDEX)**	**WOMEN'S BARGAINING POWER INDEX**
Clean fuel adoption	0.045*** [0.008]
Women's age	0.017*** [0.001]
Women's years of education	0.022*** [0.003]
Women's Land Ownership	0.51*** [0.028]
Women's House Ownership	0.21*** [0.029]

DEPENDENT VARIABLE 2 **(Clean fuel adoption)**	**CLEAN FUEL ADOPTION**
Women's Bargaining power index	0.43*** [0.12]
Household wealth index	0.85*** [0.036]
Household size	-0.019 [0.015]
Household situated in rural area	-0.17** [0.075]
Household head age	0.000 [0.002]

Source: *Our own computation based on the Senegal 2014 DHS data*

ANNEX C: THE LATENT TRAIT MODEL: AN OVERVIEW (VARANASI (2009))

In generic latent variable models, the goal is to find one or more latent variables ($z_1 \ldots z_q$) that completely explain the dependence between a set of observables ($x_1 \ldots x_q$). The generic latent variable regression model can be specified as (Bartholomew et al. (2002), Bartholomew and Knott (1999) and Rizopoulos, 2006), since the measure of women's bargaining power is captured by one latent variable, the discussion below assumes that there is one underlying latent trait z .

$$E(x_i/z) = g(\lambda_{i0} + \lambda_{i1} z) \qquad (1)$$

Where,

x_i = observables ; $i = 1, \ldots, p$

z = latent measure of bargaining power

$g()$ is the known as the link function

λ_{i0} = difficulty parameter for the i_{th} observable

λ_{i1} = discrimination parameter for the i_{th} observable

x is independent of x given z; $i \neq j$ (conditional independence assumption)

In factor analysis, $x's$ are continuous variables with a normal distribution and the link function is an identity link. In LTM, the $x's$ are binary or ordinal variables and the link function is an inverse logit or probit and $E(x_i/z)$ the conditional probability of a positive response given the latent variables. The factor analysis model is not valid for binary variables since the $x's$ are bounded and take values from 0 to 1 whereas z is continuous and can take any value in the $[-\infty, \infty]$ space. Hence, LTM specifies a relationship between the probability of a correct response and the latent variables instead of the response and the latent variables itself (as is the case in factor analysis). The logit link function maps the $[0,1]$ space onto to the $[-\infty \infty,]$ space and is also a monotonic function which means that increasing the latent trait z (the woman's bargaining power in this case) increases the probability of a positive response (wife's participation in decision-making within the household).