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Multidimensional Poverty, Energy Poverty and Cook Stove Technology Adoption in Ethiopia

Mekonnen BERSISA GADISA

A Dissertation Submitted to
The Department of Economics

Presented in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Economics

Addis Ababa University

Addis Ababa, Ethiopia

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Approval sheet

This is to certify that the dissertation prepared by Mekonnen Bersisa, entitled: *Multidimensional Poverty, Energy Poverty and Cook Stove Technology Adoption in Ethiopia* and submitted in partial fulfillment of the requirements for the Degree of Doctor of Philosophy in Economics complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

Signed by the examining Committee:

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Chair of Department or Graduate Program Coordinator

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Mekonnen Bersisa
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Dedication

To

my dearest wife: Berhane Merga, and
my childreen Fenet, Birra, and Bekam

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List of Acronyms

AE	Adult equivalence
AF	Alkire and Foster
AfDB	African Development Bank
CDFs	Cumulative Distribution Functions
CE	Choice Experiment
CPG	Cumulative Poverty Gap
CRGE	Climate Resilient Green Economy
CSA	Central Statistical Agency of Ethiopia
CVM	Contingent Valuation Method
EDI	Energy Development Index
EAs	Enumeration areas
ESS	Ethiopian Socioeconomic Survey
FDRE	Federal Democratic Republic of Ethiopia
FGT	Foster, Greer and Thorbecke
FSD	First order Stochastic Dominance
GBD	Global Burden of Disease
GDP	Gross Domestic Product
GMNL	Generalized Multinomial Logit
GTP	Growth and Transformation Plan
HDI	Human Development Index
HDR	Human Development Report
HH	Households
HPI	Human Poverty Index
IEA	International Energy Agency
kWh	Kilowatt hour
LCM	Latent Class Model
MDGs	Millennium Development Goals
MEPI	Multidimensional Energy Poverty Index

MNL	Multinomial Logit Model
MoFED	Ministry of Finance and Economic Development
MPI	Multidimensional Poverty Index
OECD	Organization for Economic Co-operation and Development
OFID	OPEC Fund for International Development
OPHI	Oxford Poverty and Human Development Initiative
PPP	Purchasing Power Parity
SDG	Sustainable Development Goals
SDSN	Sustainable Development Solution Network
SES	Socioeconomic Status
SSA	Sub-Saharan Africa
SSD	Second order Stochastic Dominance
UNDP	United Nations Development Programme
WB	World Bank
WEO	World Energy Outlook
WHO	World Health Organization
WTP	Willingness to Pay

Chapter One: Introduction

1.1Background to poverty and its measurement

Measuring and analyzing poverty have long been the tenets of development economics. They are still at the center of debates among researchers, development practitioners and policymakers. The striking issues which remain unresolved in a definition of poverty are conceptualization of poverty and its measurement. The World Bank (2000) defines poverty as 'pronounced deprivation in well-being.' This definition encompasses low incomes and the inability to acquire goods and services necessary for survival with dignity. In this case the concept of poverty also includes low levels of health and education, inadequate physical security, poor access to clean water and sanitation, lack of voice and insufficient capacities and opportunities to better one's life. However, what constitutes 'well-being' and how it is measured does not have universal consensus. The traditional approach considers well-being as a command over commodities in general. It assesses households' or individuals' well-being or poverty with regard to possession of enough resources to meet their basic needs. Here the poverty status of an individual is determined by comparing his or her income or expenditure against a pre-defined threshold level (Townsend, 2004a).

Alternatively, well-being or poverty status has also been viewed as a vector of achievements in the consumption of various goods. This approach asks whether people are able to obtain a specific type of consumption good. It asks questions on availability of enough food, shelter, healthcare or education (Atkinson, 1989; Sen, 1981). Sen's capability approach is another method of defining well-being and hence poverty. Sen (1985) defines poverty as lack of 'capability' to lead the kind of life one values. It defines poverty as the lack of basic capabilities such as being able to participate with dignity in society's affairs. It further elaborates that this deprivation is reflected in higher levels of human poverty such as low levels of health and education, poor access to clean water and sanitation, lack of voice, inadequate physical security and insufficient capacities and opportunities to improve one's life. On the other hand, higher income and human poverty are accompanied by social deprivations such as high vulnerability to adverse events - economic crises, avoidable morbidity, widespread diseases or natural calamities, powerlessness to improve one's living circumstances and voicelessness in most of society's institutions (Deaton, 2005; Townsend, 2004b).

Hagenaars and Vos (1988) provided a clear picture of the definition of poverty and poverty conceptualization. They define poverty as having less than an objectively defined absolute minimum, having less than others in society, or feeling that you do not have enough to get along. The first approach defines poverty as failure to meet the absolute minimum in terms of 'basic needs' such as food, clothing and housing. This is the absolute approach to measuring poverty and falls under the resource approach to poverty conceptualization explained earlier. They also define poverty relative to the community that we live in. This approach defines households as poor when they lack certain commodities that are common in the society that they live in. A standard consumption pattern is chosen to represent society's common practices and the more the aspects of one's actual consumption practices differ from this standard, the higher one's deprivation is assumed to be. Hence a deprivation score is derived as the total number of times such a shortfall of standard consumption practices is observed (Townsend, 1979, 2004c). Finally, they define poverty as self-perception of one's circumstances. In this approach, poverty is defined as feeling that one does not have enough to get along. It is measured in terms of income or basic needs and the expenditure required to be 'just sufficient' to meet basic needs.

In recent works scholars and international organizations while acknowledging that there is no universally accepted definition of poverty also admit that poverty is multidimensional. Poverty is virtually conceptualized as multidimensional and a poor person suffers from multiple disadvantages (deprivations) such as deprivations in health or malnutrition, lack of electricity or clean water, poor quality of work or little schooling (Bourguignon and Chakravarty, 2003; Deutsch and Silber, 2005; Tsui, 2002).

1.2 Approaches to measuring poverty

Various approaches for constructing poverty measurements have been developed following the different conceptual framings of poverty mentioned earlier. These can be categorized as uni-dimensional and composite index or the multidimensional measure of poverty. The uni-dimensional approach uses a single dimension of poverty, usually income or expenditure necessary to meet basic needs. In this context, the poverty status of an individual is determined on the basis of a pre-determined poverty line. Several categorizations of determining the poverty line have been developed in poverty analysis literature, for instance, absolute poverty line, relative poverty line, and subjective poverty line. Sen (1976) indicated two-fold categorization in poverty measurement using this approach. The first problem is identifying the poor among the total population. This involves determining the poverty line and identifying the poor from the non-poor. Once this is done, poverty analyst would face another problem—aggregation. This stage requires aggregating the features of poor people into overall indicators. This entails selection of appropriate poverty index. Subsequently, the composite index of poverty measure converts different indicators of deprivation levels into a single index. This category has been advocated and used by the United Nations Human Development Program (UNDP) in its Human Development Reports (HDRs) for various years. It includes the human development index (HDI) and the human poverty index (HPI).

The human development index defines poverty as the lack of opportunities in the areas of education, health and command over resources. This approach reflects the condition of all people in a society, while the human poverty index measures deprivations in three of the four key dimensions of the human development index: the capability to survive, the capability to be knowledgeable and having access to private income as well as public provisioning (UNDP, 1990, 1996).

On the other hand, the multidimensional approach embraces multiple deprivations of individuals or households in computing the level of poverty. In other words, the multidimensional poverty index embraces the plurality of poverty and comprehensively shows the channels through which poverty may manifest itself. The turning point in measuring poverty in this perspective was due to Sen's (1985) seminal work. Identifying the poor using the multidimensional measure, however, got methodological clarity with Tsui's (2002) pioneering work on the axiomatic approach to measuring multidimensional poverty. Bourguignon and Chakravarty (2003) further clarified the concept by introducing specifications of individual dimensions of the poverty line, the intersection method of determining an individual's poverty status and issues of aggregation to overall poverty.

Hitherto, several approaches for measuring poverty in a multidimensional perspective have been developed on the basis of the theory of fuzzy sets, information theory, efficiency analysis and axiomatic derivations of poverty indices (Deutsch and Silber, 2005). The fuzzy set theory utilizes the class membership theory to compute weights and aggregates multiple deprivations into a single index. Similarly, the information theory which maximizes entropy or minimizes the general entropy divergence (Decancq and Lugo, 2013; Maasumi and Xu, 2015) is also used. The efficiency approach utilizes the concept of the capability approach and maps capabilities (resources) to individuals' functionings in the framework of the distance function used in production. On the other hand, the axiomatic approach views multidimensional poverty as an aggregation of shortfalls of all the individuals where the shortfall with respect to a given need reflects the fact that an individual does not have even the minimum level of basic needs. The poverty index computed in this approach has to satisfy some desirable properties (axioms) (Tsui, 2002).

1.3 Justifications for using the multidimensional measure of poverty

The multidimensional poverty index (MPI) provides a comprehensive picture of the living conditions of poor people. Primarily, the availability of detail and multi-topic secondary datasets begs for a broader poverty analysis which is beyond what the uni-dimensional poverty analysis can offer. This, in turn, extends the demand for an analysis of poverty in a multidimensional perspective. Besides, analyses of multidimensional poverty in recent poverty studies are partly, but quite importantly, attributable to the fact that the on-going and overarching global development agenda tends to embrace the multidimensionality of development. The sustainable development goals (SDGs) in particular have recognized the goal of eradicating poverty in all its forms and dimensions (SDSN, 2015). Moreover, measuring and analyzing poverty from a multidimensional perspective is justified due to three underlying motivations: normative, empirical and policy. A normative motivation of a multidimensional measurement and analysis of poverty is grounded in the framework of the capability approach which suggests that measures of poverty should account for the plurality of deprivations and attempt to go beyond a mere focus on physical resources such as income. The second, empirical motivation, hinges on the weakness of the absolute poverty measurement and limitations of the existing framework for identifying the poor. Finally, policy motivation focuses on the importance of incorporating the multiplicity of deprivations into the policy debate that is, 'ignoring the cumulative effects of multiple disadvantages leads to sub-optimal policies' (Alkire et al., 2015: 5).

Therefore, before designing and implementing poverty alleviating strategies one needs to identify and better understand the various dimensions of poverty and how they interact over time and across space. This can give a broader picture of poverty and also play a tremendous role in the effectiveness of poverty alleviation policy interventions. Moreover, MPI permits comparisons across countries, regions and the world. It further allows disaggregate comparisons within countries by ethnic groups, urban-rural locations and others key household and community characteristics. The dimensional contribution of each attribute to the overall poverty level can be disentangled and this makes it an important analytical tool for identifying the most vulnerable people and enabling policymakers to target resources and designing policies more effectively.

This dissertation employs a multidimensional poverty measurement based on the Alkire and Foster (2007, 2011) (AF) approach and energy poverty which is an extension of the former. Its flexibility in incorporating different dimensions and indicators to create measures specific to particular contexts makes it more desirable for effective resource allocation and policy design; it also shows the impact over time. Further, it helps in identifying interconnections among deprivations and hence poverty traps. The dual cut-off method of identifying the poor gives superiority to this approach. However, this dissertation acknowledges the limitations surrounding the AF approach such as failure to satisfy transfer principles and arbitrariness of the poverty cut-off at the aggregation stage (Rippin, 2010).

1.4 Nexus between multidimensional poverty, energy and development

Access to modern and sustainable energy is fundamental for enhancing the well-being of society. It is also crucial for economic progress. Specifically, energy deeply touches the lives of the poor and it is central to virtually all aspects of human welfare, including but not limited to, access to healthcare, water, education, agricultural productivity, job creation and environmental sustainability. Access to modern energy is crucial for attaining good health conditions, reducing indoor air pollution, increasing production and productivity using modern technologies and machinery, saving time and adding to further education and expansion of health facilities (Barnes et al., 2011, UNDP, 2005). It plays a prominent role in addressing many of today's global development challenges like poverty, inequalities, health, education, digital divide, connectivity and climate change. Access to modern energy services can reduce poverty by making society more productive, saving time, using more information and communication and reducing energy's income share. Women and young girls in particular have to spend significant time per day for gathering fuelwood and water, cooking and agro-processing which they would have otherwise spent on alternative productive activities. Lack of economic as well as physical access to modern energy is an impediment to social and economic development (Foster et al., 2013; Guruswamy, 2011; Nussbaumer et al., 2012; UNDP, 2005) and as such it is part of deprivation in the wider definition of well-being.

Unfortunately, about 38 per cent of the global population (2.7 billion people) relies on inefficient and polluting fires for cooking and other household needs and about 1.2 billion people in developing countries (about 16 per cent of the global population) lack access to electricity (UNDP, 2015a; WEO, 2014, 16). One can imagine the huge social and economic costs of such massive deprivations and the extent of efforts needed to alleviate this problem.

Nowadays energy issues have come to the center of the global political agenda due to the complex relationship between energy use, economic growth and environmental problems. Specifically, energy poverty is considered one of the most important issues related to economic development. It is believed to be both the cause and the manifestation of poverty and thus poverty alleviation policies need to give due consideration to reducing energy poverty. Cognizant of this fact, the SDGs explicitly included one goal related to energy as a goal for achieving sustainable development. It clearly indicates the role of energy for development and poverty reduction. Goal 7 of the SDGs states, '*Ensure access to affordable, reliable, sustainable, and modern energy for all.'* Realizing this goal, however, needs up-scaling access to electricity, expanding clean fuels and renewable energy, improving energy efficiency and expanding energy efficient technologies. It targets attaining environmental objectives in tandem with social and economic objectives. Moreover, improving energy use efficiency and expanding modern energy use technologies are critical for reducing energy poverty and poverty in general (Guruswamy, 2011; Kaygusuz, 2013; WB, 2016).

However, challenges persist for most developing countries to realize poverty and inequality reduction goals in the midst of sustained economic growth and creating equal opportunities for citizens. Who enjoys the fruits of this growth? Does the impressive economic growth rate really touch the lives of the poor and reduce poverty in its plurality? The answers to these questions and so many other related ones are less obvious and remain controversial. A huge gap in knowledge persists in this regard in both theoretical and empirical studies. Debates in this area emphasize the mis-measurement of human progress by economic growth alone. Economic growth is merely a means to achieving well-being and could not be an end by itself. People must be at the center of all development and it should expand the freedom they enjoy - knowledge, long life, personal security, political freedom, empowerment, decent jobs, and community participation and guaranteed human rights (Deaton, 2005; Sen, 1999; UNDP, 1990, 1996).

It is in this perspective that this dissertation is written to measure the extent of poverty and energy poverty from a multidimensional perspective as their interconnection with economic development is multifaceted. Besides, the dissertation also examines the willingness to pay and preferences of households for improved cook stoves which are an important intervention in improving energy efficiency and in reducing energy poverty in general.

1.5 Nexus between poverty, energy and development in Ethiopia

Ethiopia is among the countries that have witnessed in registering the fastest economic growth rates in the world for the last decade or so; it has also scored noticeably in economic and social changes. Agriculture is the backbone of the Ethiopian economy as it accounts for about 40 per cent of its GDP, 85 per cent of its export earnings and more than 83 per cent of its labor force (AfDB, 2011; FDRE, 2016). The country has mainstreamed poverty alleviation as the over-riding objective in all its successive development plans. However, poverty remains one of the challenging developmental issues for the country (UNDP, 2015b). The country is the second most populous in Africa with a population size of about 99 million and a population growth rate of 2.5 per cent.[1] It is ranked 174 out of 188 countries with the human development index of about 0.442 which puts it at a lower level in the human development index (UNDP, 2015b). Moreover, despite the decisive role that energy plays in the development context, the country predominantly relies on unsustainable energy sources to meet prevailing demand. Biomass accounts for about 90 per cent of households' energy demands. Regardless of its high potential for the production of modern energy, only about 25 per cent of the population in Ethiopia has access to electricity (WEO, 2014).

As a development endeavor, the Government of Ethiopia launched a series of ambitious development plans, known as the growth and transformation plan (GTP) in 2011 to attain the overall development goals of the country. In its first five years (2011-15) GTP I targeted the attainment of the millennium development goals (MDGs) by 2015 among other national goals. In the next five years the growth and transformation plan (GTP II) (2016-20) focuses on modernization of agricultural development, industrialization, structural transformation and developing foreign trade. The country has a target of achieving a lower-

[1] http://www.worldbank.org/en/country/ethiopia/overview accessed on 30 November 2016.

middle income status by 2025 through maintaining an annual average real GDP growth rate of at least 11 per cent; pursuing aggressive measures towards rapid industrialization and structural transformation; and ensuring the sustainability of growth by fostering a stable macroeconomic framework and a climate resilient green economy. GTP II aligns national objectives to sustainable development goals within the framework of climate resilient green growth (FDRE, 2011a, 2011b, 2016).

1.6 Current study

With this background, this dissertation presents empirical findings for poverty and energy poverty measurement from a multidimensional perspective which will help policymakers and development planners to better understand the situation of poverty and inequalities as one of the striking development bottlenecks in Ethiopia. It will facilitate policy interventions in the fight against poverty as it clearly shows the extent of deprivation and dimensional contributions as well. It further presents empirical results of a discrete choice model on willingness to pay and preferences of households for improved cook stoves. Improvements and expansion of modern energy technologies are central in fighting energy poverty and poverty in general. However, behavioral responses matter in the effectiveness of such interventions. Thus, the results of this study will enhance our understanding of willingness to pay and households' preferences and the underlying determinants of willingness to pay for such interventions.

1.6.1 Statement of problems

Like any other developing country, though striving to achieve its multifaceted developmental objectives Ethiopia still remains underdeveloped. The extent of poverty, inequalities and access to affordable and reliable energy sources for households are noticeable bottlenecks in the country's development. The extent of poverty from a multidimensional perspective is very high regardless of the relentless efforts by the government in its fight against poverty. In 2015, the multidimensional poverty index for Ethiopia was about 0.564 while the incidence of poverty was about 87.3 per cent; the intensity (the average proportion of indicators in which the poor people were deprived) was 64.6 per cent which made the country the second poorest after Niger (OPHI, 2015).

Ironically, the country's impressive economic growth rate registered for the last decade has not been reflected in reducing poverty in its plurality and energy poverty remains at a higher level (see results in Chapters 2 and 3). The dichotomy between economic growth and poverty reduction has been at the center of debates for a long time in empirical economics as well as among policymakers. In recent policy intervention economic growth tempts to accommodate notions like pro-poor economic growth and inclusive economic growth. However, the indicators of economic growth obscure the problem of income distribution, the trickle-down effect of growth to the poor and the welfare effects of improvements in the non-income dimension (Deaton, 2005). As Sen (1999: 14) puts it, 'Economic growth cannot be sensibly treated as an end in itself. Development has to be more concerned with enhancing the lives people lead and the freedoms they enjoy.' To this end, reducing income poverty though highly desirable should not be the sole goal of policymakers. Social deprivation from a multidimensional perspective must be measured prior to designing and implementing poverty reduction interventions. Against this backdrop, the multidimensional measure of poverty has got prominence for comprehensively showing all the channels through which poverty is manifested. Globally, a bulk of the studies published uses this method for analyzing poverty in different parts of the world (Alkire and Foster, 2011; Alkire and Santos, 2014; Chakravarty et al., 1998; Deutsch and Silber, 2005; Khan et al., 2014; Maasoumi and Xu, 2015).

However, there is limited research using a multidimensional poverty analysis in Ethiopia. Specifically, existing studies employ overlapping deprivations (Ambel et al., 2015) and fixed weighting schemes to construct the multidimensional poverty index (Brück and Sindu, 2013; OPHI, 2015; Woldehanna, 2014) and to the best knowledge of the researcher, multidimensional inequality has not been accounted for (Bersisa and Heshmati, 2016). Similarly, studies on multidimensional energy poverty in Ethiopia are scant and geographically limited to urban areas (Bekele et al., 2015). Thus, this dissertation with the following core research questions, tries to fill these gaps:

- What are the extent and determinants of multidimensional poverty in Ethiopia?

- What are the extent and determinants of multidimensional energy poverty in Ethiopia?
- What are rural households' preferences and willingness to pay for improved cook stoves in Ethiopia? What are the important determinants of demand for energy efficient technologies?

1.6.2 Objectives of the dissertation

The general objective of this dissertation is to explore the extent and determinants of multidimensional poverty and inequalities in Ethiopia, to analyze multidimensional energy poverty and examine households' preferences and willingness to pay for improved cook stoves in the country.

Specifically, the objectives are:

- To examine the extent and determinants of multidimensional poverty in rural areas and small towns in Ethiopia.
- To analyze the distributional effects of multidimensional poverty and inequalities in rural areas and small towns in Ethiopia.
- To investigate the extent and determinants of energy poverty in a multidimensional set-up for rural areas and small towns in Ethiopia.
- To evaluate rural households' preferences and willingness to pay for improved cook stoves in Ethiopia.
- To examine the determinants of willingness to pay for improved cook stoves in rural Ethiopia.
- To examine preference heterogeneity and the role of hypothetical bias reduction tools and the attribute non-attendance in mean willingness to pay estimations.

1.6.3 Research methodology and dataset

This dissertation is written on the basis of information obtained from both primary and secondary data sources. Principally, the first two papers, distributional analysis of multidimensional poverty and inequalities in Ethiopia and multidimensional measure of household energy poverty and its determinants in Ethiopia, use secondary data collected by the Central Statistical Agency of Ethiopia and the World Bank. Two waves of the Ethiopian Socioeconomic Survey (ESS) data, which is a collaborative project between CSA and the World Bank's Living Standards Survey, were used for this. Data was collected on multiple-topics and it is comprehensive enough so that it can be flexibly used for welfare analyses using different attributes. The first wave of the data was collected in 2011 and the second in 2014. The first wave of the survey covered almost all the rural parts of the country and small towns.

In the first round, information was collected from 3,969 respondents in all regions of the country. In its second wave, the survey extended the sampling frame by including respondents from large urban areas including the capital, Addis Ababa. The second round of the survey collected information from 5,262 respondents of which 3,776 were from the first wave. The two waves are expected to gradually form panel data where households are observed over time. The panel attrition rate between the two waves was only 5 per cent or the two-survey panel success rate was about 95 per cent which can be safely used for a simple panel data analysis for multidimensional poverty and energy poverty analysis and show changes between the two survey periods. The two papers were written on the basis of information obtained from 3,776 respondents in rural areas and small towns in Ethiopia which were covered in both rounds of the survey.

The third paper, an analysis of willingness to pay and preferences of households for improved cook stoves in Ethiopia: evidence from discrete choice models, uses primary data collected by the researcher using the multi-stage random sampling procedure. Primary data was collected from 307 households randomly selected from eight kebeles in three zones of rural Oromia, which is the largest region in the Federal Democratic Republic of Ethiopia. Face to face interviews were conducted with selected households using a structured interview questionnaire and well-trained enumerators. Moreover, two stated preference methodologies were employed to generated data on willingness to pay: contingent valuation and choice experiment. A double bounded elicitation format was used for the former while the experimentally designed attribute-level combinations using orthogonal fractional factorial design of R software provided choice sets for the latter. Six choice sets were presented to respondents with different combination levels of the selected attributes of the proposed improved cook stove. Respondents were asked to make successive choices stating his/her purchase plans for the proposed improvements under the indicated changes.

Further, the dissertation uses mixed methodology for data analysis. In the first essay, the FGT poverty analysis, the Alkire-Foster multidimensional poverty analysis and the multidimensional inequality and stochastic dominance analysis are used to examine the extent of poverty and inequalities. Determinants of both uni-dimensional and multidimensional poverty are also examined using the logit model. A distributional analysis of poverty for different groups and dimensional contributions to multidimensional poverty are examined in detail. The second essay employs the multidimensional method for analyzing energy poverty. It also examines the determinants of energy poverty using the logit model. Finally, the third essay uses various discrete choice models in examining mean willingness to pay and its determinants for an improved cook stove. This essay extensively uses the multinomial logit model, the mixed logit model, the latent class model, the generalized mixed logit model and the interval data analysis model to examine the data collected through the choice experiment and contingent valuation methods. Attribute non-attendance and hypothetical bias that could arise from the survey are also tested using appropriate methods.

1.6.4 Outline of the dissertation

This dissertation is written on topics pertinent to an analysis of households' welfare and developmental challenges for developing countries in multifaceted perspectives. It encompasses poverty, energy poverty and willingness to pay and preferences of households for energy efficient technologies in a developing country.

The dissertation is organized into four chapters. The first chapter provides a detailed background of the study, statement of the problem and the objectives and rationale of the study. It introduces the reader to the dissertation and shows the contribution of the dissertation. Chapters 2 to 4 have three standalone papers which could be published as journal articles which have an intimate relation with each other, especially via their welfare implications for households in developing countries.

Chapter 2 is a paper titled *Distributional Analysis of Multidimensional Poverty and Inequalities in Ethiopia*. It examines the extent of poverty and inequalities from a multidimensional perspective. A comparison of poverty using a one dimensional approach and a multidimensional index; stochastic dominance analysis; weight estimation for the construction of the multidimensional poverty index; and an analysis of the extent of multidimensional inequalities and examination of determinants of poverty are the focus of this paper. An earlier version of this paper was published as **Bersisa, M. and A. Heshmati (2016).** 'Multidimensional Measure of Poverty in Ethiopia: Factor and Stochastic Dominance Analysis', in Almas Heshmati (ed.), *Poverty and Well-being in East Africa: A Multifaceted Economic Approach*, Chapter 10, pp. 215-238, Springer, and its revised version appears in a conference proceeding and working paper series. It is hoped that it will be published after incorporating the reviewer's comments as a journal article.

Chapter 3 is the second paper titled *Multidimensional Measure of Household Energy Poverty and its Determinants in Ethiopia*. It sheds light on the extent and determinants of energy poverty from a multidimensional perspective. This paper has already been published in a working paper series of East Africa Research Papers in Economics and Finance (EARP-EF No. 2016:15) and as a chapter, **Bersisa, M. (2017).** 'Multidimensional Measure of Household Energy Poverty and its Determinants in Ethiopia', in Almas Heshmati (ed.), Economic *Transformation for Poverty Reduction in Africa: A Multidimensional Approach*, Chapter 4, Routledge, Taylor and Francis Group. It is also hoped that this paper will be published as a journal article after revising and incorporating the reviewer's comments.

The final chapter presents the third paper titled *An Analysis of households' Preferences and Willingness to pay for improved cook stoves in Ethiopia: Evidence from Discrete*

Choice models. This paper uses primary data collected using the two stated preference methodologies. It is crucial both from empirical as well as policy perspectives as it is central in a welfare and preference analysis. Empirical evidence on this topic in the study area is rare in the context of rural areas in the sub-Saharan Africa in general and in rural Ethiopia in particular. Thus, this chapter attempts to bridge this gap. The paper examines in detail the presence of preference and scale heterogeneity in choice decisions. It also explores socioeconomic and product related determinants of willingness to pay for improved cook stoves. Finally, it estimates mean willingness to pay and marginal rate of substitution between attributes of the designed cook stove. This paper was presented in a seminar organized by the Jonkoping International Business School (JIBS) in February 2017 and was presented in a workshop co-hosted by the Center of Excellence for Science and Innovation Studies, Royal Institute of Technology, CESIS-KTH, Stockholm and Department of Economics at Sogang University, Seoul, in June 2017.

1.6.5 Contributions of the study

This dissertation contributes to the limited but growing literature in Ethiopia on different measures of poverty and inequalities and the multidimensional measure of energy poverty. It examines the role of households' preferences and willingness to pay for dissemination of energy efficient cook stoves in Ethiopia. Specifically, the dissertation provides detailed empirical results on:

- An analysis of poverty using a multidimensional perspective with an extended dimension and up to date data. It also estimates weights using a factor analysis for computation of MPI. Further, it conducts a rigorous and disaggregated analysis and comparison of the extent of poverty using uni-dimensional, multidimensional poverty and stochastic dominance analysis for different groups.
- The determinants of a multidimensional poverty analysis (not yet studied for Ethiopia).
- An analysis of energy poverty from a multidimensional perspective for Ethiopia by covering a broader area and focusing on rural areas which has not been done so far.

- Willingness to pay for improved cook stoves in the study area using stated preference methodologies which will be a base for ex-ante policy evaluation for rural energy intervention which has very limited literature so far for the study area.
- The effect of preference heterogeneity in improved cook stove choice and tests the effect of cheap-talk in reducing hypothetical bias in contingent valuation.

1.7 Summary and conclusion

This dissertation is written with the argument that every aspect of life matters for the well-being of society and this requires a broader measurement and analysis. As a result, the multidimensional perspective is used to write the first and second papers. The third paper is written as an extension of the second paper for evaluating the effectiveness of an energy efficiency improvement intervention. It states that households' preferences and willingness to pay are crucial for the effectiveness of such interventions.

The first paper, distributional analysis of multidimensional poverty and inequalities in Ethiopia, uses two rounds of household survey data from rural and small towns in Ethiopia to analyze the extent and determinants of poverty. It uses both a conventional and a multidimensional approach for measuring poverty. In the conventional method, it uses consumption expenditure and analyzes the poverty status of households. Likewise, the study employs the multidimensional method of poverty analysis to corroborate and compare the extent of poverty with the former. An exploratory factor analysis is also done to estimate relative weights used for creating the multidimensional index. Using these weights, we construct a multidimensional measure of poverty. Similarly, the study conducts a stochastic dominance analysis of consumption expenditure for different groups and examines the extent of multidimensional inequalities using the Araar (2009) composite index. Finally, the logit model is estimated to examine the determinants of poverty.

The results of the study show that a uni-dimensional approach understates the extent of poverty as it does not consider its non-monetary aspects. The FGT poverty index shows that the incidence of poverty was about 36 per cent whereas the multidimensional poverty index indicates that the incidence of multidimensional poverty was about 85 per cent.

Dimension-wise contributions to multidimensional poverty carry important information for policy design and poverty targeting interventions. The results of this study show that the extent of multidimensional poverty is very high which requires concerted policy interventions. Besides, inequalities among the multidimensionally poor are about 0.33 with observable variations over time and across regions. To combat this multifaceted, spatially diverse and deep-rooted poverty in its different forms a one-size-fits-all policy may not produce desired results. Policymakers should consider regional variations, community realities and households' characteristics to fight poverty. Expanding education and production opportunities (access to credit) and pro-poor policy interventions will play significant roles in reducing poverty.

As we see from the results of this study, income poverty levels for Ethiopia are relatively lower as compared to the multidimensional poverty level. This can be attributed to the over-riding poverty reduction objectives of the government in various development strategies implemented so far. However, the extent of multidimensional poverty remains at an unbearable level which calls for concerted government interventions. It may require a revision of the national poverty reduction strategies to embrace the multidimensional aspects of deprivation and combating poverty in its plurality. Future poverty alleviation policies and strategies should view poverty broadly and design appropriate multifaceted interventions. Moreover, national or global development targets should consider indicators of multidimensional poverty to monitor and reduce poverty in its many dimensions as post-2015 development goals. As a further research area extending the indicators to capture missing dimensions of well-being, decomposition of inequalities using functional income distribution and examining the extent of horizontal inequalities may address the knowledge gaps in this area.

The second paper on determinants of multidimensional households' energy poverty in Ethiopia examines in detail the extent and determinants of energy poverty in rural areas and small towns in Ethiopia. The study uses two rounds of overlapping data from a survey conducted in a joint project of the Central Statistical Agency of Ethiopia and the World Bank as part of the Living Standards Survey. With the primary objective of analyzing the extent and determinants of multidimensional energy poverty in the study area, this article highlights the status of households with regard to energy use and energy use technologies in the area. The results of the descriptive statistics clearly reveal the energy use status of the respondents in both the survey years.

The study also examines the extent of energy poverty in the area using the multidimensional measure following the Nussbaumer et al., (2012) methodology adopted from Alkire and Foster (2007) as the multidimensional measure of poverty. The results of the multidimensional energy poverty index show that about 82.4 and 81.1 per cent of the respondents were multi-dimensionally energy poor in 2011 and 2014 respectively. The results also show that there was no significant improvement in the energy poverty status of the households in the survey periods with a three-year difference. The relative contribution and decomposition of multidimensional energy poverty by dimension can help policymakers and development planners to direct resources and efforts in appropriate intervention areas. Specifically, policy interventions for improving households' energy poverty should consider each attribute and design appropriate tools for public interventions.

On the other hand, the results of the random effect logit model show the determinants of the MEP status of households. Households with larger family size, married, widowed or divorced household heads and located in rural areas had a higher probability of being multidimensionally energy poor. On the contrary, higher age of the head of the household, access to credit and higher total household expenditure (proxy for income) reduced probability of households being multidimensionally energy poor. As noted in the literature as well as confirmed by the positive coefficient of income on energy poverty from the regression results of this study, energy poverty is highly correlated with income poverty. As income increases, the energy poverty level decreases which imply that affordability of energy sources and energy use technologies require a series of policy interventions. Policies promoting clean energy technologies and clean energy sources should be supported to enhance households' incomes.

Moreover, the results of the study show that the Government of Ethiopia has a long way to go still to realize access to rural clean energy regardless of the relentless efforts that have been made so far. More efforts are required for promoting rural clean energy and energy use technologies (for example, through rural electrification and promoting solar energy) coupled with an appropriate pricing mix (subsidy) to reach the poor thus reducing energy poverty.

Energy poverty is a new dimension of poverty. Most incidences of energy poverty emanate from lack of access to clean, affordable and modern energy services. Unlike income poverty energy poverty can be improved through price reduction, improvements in energy efficiency, expanding modern energy and increasing household incomes. In effect energy efficiency plays a prominent role in reducing energy poverty. Energy efficiency will make it necessary for basic energy needs to be affordable at a lower expenditure. It also has double dividend benefits. It makes energy required for basic life to be affordable at lower costs and it helps in mitigating global warming through reducing emissions related to energy use.

Reducing energy poverty provides enormous welfare benefits to poor households. It contributes to reducing poverty through improvements in the health of household members -- lower indoor air pollution means lower respiratory diseases and lower health expenditures. Moreover, use of modern energy and technologies increases productivity and new opportunities for additional incomes and reduces time and labor spent on household activities. Modern technologies for energy use especially in the rural parts of developing countries contribute to poverty reduction; improve health and education; and promote development in these areas. Policymakers can use the results of this study in finding synergy between poverty reduction and energy poverty reduction policies. The results can also be used for aligning international goals like SDGs with national realities.

Against this backdrop, the third paper is written to test the effect of households' preferences and willingness to pay for the energy efficient cook stove intervention in Ethiopia. The study employs two stated preference survey techniques to analyze households' willingness to pay and preferences for the improved cook stove.

Results from various discrete choice models used for the analysis of willingness to pay show that cook stove related attributes and socioeconomic characteristics of the respondents were vital in determining preferences for adopting the improved cook stove. Emission reduction, lower risks of use and durability of the stove positively and significantly affected the probability of households adopting the improved cook stove. Among the attributes, the estimated marginal rates of substitution (part-worth) showed the trade-off that households make while deciding about purchasing the improved cook stove. Cook stove designers, producers and pricing policymakers can draw lessons from this study and consider the trade-off that households make in choosing the improved cook stove for its effective dissemination.

Besides, existence of scale and preference heterogeneity is tested from the results of the random logit model, latent class model and generalized multinomial logit model. Therefore, an empirical examination of the data generated by a choice experiment should employ such models to reduce risks of miscalculation of respondents' mean willingness to pay. Results from the descriptive data analysis further show that sample respondents were aware of the side effects of traditional energy sources and their health, environmental and economic consequences. They were interested in adopting and using the improved cook stove but were frustrated by low quality products and related inconveniences of use of existing products. Attribute non-attendance was not a serious problem in this survey exercise but cheap-talk played a significant role in reducing the hypothetical bias in the stated preference survey.

Finally, the estimated mean willingness to pay ranged from about 150 Birr to 350 Birr. This indicates that the respondents' willingness to pay was below the supply price of the improved cook stove in the area. This needs a pricing policy intervention (subsidizing) for its effective dissemination.

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Chapter Two: Distributional Analysis of Multidimensional Poverty and Inequality in Ethiopia[2]

Abstract
This study does an in-depth analysis of multidimensional poverty and inequalities in rural and small towns in Ethiopia. As social well-being or poverty are multidimensional phenomena, a multidimensional perspective in measuring poverty helps circumvent problems surrounding conventional methods of measuring poverty and helps to clearly show households' realities. The multidimensional measure of poverty clearly shows all the channels through which poverty may manifest itself; it also shows the extent of deprivations. Our analysis used six dimensions with 14 indicators to construct a multidimensional index of poverty and inequalities using two rounds of Ethiopian Households' Socioeconomic Survey dataset, which is part of the World Bank's living standards survey. The study also used an exploratory factor analysis for determining relative weights in computing a multidimensional index and did an in-depth analysis of the stochastic dominance of poverty for different population segments in society. It also sheds light on the degree of inequalities in consumption expenditure and multidimensional deprivations. In addition, a comparison of the degree of poverty using the conventional measure of poverty and the multidimensional approach was also done. It also examined determinants of household poverty status for both uni-dimensional and multidimensional measures using the logit model. The results of the study show that the intensity, severity and depth of poverty vary substantially across the two measures. The Foster, Greer and Thorbecke (1984) index of the uni-dimensional measure of poverty shows that 36 per cent of the households were poor as compared to 53 per cent multidimensionally poor households. Moreover, demographic, regional and household heads' characteristics were found to affect the poverty status of households.

Keywords: Ethiopia, multidimensional, poverty, inequality, factor analysis, stochastic dominance and well-being.

JEL Classification Codes: C25, C31, C43, D31, I32.

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2.1 Introduction

Measuring and analyzing well-being or poverty has attracted considerable efforts from academics, policymakers and planners. No consensus about its measurement has been reached so far, despite the issue having been under scrutiny for a long time. Contemporary work admits that it is a multidimensional phenomenon and measurements that account for various aspects of poverty have got prominence in the literature. It is found that conventional wisdom about measuring poverty is far removed from households' realities. This approach defines poverty as scarcity of economic resources or incomes to meet minimum basic needs of a decent life. It shows monetary values of the materials necessary for meeting basic needs in terms of consumption expenditure or income (Gustafsson, 1995; Townsend, 1970, 2004). Thus, poverty alleviation policies have focused on providing the poor with means to ends. However, a resource-based measurement of poverty has been criticized as it fails to show the channels through which poverty manifests itself comprehensively. It also does not unambiguously reveal the true picture of social ills, capabilities, functioning and income distribution.

As explained by Sen (1976), two inter-related, but pertinent, problems are encountered when measuring poverty. The first is identifying the poor among the total population. This involves selecting a criterion for determining the poverty line and identifying the poor from the non-poor (that is, identifying people whose expenditures/incomes are below the selected poverty line) and the second is aggregating the features of poor people into overall indicators. Sen's criticism about the existing uni-dimensional indices of well-being/poverty and his suggestion for an axiomatic approach for measuring poverty instigated waves of research work in the area. Countless efforts have been made to develop multidimensional indices (Alkire and Foster, 2007, 2011; Alkire and Santos, 2010; Bourguignon and Chakravarty, 2003; Kakwani and Silver, 2008; Tsui, 2002).

A better indicator of poverty should go beyond the mere expenditure or income required to attain minimum basic needs to show deprivation and capabilities (Sen, 1976, 1990, 1999). A multidimensional approach for measuring poverty thus plays a prominent role in tracking and showing all channels through which poverty may be manifested. Recently, empirical work is emerging in the study of poverty using this approach (Bersisa and Heshmati, 2016; Chakravarty et al., 1998; Khan et al., 2014; Maasoumi and Xu, 2015; Nussbaum, 2003).

Poverty and inequalities are critical for developing countries where there is pervasive, deep-rooted and multifaceted poverty and the extent of inequalities is intolerable. Ethiopia, with great diversity in terms of landscape, climate, ethnicity and livelihood patterns, is one of the developing countries which have had abject and persistent poverty over a long period. The country is the second most populous in Africa with a population of about 99 million and a population growth rate of 2.5 per cent.[3] As per HDR (2015) Ethiopia was ranked 174th out of 188 countries for which the Human Development Index (HDI) was computed. Components of the 2014 HDI for the country show that its HDI was 0.442 (lower human development), life expectancy at birth was 64.1 years; expected years of schooling was 8.5 years; mean year of schooling was 2.4 years; Gross National Income (GNI) per capita in purchasing power parity (PPP) was about $1,428; and GDP per capita was $590 using the Atlas method which is substantially lower than the regional average. The country is poor by all indicators of standard of living, though it has been showing noticeable improvements in HDI since the end of the 2nd millennium. Table 2.1 shows trends and growth in HDI for Ethiopia for the last 15 years.

Table 2.1: Human Development Index (HDI) for Ethiopia

Year	HDI	Growth rate (percentage)
2000	0.284	-
2005	0.347	22.18
2010	0.412	18.73
2011	0.423	2.67
2012	0.429	1.42
2013	0.436	1.63
2014	0.442	1.38

Sources: Compiled from HDR (2013, 2014, and 2015).

[3] http://www.worldbank.org/en/country/ethiopia/overview accessed on November 30, 2016.

Figures 2.1 and 2.2 show trends and growth of HDI in Ethiopia between 2000 and 2014.

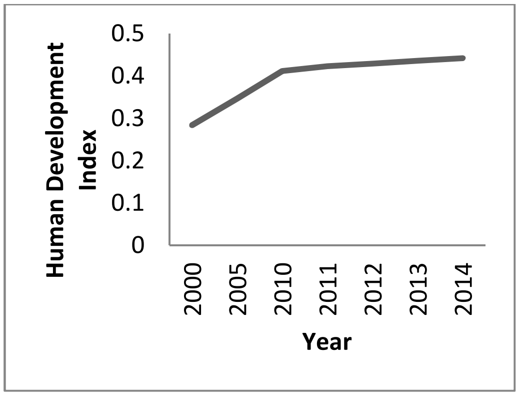


Figure 2.1. Trends in the Human Development Index for Ethiopia

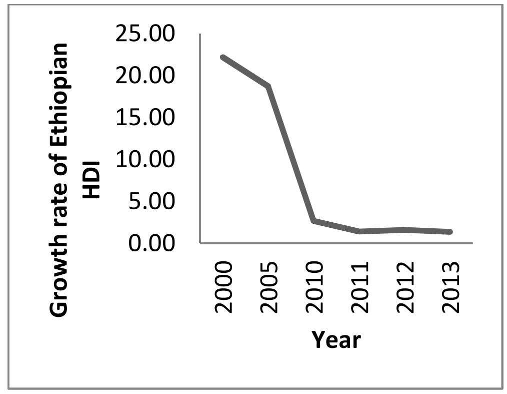


Figure 2.2. Ethiopia HDI growth rate

As we can see from Table 2.1 and Figures 2.1 and 2.2, Ethiopia has shown promising improvements in its HDI. However, it is important to realize that the growth rate of its HDI is showing a tendency of increasing at a decreasing rate, especially for the later years. In the first five years, from 2000 to 2005, it increased by 22.18 per cent followed by an 18.73 per cent increase for the 2nd five years; it increased by 7.28 per cent between 2010 and 2014.

Notwithstanding these facts, Ethiopia has been registering impressive economic growth for the last decade averaging at about 11 per cent. For reducing poverty, maintaining economic growth on a robust and steady path and attaining the overall development goals, the Government of Ethiopia launched an ambitious development plan, the Growth and Transformation Plan (GTP) in 2011. It put a target of achieving lower middle-income status by 2025. In its first five years (2011-15) GTP-I targeted attaining Millennium Development Goals (MDGs) by 2015 among other national goals. The second five years' growth and transformation plan (GTP-II) (2016-20) focuses on modernization of agricultural development, industrialization, structural transformation and developing foreign trade (FDRE, 2011, 2016).

However, regardless of a remarkable economic growth rate which puts Ethiopia in the list of the top-ten fastest growing economies in the world, this economic growth does not mean everything for a country. It might lead to further questions on fairness or the equity and welfare implications of economic growth. Further, there is also a long standing controversy on whether economic growth actually implies improving the welfare of the citizens. Indicators of economic growth obscure the problem of income distribution, the trickle-down effect of growth to the poor and the welfare effects of improvements in the non-income dimension (Deaton, 2005). As Sen (1999: 14) puts it, 'Economic growth cannot be sensibly treated as an end in itself. Development has to be more concerned with enhancing the lives people lead and the freedoms they enjoy.'

The link between economic growth and poverty reduction remains unclear. Faster economic growth does not necessarily get translated into poverty reduction which, paradoxically, leaves an unbearably higher level of poverty in the midst of plenty. Therefore, a scrutiny of the poverty situation in Ethiopia regardless of the sustained reported economic growth figures is needed.

Scholars agree on defining poverty as a 'pronounced deprivation of well-being.' However, the question of how to measure this deprivation remains unaddressed. Conventionally, it is considered as material deprivation and thus low income or consumption is used as an indicator of deprivation. A low level of income or consumption results in a high level of human poverty (low level of education, nutrition and health); the reverse causality also works. There is a plethora of literature on poverty which uses this approach. But the measurement of poverty using this method has been subject to criticism (Bourguignon and Chakravarty, 2003; Kakwani and Silver, 2008; Sen, 1979, 1985; Tsui, 2002). Moreover, income and human poverty are accompanied by social deprivations such as high vulnerability to adverse events - economic crises, avoidable morbidity, widespread diseases or natural calamities; powerlessness to improve one's living circumstances; and voicelessness in most of the society's institutions. The broadest approach of measuring poverty (well-being) gives due emphasis to the capabilities of individuals to function in a society rather than a mere command over commodities. To encompass these multifaceted deprivations in measuring well-being it is inevitable that we have to look beyond income deprivation.

In Sub-Saharan African (SSA) countries including Ethiopia, there is considerable literature on measuring poverty using the former approach. However, limited studies have been conducted so far for the country using a multidimensional index (Ambel et al., 2015; Bersisa and Heshmati, 2016; Brück and Sindu, 2013; Woldehanna, 2014). On the other hand, Berisso (2016) presents a detailed analysis of the determinants of consumption expenditure and dynamics of poverty for urban Ethiopia using panel data. His study indicates the persistence of poverty and a significant number of the households remaining transient poor for the study period. However, existing literature in this area is not rigorous enough to be an input for policy interventions. Use of a fixed weighting scheme, dashboard and overlapping approaches to an analysis of multidimensional poverty and exclusion of the extent of multidimensional inequalities are some of the gaps observed in existing literature. Therefore, the purpose of this study is to examine the determinants and extent of poverty in rural and small towns in Ethiopia in greater detail.

This study examines the extent of deprivation of households in a multidimensional set-up. One major contribution of this study is the use of estimated relative weights for attributes included in the multidimensional index. It also examines multidimensional inequalities in Ethiopia. Besides, energy use is added as an explicit indicator of well-being to account for possible externalities from energy use (for example, its health and environmental effects). Further, individual heterogeneity is taken care of by doing a disaggregated analysis of poverty and inequalities for different groups. Our research also examines the contribution of each dimension to multidimensional poverty. It also conducts a stochastic dominance analysis in the conventional and multidimensional measurements of poverty. Finally, our study examines the determinants of income and multidimensional poverty.

The rest of this chapter is organized as follows. Section 2.2 presents a review of previous work on basic concepts of poverty, measuring poverty/well-being and its distribution and dominance and weight estimations. It shows the gap in literature on poverty analyses and measurement. Section 2.3 presents the theoretical foundations and models for both uni-dimensional and multidimensional poverty analyses. Section 2.4 discusses the results and the final section gives a conclusion.

2.2 Issues in poverty measurement and analysis

An analysis of poverty has been long due for various reasons. The issue has been at the forefront of economic and policy agenda since the 1970s with various degrees of emphasis. Over the years, the concept has evolved a dynamic nature. It has been the central focus of development policymakers and academics and been a subject of political debates. All these have created an overwhelming interest in its various dimensions and broadened its measurement. Nevertheless, the most debatable issue at this junction is the conceptual framing of poverty and its measurement. Sen (1976) showed two distinct problems in measuring poverty. The first problem is identifying the poor among the total population while the second is constructing an index of poverty from the information that we have on the poor. In early writings, poverty alleviation or targeting was defined as providing or endowing the poor with the means to ends or with the ends directly. The center of focus in this line was using income or expenditure as an indicator of well-being of individuals or households. It addressed the former problem by setting a minimum income or consumption expenditure required to meet a minimum standard. The latter constructs an index of poverty (headcount) by counting individuals whose income or expenditure fall short of this minimum requirement (poverty line). The headcount ratio merely shows the percentage of people below the poverty line.

However, the headcount measure of poverty (H) faced severe criticism as a response to which tremendous efforts have been made in developing various indices to circumvent its shortcomings. Sen (1976) developed an index of poverty measurement using an axiomatic approach. This index of poverty measurement adjusts the headcount ratio to income gap and the Gini coefficient of distribution of income among the poor. On the other hand, Foster et al., (1984) developed a class of decomposable poverty measures that vary with a 'poverty aversion' parameter, resulting in the headcount ratio, the poverty gap index and the squared poverty gap index to measure incidence, depth and severity of poverty respectively. Though general, Atkinson (1987) established a common approach for evaluating poverty indices using the dominancy condition. Foster and Shorrocks (1991) introduced a sub-group consistent index of poverty measurement and Shorrocks (1995) extended Sen's index.[4] In the literature on poverty analysis considerable empirical work is available using these indices of poverty measurement (Dercon and Krishnan, 2000; Dercon et al., 2005; Hagenaars and De Vos, 1988; Kakwani, 1993; Ravallion, 1996; Ravallion and Huppi, 1991).

The focus on defining and measuring poverty was challenged by Sen's (1976) seminal work. Following his footsteps tremendous scholarly efforts have been devoted and several indices of poverty measurement have been developed. Sen's groundbreaking work in 1999 on the capability approaches to measuring well-being (poverty) created an impetus for poverty measurement. As a result, over the last two decades or so, interest in multidimensional poverty measures has been growing steadily (especially groundbreaking work by Tsui, 2002 and Bourguignon and Chakravarty 2003); it has also motivated the development of several approaches for measuring or analyzing poverty beyond the uni-dimensional unit considering its multidimensional aspects. The Oxford Poverty and Human Development Initiatives (OPHI) in collaboration with the United Nations Development Program's Human Development Report Office developed consistent and broad metrics for an international comparison among countries using multidimensional poverty in 2009-10. The first round of the Multidimensional Poverty Index (MPI) was released in 2010 (Alkire and Santos, 2010).

This multidimensional measure has got merits as compared to the conventional measure of poverty with income cut-off per day (US$1.25). Many researchers have shown that the two methods complement each other in measuring poverty. While MPI identifies those who actually fail to meet the accepted conventions of minimum needs or functioning, the latter measures poverty from the angle of the income necessary for meeting certain basic needs. There is well-established literature on the poverty measure in its multidimensional aspect (Alkire and Foster, 2011; Alkire and Santos, 2014; Atkinson, 2003; Bourguignon and Chakravarty, 2003; Chakravarty et al., 1998; Deutsch and Silber, 2005; Khan et al., 2014; Maasoumi and Xu, 2015; Tsui, 2002; Whelan et al., 2014).

[4] Details of a survey of the various poverty indices can be obtained from Hagenaars (1987).

Countless studies on poverty and well-being have been published using multidimensional poverty measures for different parts of the world. For instance, Deutsch and Silber (2005) did a detailed analysis of multidimensional poverty using four different approaches: the fuzzy set theory, information theory, efficiency analysis and axiomatic deprivation of poverty analysis. The results of their study show that the four approaches used for an analysis of multidimensional poverty using Israel's Census data of 1995 provided consistent results on poverty. This study shows that multidimensional poverty has a non-linear relationship with age of the household head and family size.

Khan et al., (2014) investigated the incidence of multidimensional poverty in the Rawalpindi region of Pakistan considering three dimensions: education, health and housing. They used ten variables to construct MPI. Their findings revealed an inconsistent declining trend of multidimensional poverty over time. This inconsistency was mainly attributed to observed fluctuations in deprivation levels of education, health and housing in the region. They concluded that the multidimensional approach was better in showing the extent of poverty and its severity for different groups. Similarly, Housseima and Jaleleddine (2012) used a multidimensional approach to do an in-depth analysis of poverty for east-central Tunisia. Their study used a multi-correspondence analysis for determining relative weights for each attribute. Alkire and Santos (2014) using three datasets – the demographic and health survey, the multiple indicators cluster survey and the world health survey -- rigorously analyzed a multidimensional poverty index for developing countries.

One can find vast literature on poverty analyses using both conventional and multidimensional measures, yet due to its dynamic nature and its being location specific and policy relevant, it is important to conduct more research to foster policymaking and for broadening the academic and political dialogue in this area.

2.3 Analytical framework and data

2.3.1 Data sources and selection of variables

This study used secondary data obtained from various sources. Primarily, the study relied on secondary data collected by the Central Statistical Agency of Ethiopia (CSA) and the

World Bank (WB). It also employed data from different sources to complement the main data source for this study. Two waves of data from the Ethiopian Socioeconomic Survey (ESS) which is a collaborative project between CSA and the WB Living Standards Survey were used. The first wave of the data was collected in 2011 and the second in 2014 which was released in March 2015. The survey is comprehensive and is multi-topic that can be flexibly used for welfare analyses using different attributes. The first wave of the survey covered almost all the rural parts and small towns in the country. The purpose of the project was to share knowledge across countries, build capacity and improve survey methodologies and technology. The survey encompassed all regional states in the first round except capital Addis Ababa. Its primary focus was rural parts and small towns. The information was collected from 290 rural and 43 small town enumeration areas (EAs).[5] The 2011 survey was the first round of a long-term project to collect panel data on rural and small town households, their characteristics, welfare and agricultural activities.

As part of the first survey, information was collected from 3,969 respondents in all regions of the country. In its second wave, the survey extended the sampling frame by including respondents from large urban areas including the capital Addis Ababa. By doing this it tried to maintain country-wise representativeness of the data collected from the sample respondents. The second round of the survey collected information from 5,262 respondents of which 3,776 were from the first wave. The two waves are expected to gradually form panel data where households are observed over time. The panel attrition rate between the two currently used waves is only 5 per cent (or the two-year panel success rate is about 95 per cent) which can be safely used for a simple panel data analysis following households' poverty status over time. Thus, our study used information from 3,776 respondents in rural and small towns in Ethiopia which were covered in both rounds of the survey.

A multi-level questionnaire was used to collect data on household, community and agricultural levels. A household was used as a primary sampling unit for the household

[5] The Central Statistical Agency of Ethiopia has designed and formulated a sampling frame. The smallest units from which households or individuals will be selected to keep representativeness is known as the enumeration area (EA).

questionnaire and it was drawn from a population frame so as to be representative of the Ethiopian population, including all rural and small town areas in the country except the three zones of Afar and six zones of the Somalie region. A two-stage stratified sampling method was employed to select the sampled households, where in the first stage primary sampling unit was selected using the simple random sampling method from a sample of CSA enumeration areas. At this stage, probability proportion to size was used to determine the sample size for EAs. In the second stage of the sampling, households were randomly drawn from selected EAs for interviews. A detailed sampling procedure, sampling frame, sample size determination and data quality can be obtained from the respective years of ERSS-basic information reports (CSA and WB, 2013, 2015).

2.3.2 Theoretical framework for poverty analysis

I. A uni-dimensional analysis of poverty

There is vast literature in poverty analysis using a uni-dimensional approach. Regardless of its downsides, it conveys pertinent information to gauge the extent of poverty challenges; distributional comparisons; assessing public policies; and evaluating the impact of interventions (Ravallion, 1994). For sound comparisons we first explored the extent of poverty in rural and small urban areas in Ethiopia using the conventional uni-dimensional measures. The family of Foster, Greer, and Thorbecke (1984) poverty measure (p_α) was computed using consumption expenditure. Here α was used to aggregate poverty to measure its incidence, depth and severity for households. Suppose the per capita household consumption expenditure, denoted by CE_i, is arranged in an ascending order as: $CE_1 \leq CE_2 \leq CE_3 \leq \ldots \leq CE_r \leq Z \leq CE_{r+1} \leq \ldots \leq CE_n$, where *Z* stands for the poverty line, *n* is the total population and *r* is the number of poor, then the consumption poverty index, p_α, is given by:

(1) $$p_\alpha = \frac{1}{n}\sum_{i=1}^{r}\left(\frac{Z - CE_i}{Z}\right)^{\alpha}$$

Here the parameter α measures a policymaker's degree of aversion to inequalities among the poor. The higher the value of α, the higher the weight attached to the poorest of the poor (Foster et al., 1984; Ravallion and Huppi, 1991). Based on α (α = 0, 1 and 2) three indices of poverty measures can be constructed. For α=0 the index is known as the headcount poverty index (p_o). Headcount poverty measures the incidence of poverty, that is, it shows the proportion of the population whose consumption expenditure per capita puts it below the poverty line or the share of the population that cannot afford to buy a basic basket of goods. On the other hand, when α=1, it gives the poverty gap index (P_1) which captures the depth of poverty. This provides information regarding how far households are from poverty line measures. It shows the average distance separating the poor from the poverty line as a proportion of that line. Finally, when α=2, one gets the squared poverty gap index **(**P_2**)**, which captures the severity of poverty. It considers not only the distance separating the poor from the consumption poverty line, but also the inequalities among the poor.

However, determining the cut-off point in an analysis of poverty remains controversial. The definition of a poverty line, in fact, depends on the purpose of the analysis. Poverty measurements and analyses can be done to know the situation; to understand factors responsible for the situation; to design interventions; or for monitoring and evaluating policy interventions. For purposes of measuring and analyzing poverty, various poverty lines have been established in literature: the absolute poverty line, the relative poverty line and the subjective poverty line. Detailed definitions and measurements of the poverty line are given in Duclos and Araara (2006) and Hagenaars and De Vos (1988). An absolute poverty line is defined as those people who fail to satisfy the minimum physical needs of food and non-food items to enable them at the lower end of the income distribution to engage in economic activities. From this perspective, poverty is defined in terms of earnings per day, cost of basic food and non-food items and expenditure levels that meet food energy requirements (Anwar and Qureshi, 2002). It is also common to define the poverty line relative to some overall distribution of sample statistics.

The most frequently used relative poverty line is some proportion of central tendencies' (mean or median) income or consumption expenditure (Foster et al., 2013; Muller, 2006). Following literature, we used both absolute and relative measures and see the extent of poverty using consumption expenditure per capita. We used consumption expenditure aggregates calculated as the sum of food and non-food expenditure for analyzing poverty in rural and small urban areas in Ethiopia. We used the consumption expenditure poverty line, as the amount of money required to purchase 2,200 Kcal per capita per day plus essential non-food items, as defined by the Ministry of Finance and Economic Development (MoFED, 2008). Besides, the relative poverty line as 50 per cent of mean expenditure was used to analyze the relative poverty in the study period.

II. Effect of household size on consumption expenditure

There is well-documented evidence in literature on the effect of family size and its composition on the status of households. Household composition (gender and age of members) significantly affects expenditure per capita and the poverty level for the household. Computation of per capita income/expenditure using the number of members in a household produces an inaccurate measure of the standard of living. More importantly, it is difficult to compare the living standards of families of different sizes and compositions. Such a measure needs to be adjusted for the differences in the needs of people of different age and sex as well as the economies of scale advantage (cost saving advantage) of larger family sizes (Deaton and Paxson, 1998; Gronau, 1988; Ray, 2000). The essence of adult equivalence computation is precisely explained by Glewwe (1991: 212): 'two may not be able to live as cheaply as one, but two can certainly live more cheaply together than they can apart.' In other words, it measures the relative incomes required to enable families of different sizes and compositions to enjoy the same standard of living.

The equivalence scale adjustment has tremendous implications for a poverty, inequality and welfare analysis. It has attracted many adherents who have contributed to the development of several approaches for its computation. However, there is no generally accepted measure of equivalence scale to account for cost of children or the advantages of economies of scale in larger families (Deaton, 2003; Deaton and Paxson, 1998; Dercon and Krishnan, 1998;

Glewwe, 1991; Gronau, 1988; Ray, 2000). The various approaches of computing an equivalence scale can be categorized under two heads: objective and subjective measures. The objective approach is generally based on observed behavior and uses econometric techniques. It can be further classified as: appropriate proxy variables for household welfare and utility-based methods. The subjective approach encompasses the parametric, questionnaire based and nutrition or subsistence income-based approaches (Coulter et al., 1992). The nutrition based approach follows some steps to drive adult equivalence family size. It first determines the nutritional requirements of each household member or the food security standards of each member. It then computes the money metric value of the nutritional requirements or food security levels. Finally, it derives the equivalence scale adjustment for households of different sizes and compositions. Following this line our study used the nutrition based approach for computing the equivalence scale. It converted family size to adult male equivalence to account for cost of children and the advantages of economies of scale in larger families following Dercon and Krishnan's (1998) methodology (Appendix 2.1).

III. A multidimensional analysis of poverty

A. Description of dimensions and variables

In literature on multidimensional poverty/well-being, selection of attributes and determination of their cut-off points are very important (Alkire, 2007). There is no hard and fast rule for selecting attributes as it is constrained by the availability of reliable and comprehensive data which is a bottleneck in developing countries in conducting multidimensional analyses. However, the more the attributes the better the indices will reflect the capabilities and functioning of individuals and the best measures of deprivation. Conventionally, these dimensions are related to the MDGs and their core functioning. The dimensions selected may represent both intrinsic and instrumental values. Beside this, weights attached to each attribute and their substitution degree matter for a comprehensive well-being analysis (Decancq and Lugo, 2013; Maasoumi and Xu, 2015). Yet there are common steps that one should follow in constructing a multidimensional index of poverty, well-being or inequality. Alkire and Foster (2011) have developed a dual cut-off approach for measuring multidimensional poverty which has both empirical and substantive advantages than the union or intersection methods of determining deprivation for each attribute. They have also developed the Adjusted Headcount Ratio (M_0) family of the multidimensional poverty measure. Alkire and Santos (2014) outlined the steps that one should follow in constructing a multidimensional index of poverty. The first step is defining a set of indicators which will be considered in the multidimensional measure. There is no rule for defining the set of attributes. However, one should use normative/value judgment in choosing the indicators which explain the three basic dimensions of the MPI measures (education, health and living standards). Second is the setting of deprivation cut-offs for each indicator and applying the cut-offs to ascertain whether each person is deprived or not in each indicator. Then comes selecting the relative weights that each indicator has such that they add to one. This is followed by creating the weighted proportion of deprivations for each person, which can be called his/her deprivation score.

Determining the poverty cut-off, namely, the proportion of weighted deprivations that a person needs to experience to be considered multidimensionally poor, and identifying each person as multidimensionally poor or not according to the selected poverty cut-off is the next step; this is followed by computing the proportion of people who have been identified as multidimensionally poor in the population. This gives the headcount ratio of multidimensional poverty, H, also called the incidence of multidimensional poverty. Then comes computing the average share of weighted indicators in which the poor people are deprived. This entails adding up the deprivation scores of the poor and dividing them by the total number of poor people. This is the intensity of multidimensional poverty, A. Finally, the M_0 measure has to be computed as the product of the two previous partial indices: $M_0 = H \times A$. MPI identifies people with joint disadvantages and as such contains more information than what the individual MDG indicators can offer (Alkire and Santos, 2014). The latter is called the Dashboard approach and shows dimension-wise deprivation for the selected indicators (Ravallion, 2011).

Following literature on the multidimensional poverty measure (Alkire and Foster, 2007, 2011; Alkire and Santos, 2014) we developed and measured poverty in a multidimensional index. As a first step, we selected attributes and their cut-off points (Table 2.2).

Table 2.2: Description of attributes, variables and their cut-offs

No.	Attributes	Variables	Criteria for deprivation cut-off
1	Consumption expenditure (Y_i)	Uni-dimensional	Household is deprived if expenditure per capita falls short of the poverty line
2	Health facilities (H_i)	Safe drinking water	If HH's source of water is not protected, D =1, and 0 otherwise
		Parental consultation	If HH has never consulted any medical assistant for the last 12 months, D =1, and 0 otherwise
		Safe kitchen to reduce indoor air pollution	If the household possess no kitchen or uses a room inside the house as a traditional kitchen, D=1, and 0 otherwise
3	Education (E_i)	Number of years of schooling	If years of schooling is less than 6, D =1 and 0 otherwise
		Reading and writing abilities	If unable to read and write in any language, D=1 or 0 otherwise
4	Housing facilities (HF_i)	House occupancy status	If HH does not own house, D=1, and 0 otherwise
		Number of rooms for members	If number of family members per room is greater than or equal to 3, D =1, and 0 otherwise
		Type of roof	If roof of the house is non-corrugated/cement; D=1, and 0 otherwise.
		Toilet facilities	If toilet is not flush or ventilated, D=1, 0 otherwise
5	Asset ownership	Asset status of household	If HH does not own at least one of the following assets: radio, TV, telephone,

	(AO_i)		bicycle, motorbike or refrigerator, D=1 and 0 otherwise
6	Energy use (EU_i)	Energy sources for lighting	If HH does not use modern energy for lighting; D=1, and 0 otherwise
		Energy sources for cooking	If HH does not use modern energy for cooking, D=1, and 0 otherwise
		Type of *mitad* for cooking	If HH uses traditional *mitad*, D=1 and 0 otherwise

Note: Attribute specific dimension cut-offs are derived from MDG related indicators and local realities.

As shown in Table 2.2, our study used six dimensions with 14 variables to construct household deprivations. The first dimension measured conventional income or consumption expenditure poverty. Using the nationally defined poverty line, it defined the deprivation level as those households whose expenditure did not allow them to meet their basic calorie requirements. But income/expenditure cannot fully show the capabilities of the household. As a result, it included other measures of well-being such as education, health, housing, asset ownership and energy use to capture a household's well-being from different perspectives. Three variables were used to construct the index of health status of households -- access to safe drinking water, type of kitchen used for cooking and parental consultations -- to measure potential health hazards and their immediate consequences on health. Rather than outcomes of diseases, derivers of health risk, levels of personal exposure and the number of people exposed and disease rates, can provide an idea of the overall global burden of disease (GBD) due to indoor air pollution and unsafe drinking water (WHO, 2002, 2007). Our study used education as a third dimension.

Two variables were used to construct the education index: level of education of the household head and literacy rate of the household head. These two capture basic skills and educational attainments of household heads. However, we acknowledge that these indicators may obscure households' education attainment. Had it not been due to data limitation, inclusion of members' achievement in education would improve welfare of households. Four variables were used to construct the index of housing facilities: type of roof, occupancy status, toilet facility and number of members per room (to measure overcrowding of dwellings). Ownership of any of the six fixed household assets (refrigerator, radio, television, bicycle, motorcycle and telephone) was used to measure the asset deprivation of households. Finally, energy use was used to capture externalities that could result from energy use. It is claimed that reliance on traditional sources of energy reduces a household's well-being. Therefore, our study used three variables to construct the energy index and capture its effects on a household's well-being. Energy type for lighting, cooking and type of stove used (*mitad*) were selected as indicators of energy deprivation. Cut-off at the individual attribute level (level of deprivation) was determined by looking at sample characteristics and realities in survey areas.

B. Estimation of relative weights for attributes of multidimensional poverty

In a multidimensional analysis of poverty besides identifying the attributes and determining their deprivation cut-off levels, analysts also worry about the choice of weights for each attribute/dimension in computing the aggregate index. The conventional approach of assigning equal weights has been criticized as people may not value the different indicators of well-being equally. As a result, several approaches of weighting have been developed for estimating weights used in aggregating the selected indicators in a composite index. Deutsch and Silber (2005) made a systematic comparison of multidimensional poverty measurement using four approaches: theory of fuzzy set, information theory, efficiency analysis and axiomatic derivation of poverty indices. Housseima and Jaleleddine (2012) and Decancq and Lugo (2013) give comprehensive reviews of various approaches and their relative merits and demerits. In the non-axiomatic approach, multidimensional poverty or welfare is aggregated using the fuzzy set theory (Kim, 2013; Zimmermann, 2010), entropy approach (Maasoumi, 1986; Maasoumi and Xu, 2015) or the inertia approach which includes a principal component analysis, factor analysis and a multi-correspondence analysis (Housseima and Jaleleddine, 2012; Krzanowski, 1987; Rao, 1964).

Our study used the inertial approach to estimate weights in creating an aggregate index of multidimensional poverty from the selected attributes. In this approach the data speaks for itself and the dimension to be used is determined within the analysis; it also helps in reducing dimensionality in creating the index. We used a mix of discrete and continuous variables and a factor analysis (exploratory factor analysis) was selected for determining weights. This is a multivariate statistical tool used for reducing the number of dimensions. It reduces initial n correlated dimensions to an uncorrelated index or components, where each component is a linear weighted combination of the initial variables that contains most of the information. It produces a few common factors (q) that linearly reconstruct the p original variables. Generally, factor analysis is given as:

(2) $$y_{ij} = z_{i1}\beta_{1j} + z_{i2}\beta_{2j} + \dots + z_{iq}\beta_{qj} + \varepsilon_{ij}$$

where y_{ij} stands for the value of the i^{th} observation on the j^{th} variable, z_{ik} is the i^{th} observation on the k^{th} common factor, β_{kj} is the set of linear coefficients called the factor loadings and ε_{ij} stands for the j^{th} variable's unique factor. After estimating the coefficients, which have subjective interpretations, we must rotate the factor. For our study, we used orthogonal rotation. It may be the case that estimated factors appear with different signs. A variable with a positive factor score relates to higher socioeconomic status or less deprivations while a variable with a negative factor score is associated with lower socioeconomic status or higher deprivations (Vyas and Kumaranayake, 2006).

C. Theoretical models for analyzing multidimensional poverty and inequalities

For an analysis of poverty using a multidimensional index we followed Alkire and Foster (2007, 2011) given as:

(3) $$p(\alpha, X_i, Z) = \frac{1}{N}\sum_{i=1}^{N}\frac{1}{J}\sum_{j=1}^{J} w_j \left(\frac{z_j - x_{i,j}}{z_j}\right)_+^{\alpha} I(d_i \geq d_c)$$

where $\sum_{j=1}^{J} w_j = J$, d_i denotes the number of dimensions in which individual i is deprived, J denotes the number of dimension and dc denotes the normative dimensional cut-off.

However, the Alkire and Foster method of computing multidimensional poverty has some limitations. Its second stage cut-off determination suffers from some arbitrariness. Further, it does not account for the degree of substitutability among the attributes used and also fails to exhibit the transfer principle (Deutsch and Silber 2005; Maasoumi and Xu, 2015; Rippin, 2010). However, this method has several advantages and some of its limitations are salvaged through different techniques. In this regard, our study used estimated weights to reduce the limitations of this method.

We also analyzed the extent of multidimensional inequalities using the Araar (2009) index for K dimensions of poverty as given by:

(4) $$I = \sum_{i=1}^{K} \phi_k \left[\lambda_k I_k + (1 - \lambda_k) C_k \right]$$

where ϕ_k is the weight attached to the dimension *k* (the same weights estimated for multidimensional poverty using factor analysis are used in our paper), I_K and C_k stand for the relative/absolute Gini and concentration indices of component K. The normative parameter λ_k controls the sensitivity of the index to the inter-correlation between dimensions.

2.3.3 Theoretical framework for poverty dominance

This section presents models for decomposing poverty across different groups (gender, age, education, rural-small town). A test of stochastic dominance of various degrees for distribution of poverty and inequalities is well-documented in literature on poverty and in inequality analyses (Anderson, 1996; Atkinson, 1987; Barrett and Donald, 2003; Davidson and Duclos, 2000; Maasoumi and Heshmati, 2000, 2008). In line with the theoretical foundation outlined in Davidson and Duclos (2000) we assumed that there were two distributions (A and B) of welfare measures (say consumption expenditure or the MPI), characterized by cumulative distribution functions (CDFs) of F_A and F_B, with support contained in the non-negative real line. Let $D^1A(x) = F_A(x)$ and:

(5) $$D_A^s(x) = \int_0^x D_A^{(s-1)}(y)\,dy$$

For any integer s ≥ 2, and let $D_sB(x)$ be defined analogously, then we can express $D_s(x)$ for any order s as:

(6) $$D^s(x) = \frac{1}{(s-1)!}\int_0^x \left(x-y\right)^{s-1}(y)\,dF(y)$$

Distribution B is said to dominate distribution A stochastically at order s if $D_A^s(x) \geq D_B^s(x)$ for all $x \in \Re$. For strict dominance, the inequality must hold strictly over some interval of positive measure. The important orders in the stochastic dominance test are the first and second order. First order stochastic dominance (FSD**)** of A by B up to a poverty line z implies that $F_A(x) \geq F_B(x)$ for all income levels less than the poverty line. It is tantamount to saying that the proportion of individuals below the poverty line is always greater in A than in B for any poverty line not exceeding z. Similarly, second order stochastic dominance (SSD) of A by B up to a poverty line z implies that $D^2_A(x) \geq D^2_B(x)$, that is:

(7) $$\int_0^x (x-y)\,dF_A(y) \geq \int_0^x (x-y)\,dF_B(y)$$

In line with this theoretical foundation, we conducted a dominance analysis of both uni-dimensional and multidimensional indices of poverty for different social groups.

2.3.4 Econometric models for determinants of poverty

There are various techniques for identifying the determinants of poverty. The most widely used method for identifying the contribution of different indicators to poverty status is a regression analysis. Two techniques are most frequently used in a regression analysis. The first one explains the level of consumption expenditure per capita as a function of covariates and the second technique explains the probability of households falling into poverty and its determinants using probit or logit regression. In this case, the dependent variable is binary, taking the value of 1 if the household or individual is poor and zero otherwise. To examine the determinants of poverty in rural and small urban areas in Ethiopia we employed the second method. The probability of households falling into poverty is modeled as a function of the household head's characteristics: age, gender, marital status, education, household's characteristics like size and regional level characteristics such as regional dummies and access to credit.

First, we determined a household's status using consumption expenditure and MPI as being poor or not:

$$\text{(8)} \qquad SES_i = \begin{cases} 1, & \text{if household is poor} \\ 0, & \text{otherwise} \end{cases}$$

where SES_i stands for social economic status and it shows the status of households using either consumption expenditure or the multidimensional index. The probability that a household is poor given the covariates can be represented by a cumulative distribution function given as:

$$\text{(9)} \qquad \Pr\left(SES_i = 1/X\right) = F\left(X'_i\beta\right)$$

This cumulative distribution function gives a logit or probit model on the distributional assumption for the dataset (Achia et al., 2010; Cameron and Trivedi, 2005; Green, 2003). Assuming logistic distribution, we specify the logit model as:

$$\text{(10)} \qquad \Pr\left(SES_i = 1/X\right) = \frac{\exp X'_i\beta}{1 + \exp X'_i\beta}$$

where X_i stands for predictors such as age of the household head, gender of the household head, marital status of the household head, educational level of the household head, household size, type of residence (rural or small town) and regional dummies and access to credit. Eq. 10 has no sound economic interpretation and hence we estimated the log odds ratio (logistic regression) model as:

$$\ln\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n \tag{11}$$

where X_1 to X_n stand for the covariates used as the determinants of poverty and p denotes the probability that a household is poor. Besides, the marginal effect is estimated after the logit model and we have interpreted the coefficients from this part.

2.4 Results and discussion

This section presents detailed results and their discussion. In the first part, it gives the results of a descriptive statistical analysis of major variables (Table 2.3). This is followed by a poverty analysis using the FGT family for the uni-dimensional measure. It also analyzes tests for different degrees of stochastic dominance and sub-group decomposition of poverty. It also presents and discusses concise results of inequalities for both uni-dimensional and multidimensional indicators. Finally, it presents the results of the multidimensional poverty measure using the Alkire-Foster methodology and econometric results for identifying determinants of poverty.

2.4.1. Descriptive statistics' results of major variables

Table 2.3: Descriptive statistics of major variables

	Year			
	2011		2014	
Variables	Mean	Std. Dev.	Mean	Std. Dev.
Household size	4.86	2.38	4.91	2.36
Household size AE	3.93	1.95	3.96	1.93
Age of household head	44.23	15.63	45.84	15.32
Annual food consumption expenditure	26553.64	82034.7	19573.04	45911.00
Annual non-food consumption expenditure	3280.57	9319.89	4311.92	5064.84

Annual education expenditure	202.43	735.80	219.00	551.75
Annual total expenditure	30036.64	82855.5	24103.97	46943.89
Nominal per capita expenditure per AE	8350.83	25197.01	6772.09	12548.99
Real per capita expenditure per AE	8097.76	24617.85	6703.72	11903.92

Adjusting income or expenditure for family composition is a pertinent factor in any poverty analysis. Income per capita computation, as well as the economies of scale advantage argument for bulk purchases, is the reason for an explicit consideration of family size for a poverty analysis. Thus, our study used the adult equivalence family size to consider this. It converted household size to adult male equivalence accounting for age and gender compositions. As given in Table 2.3, on average, a household had about five members while its adult equivalence was lower in both survey years. In the 2014 survey, there was a slight increase in family size as well as its adult equivalence yet it showed a similar degree of dispersion. Besides, the age of the household head was on average about 44 years in 2011 and 46 years in 2014. Table 2.3 further gives different components of a household's consumption expenditure. As we can see, on average, a household spent about 26,553 Birr, 3,280 Birr and 202 Birr per year in 2011 and 19,573 Birr, 4,311 Birr and 219 Birr per year in 2014 on food consumption, non-food consumption and education respectively. Average annual total expenditure shows quite a significant decrease in the later survey year. It decreased from about 30,036 Birr per year to about 24,103 Birr per year.

Both nominal and real per capita adult equivalence expenditure showed decreasing trends in 2014. The standard deviation figures clearly indicate that there were observable variations among households regarding various components of consumption expenditure. This could signal persistence of significant income inequalities as explained later using inequality measures.

Table 2.4: Frequency distribution of categorical variables

Variables		Year	
		2011	2014
Sex of household head	Male (per cent)	75.48	74.12
Marital status of household head	Married (per cent)	76.28	74.49
Literacy status of household head	Read and write (per cent)	40.61	41.05
Household members' use of credit	Yes (per cent)	23.88	26.75

There was a strong relationship between gender and headship of the household. In 2011, about 76 per cent of the households were male headed while only 24 per cent were headed by females. In 2014 there was a slight change in the headship's role. About 74 per cent of the households were headed by males while 26 per cent were headed by females. The orthodoxy practice of assigning a male as the head of a household in a developing country is still persistent. Headship and gender differences convey considerable implications for resource allocations and poverty severity in the gender dimension. Similarly, as we can see from Table 2.4 that the marital status of the household head, literacy levels and beneficiaries of credit from different sources did not show considerable variations between the two survey years. Credit use does not seem to be a common practice in rural and small towns in Ethiopia. Only about 24 per cent and 27 per cent of the respondents were credit users in 2011 and 2014, respectively. Perhaps rural households are credit constrained with limited access to credit which would constrain their productivity and worsen their poverty situation.

Distribution of consumption expenditure significantly varied over time, across regions and gender wise. As we can see from Figure 2.3, poverty clearly shows its rural dimension. Mean per capita consumption expenditure was higher for both genders in small towns as compared to those in rural areas. The gap between rural-small towns tended to be wider in the 2014 survey. Further a disaggregate analysis of the data across regional states of the country indicates observable variations in consumption expenditure.

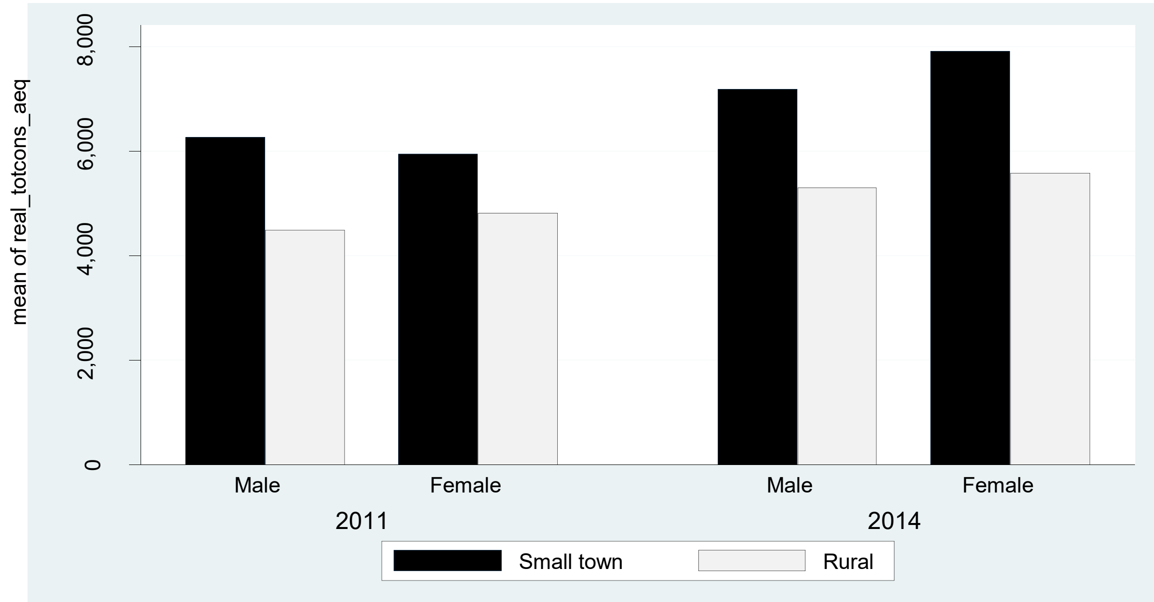


Figure 2.3. Bar chart of consumption expenditure by year, area and gender

As we can see from Figure 2.3, the rural-urban, gender and time dimensions of the poverty analysis need serious attention. We can, therefore, draw an inference for policy interventions: one-size-fits-all poverty reduction policies may not bring impressive results. Prudent policy targeted at reducing poverty, if not eradicating it, should take into account the realities of households and regional disparities.

2.4.2. Extent of poverty using FGT and the multidimensional poverty indices

The results presented by descriptive statistics can be further strengthened by empirical results from a poverty analysis using the FGT family. A relative poverty line was used to compute FGT poverty indices unlike the conversant one-dollar a day absolute poverty line. A 50 per cent mean consumption expenditure of households was used as a relative poverty line which also accounted for the extent of inequalities of income. The results are presented in Table 2.5.

Table 2.5: FGT poverty indices by year, area and sex of household head

Poverty Measured over*	Year			Area		Sex of HH head	
Poverty index	2011	2014	Pop**	Rural	Small town	Male	Female
Headcount (P_0)	41.0	32.0	36.0	36.0	20.0	37.0	30.0
Poverty gap (p_1)	14.0	9.0	11.0	11.0	6.0	11.0	9.0
Squared poverty gap (P_2)	6.0	4.0	5.0	5.0	3.0	5.0	4.0

Notes: *Relative poverty line (50 per cent of the mean income of the sample household) is used for FGT computation; ** Pop stands for population.

Table 2.5 shows intensity, severity and depth of poverty using consumption expenditure per adult equivalence by year, the area of residence and gender of the household head. There was a substantial decline in relative poverty levels between the two survey years. In 2011, 41 per cent of the population was poor while this declined to 32 per cent in 2014. The rural dimension of poverty is further confirmed from the results in Table 2.5 -- 36 per cent of rural dwellers were poor while only 20 per cent of urban dwellers were poor. Similarly, Table 2.5 also shows that relative poverty was more severe for male headed households. The results also indicate that 37 per cent of the male-headed households were poor as compared to 30 per cent headcount poverty for female-headed households.

The result of this study shows the reverse correlation of poverty and gender in Ethiopia. Speculation of the researcher is that male headed respondents might have underestimated their consumption expenditure while reporting due to information gap and less engagement in daily routine household chores. The overall poverty headcount was 36 per cent for the sample respondents, which is quite a significant number. The results further show that the severity and depth of poverty had observable variations over time with the area of residence and the sex of the household head. The regional profile of poverty measured by the FGT index is presented in Figure 2.4. The extent of poverty varied considerable across regions (see appendix 2.2 for detail regional poverty profiles).

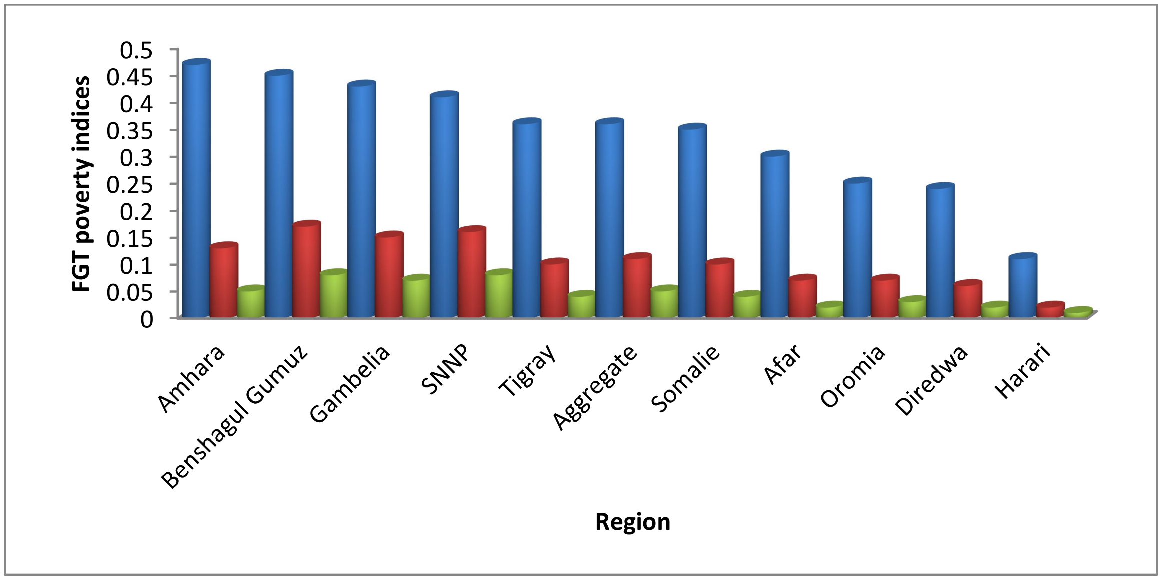
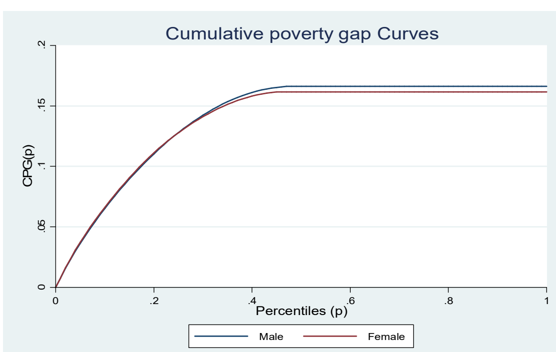


Figure 2.4. FGT indices by region

The poverty indices in Figure 2.4 can be complemented by poverty incidence curves for different groups (Figures 2.5 and 2.6).



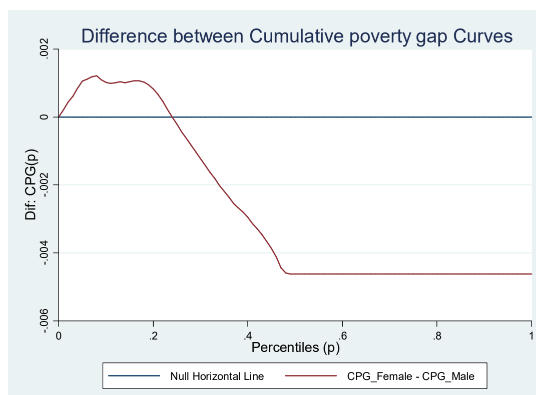


Figure 2.5. Gender-wise cumulative poverty gap Figure 2.6. Difference between CPG

As we can see from Figures 2.5 and 2.6 there was an observable poverty gap gender-wise for different percentiles. At the lower percentiles, the difference was almost insignificant but as the percentile increased, the gap became wider and in the later percentile, the difference became constant. Besides, the FGT poverty curves also show the sensitivity of poverty measures to the poverty line. For α=0, 1 and 2, the respective curves disaggregated by sex of household head are given in Figures 2.7, 2.8 and 2.9.

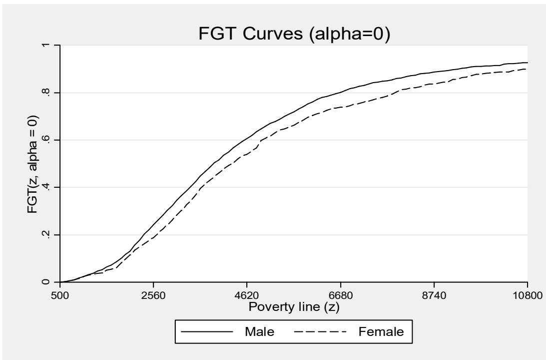


Figure 2.7: FGT curve for α=0

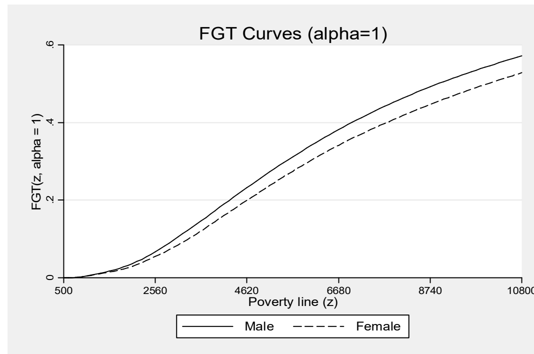


Figure 2.8: FGT curve for α = 1

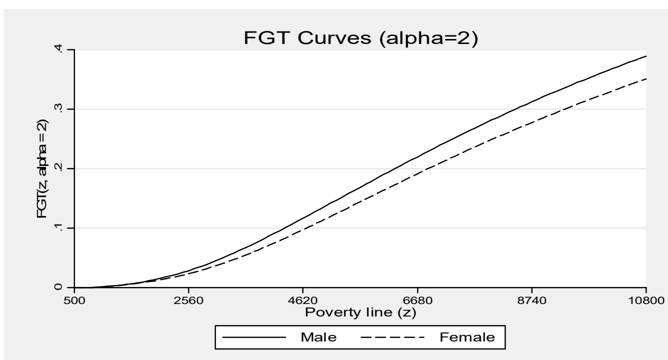


Figure 2.9: FGT curve for α =2

The FGT curves presented in Figures 2.7, 2.8 and 2.9 carry significant policy implication for examining how the level of poverty varies as the poverty lines change. It also helps to test poverty dominance between two distributions and to test for pro-poor growth conditions. As we can see clearly from the figures, headcount, poverty gap and squared poverty gap show consistent dominance of poverty for male headed households as compared to female headed ones.

Decomposing poverty into different groups and an analysis of their contribution to poverty levels is pertinent for targeting policy at reducing poverty. The most frequently used decomposition of poverty is on variables such as sources of income, occupation, gender and area of residence. A decomposition of gender-wise poverty is given in Table 2.6.

Table 2.6: Decomposition of the FGT index by gender of the household head

	Headcount			Poverty gap			Squared poverty gap		
Index/groups	Male	Female	Pop.	Male	Female	Pop.	Male	Female	Pop.
FGT index	0.37	0.30	0.36	0.11	0.09	0.11	0.05	0.04	0.05
	(0.02)	(0.03)	(0.02)	(0.01)	(0.01)	(0.01)	(0.00)	(0.01)	(0.00)
Share of all	0.86	0.14	1.00	0.86	0.14	1.00	0.86	0.14	1.00
	(0.01)	(0.01)	(0.00)	(0.01)	(0.01)	(0.00)	(0.01)	(0.01)	(0.00)
Abs. contr.	0.32	0.04	0.36	0.10	0.01	0.11	0.04	0.01	0.05
	(0.02)	(0.00)	(0.02)	(0.01)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)
Relative contr.	0.88	0.12	1.00	0.88	0.12	1.00	0.88	0.12	1.00
	(0.01)	(0.01)	(0.00)	(0.01)	(0.01)	(0.00)	(0.02)	(0.02)	(0.00)

Note: Standard errors are in parenthesis.

As we can see from Table 2.6, absolute contribution to poverty indices depends on the underlying economic status of the sub-group while the relative contribution must do with the relative proportion of each sub-group in the concerned population. Thus, the contribution of female-headed households to the overall poverty status was lower due to a lower number of female headed households in the sample.

Similarly, an analysis of stochastic dominance of consumption by sub-groups helps us to see the nature of poverty in our analysis. Stochastic dominance conditions provide a robust ordinal comparison of poverty for different groups. Figures 2.10 and 2.11 show that female-headed households' consumption expenditure first order stochastic dominated male-headed households' consumption expenditure.

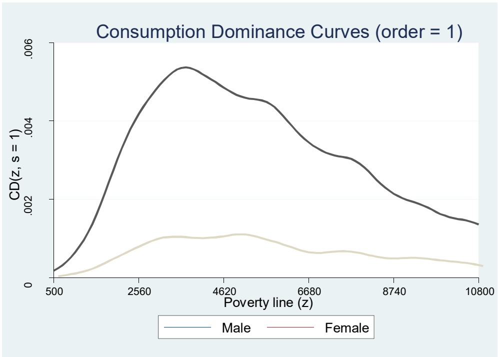


Figure 2.10. FSD of consumption by gender

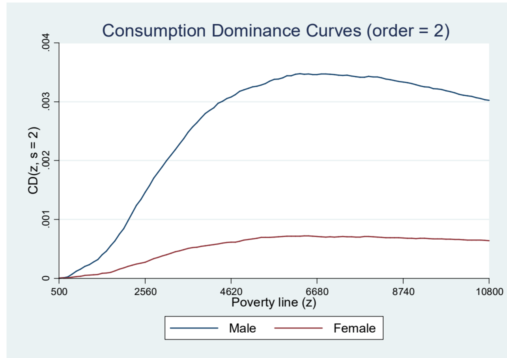


Figure 2.11. SSD of consumption by gender

However, a regional consumption dominance condition is not observed from the result. For each region both first order stochastic dominance and second order stochastic dominance showed no unique dominance relationship as we can see in Figures 2.12 and 2.13.

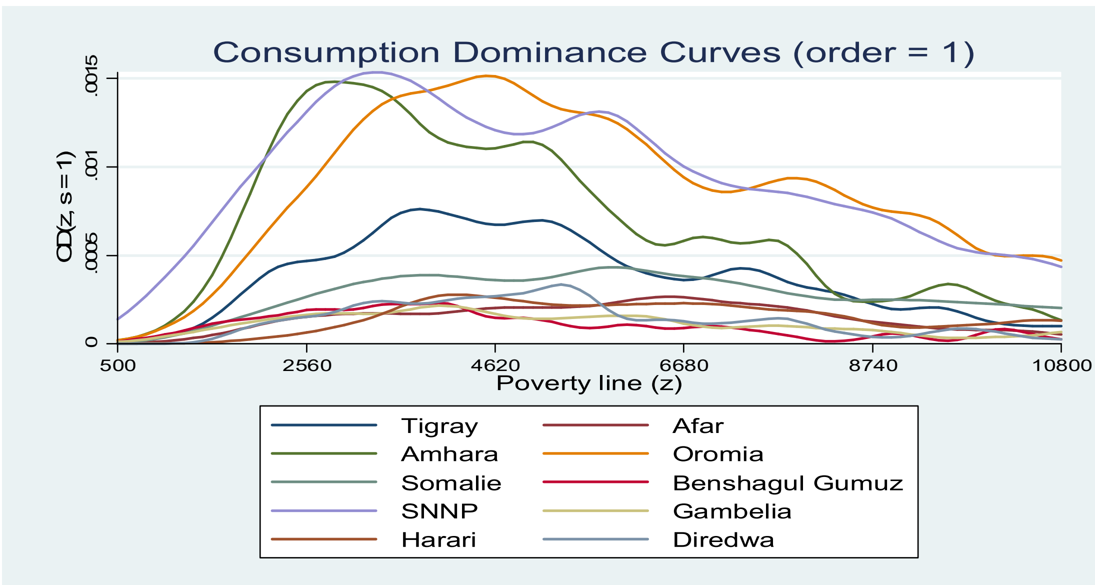


Figure 2.12: FSD of consumption expenditure by region

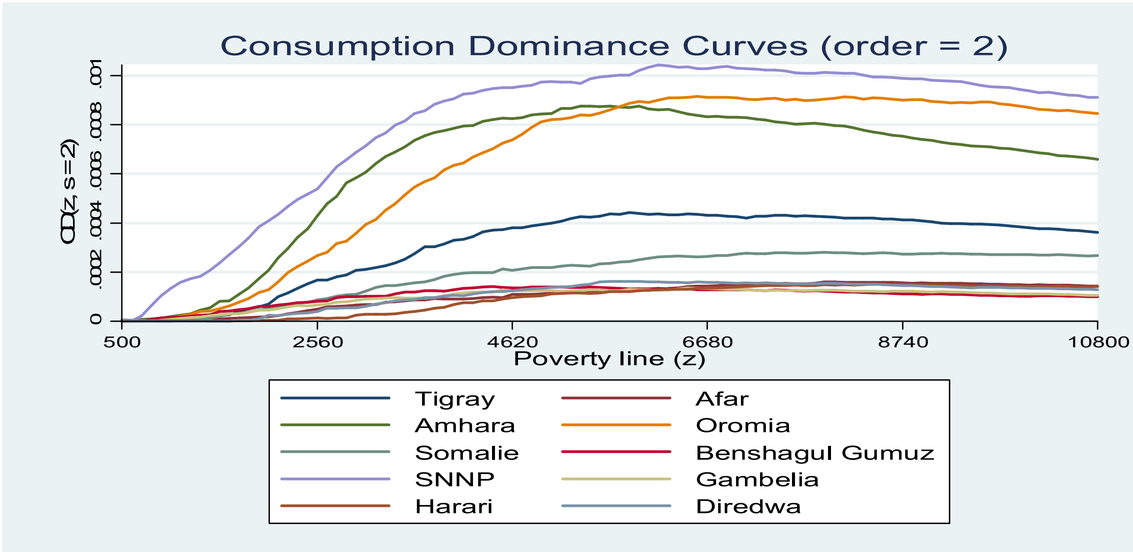
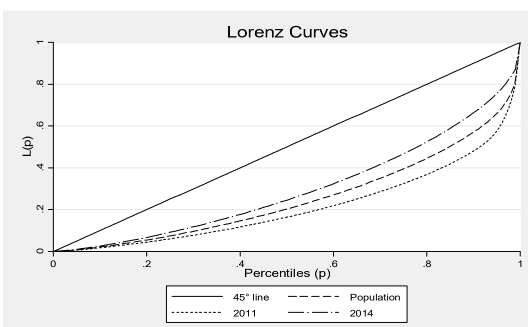


Figure 2.13. SSD of consumption expenditure by region

An analysis of the distributional pattern of consumption expenditure sheds light on the degree of inequalities for different groups. The degree of consumption expenditure inequality as presented by the Lorenz curve (Figures 2.14 and 2.15), shows observable inequalities of consumption expenditure over time and by the area of residence.



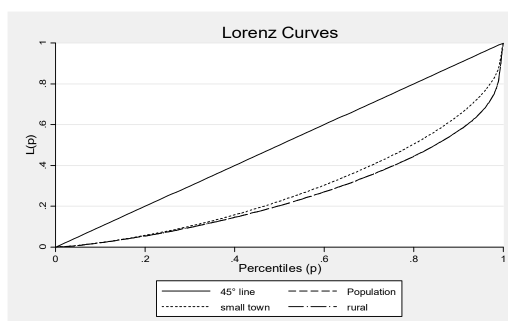


Figure 2.14. Lorenz curves by year

Figure 2.15. Lorenz curves by area

In addition to a uni-dimensional analysis of poverty, we also conducted its multidimensional analysis. Since poverty is a multidimensional phenomenon, the uni-dimensional measures presented earlier partially show the well-being status of households.

Thus, using six dimensions with 14 variables we computed a multidimensional index of poverty. This index shows that the extent of poverty was quite high for Ethiopia if one considers the non-income dimensions of households (Table 2.7).

Table 2.7: Deprivation levels of each indicator by year

Year	Cons. Exp.	Health			Education		Housing				Asset	Energy use		
	Ci	H_1	H_2	H_3	Ed_1	Ed_2	HS_1	HS_2	HS_3	HS4	AOi	Eng1	Eng2	Eng3
2011	41.0	74.0	67.0	66.6	63.5	59.4	13.2	56.6	57.0	95.8	53.1	64.0	98.3	97.0
2014	32.0	70.8	55.3	62.4	61.4	58.9	13.4	52.2	50.8	94.5	68.6	49.1	98.1	97.1

Note: The variables used for each indicator are the same as those defined in Table 2.2.

As we can see from Table 2.7, there was an observable improvement in the income deprivation index between the two survey years. In 2011 about 41 per cent of the respondents were poor by the consumption expenditure indicator but this figure decreased to 32 per cent in 2014. However, the non-income indicators of well-being selected for this study show that there were high levels of deprivation in health, education, housing, asset ownership and energy use indicators.

Table 2.8: Multidimensional poverty index by year, sex of household head and area

	Year			Sex of HH head			Area of residence		
Groups	**2011**	**2014**	**Pop.**	**Male**	**Female**	**Pop.**	**Rural**	**Urban**	**Pop.**
Head count (H)	0.83	0.87	0.85	0.87	0.77	0.85	0.89	0.72	0.85
Intensity (A)	0.65	0.59	0.62	0.63	0.58	0.62	0.67	0.61	0.62
MPI	0.54	0.51	0.53	0.55	0.45	0.53	0.56	0.44	0.53
Inequality among the MPI poor	0.32	0.34	0.33	0.34	0.25	0.33	0.32	0.65	0.33

Following the Alkire and Foster (2007, 2011) methodology a person is said to be multidimensionally poor if he or she is deprived in at least one-third of the weighted indicators used in an analysis. In other words, the cut-off point used for identifying an individual as multidimensionally poor is 33 per cent. As presented in Table 2.8, the proportion of the population that was multidimensionally poor (the incidence of multidimensional poverty, H) was about 85 per cent. The intensity of multidimensional poverty (A) shows the average proportion of indicators in which the poor people were deprived. The poor were deprived in about 62 per cent of the indicators used for this study. A detailed analysis of multidimensional poverty for different groups shows that multidimensional poverty incidence was 83 per cent and 87 per cent in 2011 and 2014 respectively. There was about 4.8 per cent increment in the incidence of poverty between the two survey years. About 87 per cent of the male headed households were multidimensionally poor as compared to about 77 per cent female headed households and 89 per cent of those living in the rural areas were poor as compared to 72 per cent living in urban areas. MPI for the country stood at a higher level as compared to income poverty. But it has decreased in the latter year. Inequalities among the MPI's poor respondents showed variations for different groups. In 2011, the MPI inequalities were about 0.32 while these were 0.34 in 2014. MPI inequalities were higher for male headed households and for those living in urban areas.

Table 2.9 presents the contribution of each attribute to multidimensional poverty. The housing facility index, education index, asset ownership index, consumption expenditure, health index and energy use index stand in their order of contribution to the multidimensional poverty index.

Table 2.9: Relative contribution of dimensions to AF MDP indices estimated as population share (in per cent)

Dimensions	Multidimensional poverty (M)	Standard error
Consumption expenditure	14.57	0.44
Health index	13.47	0.79
Education index	18.67	0.67
Housing facility Index	21.60	0.93

Asset ownership index	18.80	0.59
Energy use index	12.90	0.83

Dimensional contribution to multidimensional poverty provides more policy relevant information as it can single out the effect of each dimension on poverty. Any policy for poverty reduction and improving households' welfare can design and plan resources considering the severity of deprivations in each indicator.

2.4.3 Determinants of uni-dimensional and multidimensional poverty

Examining the extent of poverty using both one-dimensional and multidimensional measures conveys basic information on the degree of poverty in the study area. However, it does not tell us the factors which affect the poverty status of a household. Our study used a logit model to identify determinants of both uni-dimensional and multidimensional poverty. Before running the final regression, we conducted all diagnostic tests and confirmed the adequacy of our model. It passed all the relevant diagnostic tests and fit well to theory. To examine the determinants of uni-dimensional poverty using consumption expenditure we added some variables which indicate asset ownership and room facilities. These variables are excluded from the determinants of the multidimensional poverty analysis as they are already accounted for in the computation of the index. However, the probable effects of their exclusion were tested and the model without these variables passed the mis-specification test. Table 2.10 presents regression results for uni-dimensional poverty and the multidimensional poverty measure and their marginal effects.

Table 2.10: Determinants of poverty (one-dimensional and MPI)

Dependent variable	Uni-dimension		MPI	
Variables	Logit model	marginal effects	Logit model	marginal effects
Household size	0.364***	0.088***	0.096**	0.024**
Household size square	-0.010***	-0.002***	-0.008**	-0.002**
Age of household head	0.012	0.003	-0.013	-0.003
Age of household head square	-0.0001	-0.00003	0.0001	0.00003
Head of household is female	-0.084	-0.020	0.300***	0.073***
Household lives in a rural area	0.314***	0.073***	2.311***	0.486***
Head of household is married	-0.380***	-0.093***	-0.344***	-0.083***
Head of household is literate	-0.470***	-0.111***	-1.695***	-0.399***
Household has access to credit	-0.026	-0.006	-0.038	-0.009
Number of rooms	-0.208***	-0.050***		
Number of assets	-0.195***	-0.047***		
Household lives in the Tigray region	0.351**	0.086**	0.392**	0.094**
Household lives in the Afar region	-0.211	-0.050	0.770***	0.173***
Household lives in the Amhara region	1.043***	0.255***	0.629***	0.149***
Household lives in the Oromia region	0.253	0.062	0.374**	0.090**
Household lives in the Somalie region	0.018	0.004	0.747***	0.170***
Household lives in the Bensh. Gumuz region	1.294***	0.309***	0.617***	0.142***
Household lives in the SNNP region	0.753***	0.184***	0.984***	0.227***
Household lives in the Gambelia region	0.753***	0.186***	0.584***	0.135***
Household lives in the Harari region	-0.695***	-0.152***	-1.079***	-0.260***
Constant	-1.985***		-1.416***	

Note: Reference group for the regional dummy is Dire Dawa; ***, ** and * show significance at 1, 5 and 10 per cent levels respectively.

The regression results in Table 2.10 show the determinants of poverty. Household size had a non-linear effect on poverty. Poverty increased initially with an increase in household size and then decreased. This non-linear effect of household size could be attributed to scale effects in production and consumption. Economies of scale seem to be in operation in the larger family size. This result is similar to Deutsch and Silber's (2005) findings. A higher number of rooms occupied by a household, possession of one more unit of asset and access to credit reduced the probability of a household being poor for the uni-dimensional indicator. A married household head had a lower probability of being poor as compared to other groups of marital status.

Similarly, a literate household head had a lower probability of being poor as compared to an illiterate household head. On the other hand, households living in rural areas had a higher probability of being poor as compared to those living in urban areas. The probability of households living in rural parts being multidimensionally poor was about 0.486 higher than for those living in small towns. The probability that a household with a literate head became multidimensionally poor was lower by about 0.399 than a household with an illiterate head. This shows that education, though intrinsically a source of well-being is also instrumental in reducing poverty. Female headed households had a lower probability of being poor as compared to male headed households using consumption expenditure while they had a higher probability for the multidimensional indicator of poverty. Households living in various regions of the country had different probabilities of being poor. Most of the regional dummies indicate that households living in these regions had a higher probability of being poor as compared to households living in Dire Dawa (reference group) except those living in the Afar and Harari regions.

2.5 Summary and conclusion

This research used two rounds of household survey data from rural and small towns in Ethiopia to analyze in detail the extent and determinants of poverty. It explored both the conventional method of poverty analysis and a multidimensional approach. In the conventional method, it used consumption expenditure and analyzed the poverty status of households. Because of the limitations surrounding traditional measures of poverty we also employed multidimensional methods following Alkire and Foster (2007, 2011). An exploratory factor analysis was used to estimate relative weights used for creating the multidimensional index. Using these weights, we constructed a multidimensional measure of poverty. Similarly, the study conducted a stochastic dominance analysis of consumption expenditure for different groups and examined the extent of multidimensional inequalities using the Araar (2009) composite index. Finally, the logit model was estimated to examine the determinants of poverty.

The results of the study show that a uni-dimensional approach understates the extent of poverty as it does not consider its non-monetary aspects. The FGT poverty index shows that the incidence of poverty was about 36 per cent whereas the multidimensional poverty index indicates that the incidence of multidimensional poverty was about 85 per cent. Dimension-wise contribution to multidimensional poverty carries important information for policy design and poverty targeting interventions. The results of our study show that the extent of multidimensional poverty was very high which requires concerted policy interventions. Besides, inequalities among the multidimensionally poor were about 0.33 with observable variations over time and across regions. To combat this multifaceted, spatially diverse and deep-rooted poverty in its different forms a one-size-fits-all policy may not produce impressive results. Policymakers should consider regional variations, community realities and households' characteristics to fight poverty. Expanding education, expanding opportunities for production (access to credit) and pro-poor policy interventions play significant roles in reducing poverty. National or global development targets should consider multidimensional poverty indicators to monitor and reduce poverty in its many dimensions as post-2015 development goals. As a further research area extending the indicators to capture missing dimensions of well-being, decomposition of inequalities using functional income distribution and examining the extent of horizontal inequalities may address the knowledge gaps in this area.

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Appendices

2. 1. Nutrition (calorie) based equivalence scales

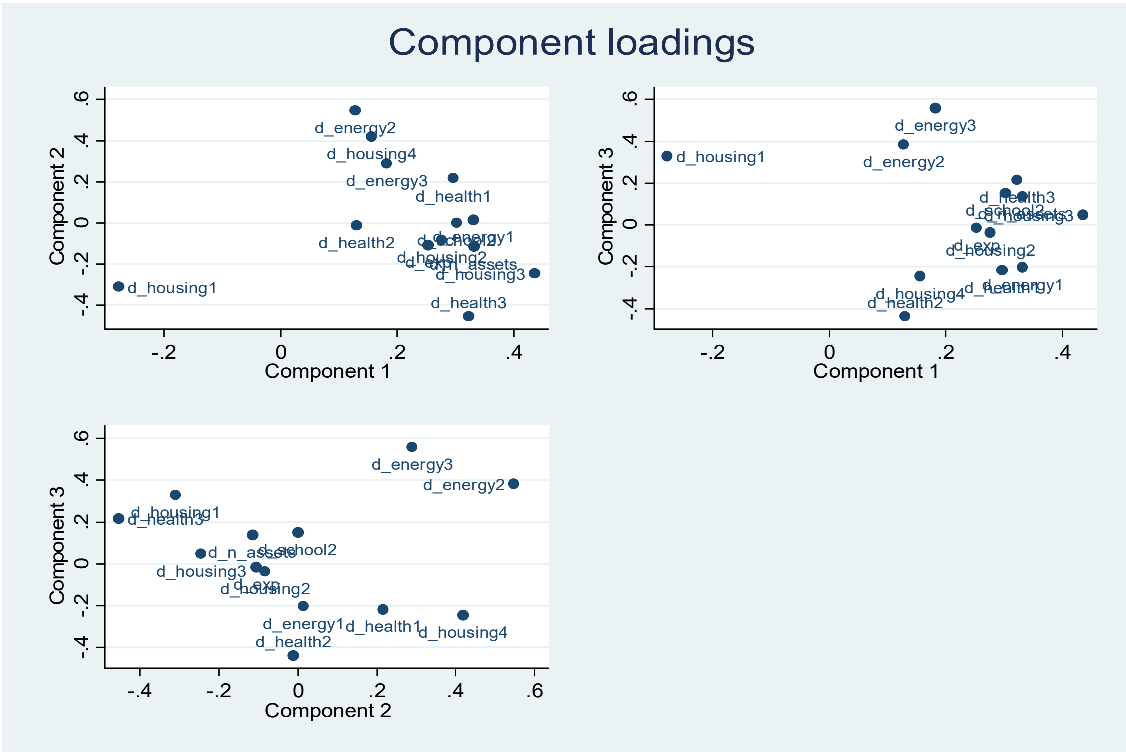
Years of age	Men	Women
0-1	0.33	0.33
1-2	0.46	0.46
2-3	0.54	0.54
3-5	0.62	0.62
5-7	0.74	0.70
7-10	0.84	0.72
10-12	0.88	0.78
12-14	0.96	0.84
14-16	1.06	0.86
16-18	1.14	0.86
18-30	1.04	0.80
30-60	1.00	0.82
60 - plus	0.84	0.74

Source: Dercon and Krishnan (1998) which was calculated from WHO data.

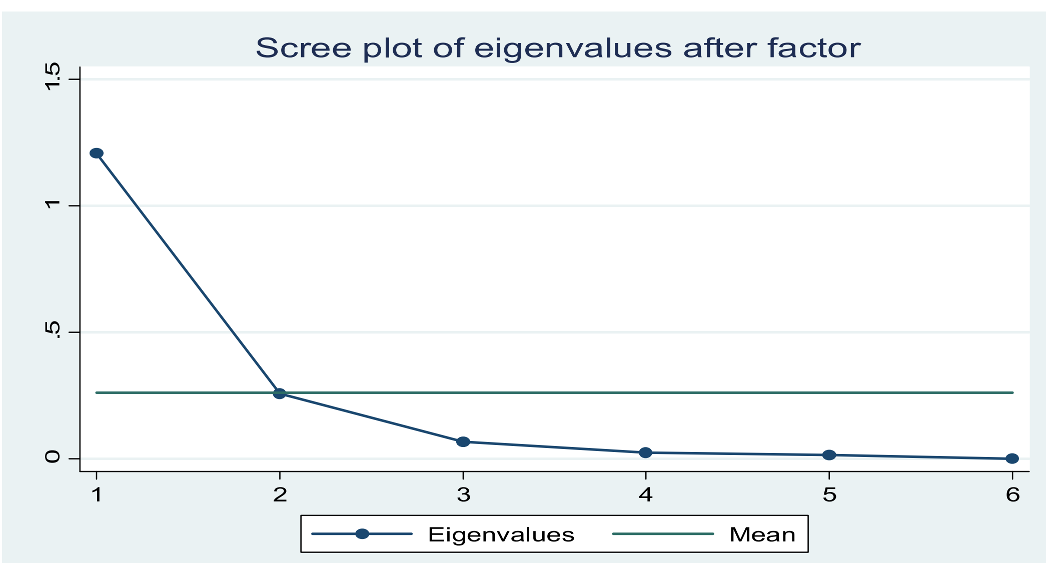
2.2. FGT poverty indices for different regions (using relative poverty lines)

Region	Head count (P0)	Poverty gap (P1)	Squared poverty gap (P2)
Tigray	0.36	0.1	0.04
Afar	0.3	0.07	0.02
Amhara	0.47	0.13	0.05
Oromia	0.25	0.07	0.03
Somalie	0.35	0.1	0.04
Benshagul Gumuz	0.45	0.17	0.08
SNNP	0.41	0.16	0.08
Gambelia	0.43	0.15	0.07
Harari	0.11	0.02	0.01
Diredwa	0.24	0.06	0.02
Aggregate	0.36	0.11	0.05

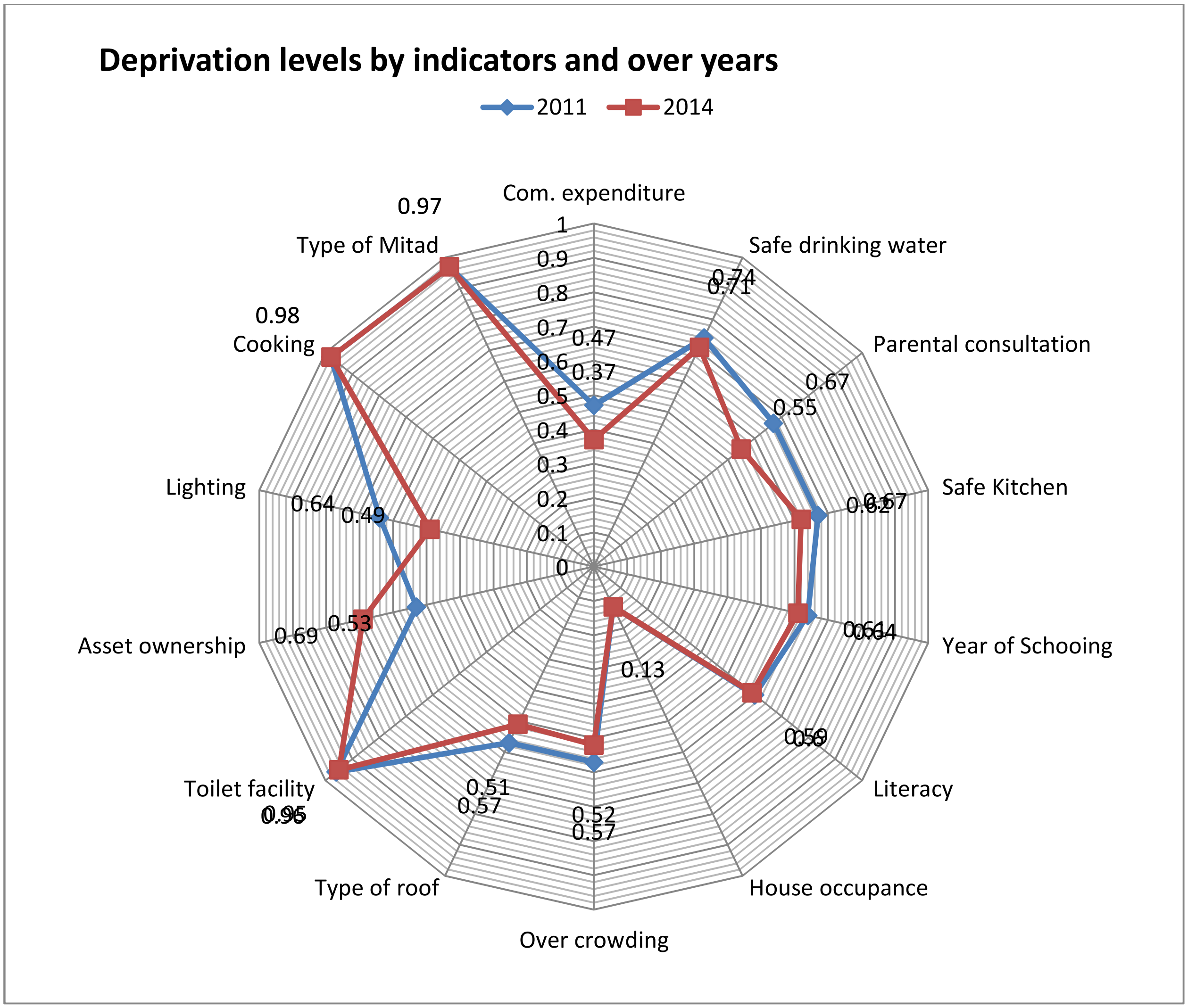
2.3. Factor loading analysis for weight determination



2. 4. Screen plot after factor analysis



2. 5. Deprivation status of household by indicator and over years



Chapter Three: Multidimensional Measure of Household Energy Poverty and its Determinants in Ethiopia[6]

Abstract

Access to clean and affordable energy is an important ingredient for attaining a good quality of life. This study analyzes the extent and determinants of energy poverty using data from two rounds of the Ethiopian Socioeconomic Survey. It computes a multidimensional measure of energy poverty using four dimensions and five variables. It also examines its determinants and their effects using the static random effect logit model. The results show that about 82.4 and 81.1 per cent of the respondents were multidimensionally energy poor in the two survey years, respectively. The study also examines the contribution of each dimension to energy poverty levels; deprivation in energy sources for cooking followed by deprivation in energy sources for lighting had higher shares. A sensitivity analysis of the weights used in constructing multidimensional energy poverty shows that the overall level of energy poverty was not sensitive to the weights. Regression results also show that a household with a larger family size, living in a rural area and being male headed had a higher probability of being multi-dimensionally energy poor while the age of the household head, the number of rooms occupied and the total household expenditure significantly reduced its probability. Hence, efforts at reducing energy poverty should be coupled with policies aimed at reducing poverty and promoting clean energy and energy use technologies with appropriate pricing mixes.

Keywords: Energy poverty, Ethiopia, multidimensional, random effect logit.

JEL classification codes: C25; D12; I32; N77; Q47.

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3.1 Introduction

Energy is used for cooking, lighting, production, transportation, communication, heating and cooling. It is crucial for the well-being of society. Life without energy is unthinkable. Energy is an important ingredient for attaining good education and health and a good quality of life in general. Access to modern energy is crucial for economic development because of its contribution to improved health conditions, reducing indoor air pollution, increasing production and productivity using modern technologies and machinery, saving time and adding to further education and expansion of health facilities (Barnes et al., 2011). Lack of access (both physical and economic) to reliable energy is believed to hamper economic growth and reduce citizens' welfare (Chakravarty and Tavoni, 2013; González-Eguino, 2015).

Moreover, energy is central to addressing many of today's global developmental challenges like poverty, inequalities, health, education, digital divide, connectivity and climate change (Foster et al., 2013; Nussbaumer et al., 2012). Despite the massive contribution of energy to economic progress and the important role that it plays in the process of economic development, there are indicators that in the future the global energy system will face various challenges that will question issues of sustainability and energy security. Among these challenges are increasing risks of shortages of energy supply, especially non-renewable sources; the threat to the environment caused by fossil fuel energy production and use; and persistent energy poverty. These challenges can be remedied only through strong and coordinated government action and public support (Birol, 2007).

For most poor households' access to and use of modern energy sources both physically and economically is inconceivable. In rural parts in developing countries not only economic access but even physical access is a major problem. The only dominant source of safe energy is electricity generated by using various primary energy sources but with limited physical access. Access to reliable and affordable energy and energy security has shown limited promising improvements for developing countries. As a result, the issue has been on the academic and policy agendas for a long time. Even though this has been a concern for developing countries since the 1980s, the problem of energy poverty has not yet been resolved in these countries (Barnes et al., 2011; Birol, 2007; Li et al., 2014; Pereira et al., 2010).

In the context of development, energy is mainly used for lighting, cooking, production and communication. Energy poverty is considered one of the most important issues related to development (González-Eguino, 2015). It is believed to be both the cause and the manifestation of poverty. Energy poor are defined as households who cannot meet their basic energy consumption needs. Breaking the vicious circle of energy poverty, eradicating energy poverty and achieving sustainable development in developing countries will be realized only with concerted efforts of researchers, policymakers, donor organizations and state governments (Birol, 2007; OFID, 2008).

Strikingly, in recent years about 1.2 billion people in developing countries have had lack of access to electricity and about 2.7 billion people have relied on inefficient and polluting fires for cooking and other household needs. Most of the electricity-deprived populations are in sub-Saharan Africa and South Asia.[7] Further, about 80 per cent of those without access to electricity live in rural areas (UNDP and WHO, 2009; WEO, 2014). Ethiopia is ranked 174 out of 188 countries for which the human development index (HDI) was computed and it is one of the least developed countries in the world (UNDP, 2015). It has one of the lowest rates of access to modern energy services. Its energy supply is primarily based on biomass. About 90 per cent of the primary energy source in the country is biomass while oil accounts for about 7 per cent and hydropower for 0.9 per cent. Besides, the energy use pattern in the country shows that households account for 88 per cent of total energy consumption followed by industry (4 per cent), transport (3 per cent) and services and others (5 per cent). Regardless of its high potential for production of modern energy, only about 25 per cent of the population in Ethiopia has access to electricity[8] (Dawit, 2012; WEO, 2014).

[7] http://www.worldenergyoutlook.org/resources/energydevelopment/energyaccessdatabase/ accessed on 22 January 2017.
[8] http://www.mowie.gov.et/energysector accessed on 14 February 2017.

As a response to development challenges and its aspirations of having inclusive and sustainable development, Ethiopia launched an ambitious medium term development plan – the growth and transformation plan (GTP) in 2011. The country put a target of attaining middle-income status by 2025 and the plan aligned its growth path with climate-resilient green growth. In line with this plan, the country embarked on an expansion of modern energy sources and its energy sector is considered an important pillar for realizing green growth and accelerating development in the country (FDRE, 2011a, 2011b). However, currently, the country's energy use pattern questions the sustainability and security of its energy use. Moreover, a majority of the households, especially in the rural areas, rely on traditional sources of energy. This signals the persistence of energy poverty in the country.

Globally there is considerable literature on energy (fuel) poverty (Barnes et al., 2011; Boardman, 1991; Chakravarty and Tavoni, 2013; Foster et al., 2000; Nussbaumer et al., 2012; Sadath and Acharya, 2017; Walkera et al., 2014). A few studies for sub-Saharan African countries are also available on energy poverty (Edoumiekumo et al., 2013; Tchereni et al., 2013). However, there is paucity of research on energy poverty in Ethiopia; in particular there is paucity of studies employing a multidimensional measurement approach. A study by Bekele et al., (2015) examines the extent and determinants of multidimensional energy poverty in Ethiopia's capital Addis Ababa. Thus, the present study contributes to the general literature on energy poverty and provides a concrete metric for Ethiopia. Using a rich dataset of the household survey, the study analyzes the extent and determinants of energy poverty in Ethiopia. This study is expected to deepen an understanding of the causes and extent of energy poverty.

Further, this study also investigates the most important attributes of multidimensional energy poverty and examines the extent of energy poverty for different groups of households in rural and small towns in Ethiopia. This is expected to indicate policy instruments for the post-2015 sustainable development strategy and will bridge the existing knowledge gap about the causes of energy poverty and indicate the way forward for a smooth transition to a modern energy system.

This research elaborates on several aspects of energy poverty with implications for the well-being of society. These include the many dimensions of energy poverty, the implications of persistence energy poverty and poverty reduction and the association between energy poverty traps and specific household characteristics. For this several research questions were formulated for an analysis:

- What is the extent of energy poverty in Ethiopia?
- What is the most important dimension of energy poverty?
- What do the extent and dimension of energy poverty mean for a country with persistent energy poverty such as Ethiopia?
- Do household characteristics really matter in energy poverty?

The rest of this study is organized as follows. Section 3.2 gives a summary of access to energy, reviews the definitions of energy poverty and presents a metric multidimensional measure. It discusses literature by summarizing empirical works on energy poverty. Section 3.3 presents the data and methodology. Section 3.4 discusses the results and the final section gives a conclusion and policy recommendations for achieving sustainable development goals (SDGs).

3.2 Issues in energy poverty

3.2.1 Energy potential and access

Access to modern energy is related to the level of economic development. The electrification rate seems to parallel a country's economic status. According to a WEO (2013) report, lower electrification rates and a higher number of people without access to electricity are more prevalent in developing countries. Globally about 1.2 billion people have no access to electricity regardless of impressive electrification rates of about 84 per cent with an urban electrification rate of 95 per cent and a rural electrification rate of 71 per cent (Table 3.1).

Table 3.1: Electricity access in 2014-regional aggregates

Region	Population without electricity (in million)	Electrification rate (per cent)	Urban electrification rate (per cent)	Rural electrification rate (per cent)
Developing countries	1,185	79	92	67
Africa	634	45	71	28
North Africa	1	99	100	99
Sub-Saharan Africa	632	35	63	19
Ethiopia	73	25	85	10
Developing Asia	512	86	96	79
China	0	100	100	100
India	244	81	96	74
Latin America	22	95	98	85
Middle East	18	92	98	78
Transition economies and OECD	1	99.9	100	99.7
World	1,189	84	95	71

Source: Adapted from the WEO (2016) database.

Developing countries are home to almost entire populations without access to electricity. Nearly half of these people are in Africa where the overall electrification rate is only 45 per cent (urban electrification rate of 71 per cent and rural electrification rate of 28 per cent). These figures are very alarming for sub-Saharan African (SSA) countries. About 53 per cent of the population without access to electricity is living in SSA countries. Here the overall electrification rate is only 35 per cent (urban electrification rate of 63 per cent and rural electrification rate of 19 per cent). Ethiopia is among those SSA countries which has lower electrification rates. Even though more than half of Ethiopia's population is geographically close to the electricity grid, about 73 million people are without access to electricity. The overall electrification rate in the country is about 25 per cent (urban electrification rate of 85 per cent and rural electrification rate of only 10 per cent). The country is performing well as compared to Africa and SSA countries' average urban electrification rates (Power Africa, 2015; WEO, 2014, 2016). However, it is performing poorly in rural electrification which is below the average SSA rural electrification rate (19 per cent). The country's per capita domestic electricity consumption is less than 100 kWh per year which is lower than the SSA countries' average level (317 kWh per year) and less than what a refrigerator uses per year in a developed country (Power Africa, 2015; WEO, 2014, 2016).

Though it is underdeveloped, Ethiopia is endowed with diversified energy sources. It has huge potential of various energy sources which are underdeveloped but promisingly exploitable at different scales. So far, the renewable energy potential of the country is predominantly generated from hydropower which is far below the capacity of the country. Energy potential from biomass remains dominant and is exploited in the rural parts (Table 3.2).

Table 3.2: Ethiopia's renewable energy potential

Resource	Unit	Exploitable reserves	Exploited	
			Amount	Per cent
Hydropower	MW	45,000	~2,100	<5 per cent
Solar/day	kWh/m^2	4 – 6		<1 per cent
Wind power	GW	1,350	171MW	<1 per cent
Geothermal	MW	7,000	7.3 MW	<1 per cent
Wood	Million tons	1,120	560	50 per cent
Agricultural waste	Million tons	15-20	~6	30 per cent
Natural gas	Billion m^3	113	-	0 per cent
Coal	Million tons	>300	-	0 per cent
Oil shale	Million tons	253	-	0 per cent

Source: Compiled from various documents of the Ethiopian Ministry of Water and Energy.

Ethiopia's capacity for electricity generation is increasing at an impressive rate. Its generation rate has grown by about 200 per cent as compared to the 2008 level. Electricity is predominantly generated from hydropower sources which account for about 90 per cent of the energy generated. However, this direction needs a cautious movement as hydropower is highly susceptible to droughts which may risk the sustainability of electricity supply. Despite this potential, the rural parts of the country predominantly meet their energy needs from non-renewable sources.

3.2.2 Definition of energy poverty

Despite a silence by development economists, the issue of energy poverty was recently brought to the global development agenda. These days, alleviating energy poverty has become a goal for many development organizations that deal with energy issues in developing countries. Though considerable efforts have been devoted to defining it, conceptualizing energy poverty remains a challenge for development thinkers. The standards that have been developed rest on arbitrary assumptions about the energy devices used as well as a normative definition of what a set of basic needs consists of.

The context in which the definition is used such as differences in cultural and climatic conditions is of paramount importance. In this regard, one can ask several questions about the definition of energy poverty. What is the distinction between energy poverty and income poverty? Is energy poverty concerned with access to energy services such as cooking, lighting, heating and communication? Or is it based on the quantity of energy that households use? These have complicated the universality of a definition of energy poverty and have generated various approaches to measuring energy poverty (Barnes et al., 2011).

Even though a universal definition is hard to come up with due to technological requirements, environmental conditions, efficiencies of the energy use technology and conceptualization of energy use and the likes, there are some commonly used definitions of energy poverty. For instance, energy poverty can be defined as the state of deprivation where a household is barely able to meet its minimum energy requirements for basic needs such as cooking, lighting, heating and communication (Foster et al., 2000; Modi et al., 2005; OECD and IEA, 2010). The energy poor are defined as households which cannot meet their basic energy needs by estimating a minimum limit of energy consumption (Parajuli, 2011; Pereira et al., 2011). Energy poverty is also defined as lack of access to modern energy services (Li et al., 2014). Further, the concept of energy poverty has been expanded to 'an absence of sufficient choice in accessing adequate, affordable, reliable, high quality, safe and environmentally benign energy services to support economic and human development'(Reddy, 2004). Besides, expenditure or income parameters are also used to define energy poverty. For example, energy poverty has been defined in terms of the percentage of income spent on energy consumption. Households that spend more than 10 per cent of their incomes on energy are considered energy poor. Justification for this approach rests on the fact that when households are forced to spend as much as 10 per cent of their income on energy they are being deprived of other basic goods and services necessary to sustain life.

Some researchers use an income point below which energy expenditure remains unchanged to define energy poverty implying that this is the bare minimum energy need. At higher incomes, the level of expenditure on energy increases which is hardly attainable by the poor. This approach derives the energy poverty line on the basis of demand (Barnes et al., 2011).

A conceptualization of energy poverty in Amartya Sen's capability approach framework has been emerging in recent studies and in energy policymaking. This approach views energy poverty as multiple deprivations which require a comprehensive measurement using a multidimensional approach (Edoumiekumo et al., 2013; Edoumiekumo and Moses, 2014; Nussbaumer et al., 2012; Pereira et al., 2011; Sher et al., 2014). Regardless of the immense efforts devoted to the issue, as of today there is no unified definition of the concept of energy poverty. The multidimensional measure which was originally developed in the context of poverty and inequality seems to be consistent with the notion of SDGs. In a recent study, Day et al., (2016: 260) define energy poverty as a 'situation of inability to realize the essential capabilities as a result of insufficient access to affordable, reliable and safe energy services, and taking into account the alternative means of realizing these capabilities in a reasonable manner.'

Literature on energy poverty differentiates between energy poverty and fuel poverty. Some attribute these concepts to different countries' concerns on the basis of their economic status and energy systems. Energy poverty is the issue of accessibility to modern energy whereas fuel poverty is an issue of affordability. The former is a concern in developing countries, at least under their current economic status, whereas the latter is more of a concern in developed countries (Boardman, 2012; Li et al., 2014). (A detailed review of the definitions of fuel poverty is available in Moore, 2012).

3.2.3 Measures of energy poverty

Various measures of energy poverty have been developed and applied in the literature on energy poverty. These metrics can be categorized as uni-dimensional, composite index and multidimensional index. The uni-dimensional metric is a powerful and unbiased measure that is easy to interpret with regard to one specific dimension and it is simple for computation. However, it is not suitable for less tangible issues such as sustainable development or poverty measures. The uni-dimensional measure of energy poverty gives a metric which could parallel the income measure of poverty with the World Bank's poverty line of $1.25 per day. Examples of this include the minimum amount of physical energy necessary for meeting basic needs, type and amount of energy that is used for those at the poverty line, the income point below which energy use or expenditure remain the same and a 10 per cent rule of expenditure. Composite indices, on the other hand, are single numerals calculated from a number of variables that represent the aggregated value of a dimension. These are advantageous over the uni-dimensional (dashboard) approach where we evaluate each dimension against some pre-determined, cut-off points. In the composite indices, we find a single number which basically facilitates a comparison across various groups. The energy development index (EDI) is an example of a composite index. Finally, the multidimensional energy poverty index (MEPI) accounts for multiple deprivations of energy access and energy technology.

Both MEPI and EDI measure access to modern energy sources; however, MEPI evaluates energy poverty whereas EDI is a measure of an energy system's transition towards modern fuels (Nussbaumer et al., 2012; Ravallion, 2010). The development of the multidimensional energy poverty measure which parallels multidimensional poverty measures reflects capabilities and functioning. The method is both data intensive and comprehensive as it considers non-income dimensions in the (energy) poverty measure. Notwithstanding its merits and relevance from the perspective of poverty, the method has had limited application in developing countries due to paucity of data. However, the recent availability of multi-topic data for these countries revitalizes its application.

As a component of multidimensional measures and a base for uni-dimensional measures various indices have been developed for assessing the level and extent of energy poverty. The commonly used index of poverty measure is by Foster et al., (1984) which has been adopted to measure energy poverty as well. The three metric measures: the headcount index of energy poverty, the energy poverty gap index and the squared energy poverty gap index are frequently computed to assess the energy poverty status of households. Following Foster et al., (2000) these indices of energy poverty can be formulated as P_α:

(3.1) $$p_\alpha = \sum_{E_i \le Z} \left(\frac{w_i}{N} \right) \left(1 - \frac{E_i}{Z} \right)^\alpha$$

where P_α stands for the energy poverty index, w_i stands for the weight for household i, E_i stands for energy consumption for household i, Z stands for the fuel poverty line and N stands for population size. This index provides three metrics of energy poverty:

intensity (headcount ratio), severity (poverty gap) and depth (squared poverty gap) for $\alpha = 0$, 1 and 2 respectively.

However, the striking issue in energy poverty literature is determining the energy poverty line. For over 20 years many researchers have been using the definition given as the minimum quantity of physical energy needed to perform such basic tasks as cooking and lighting. Others have also used a definition of the energy poverty line as the level of energy used by households below the known expenditure or income poverty line. The underlying assumption of this approach is that expenditure-based poor households are necessarily energy poor as well. However, this may or may not be the case (Foster et al., 2000).

Further, energy expenditure as a proportion of total income has been used to determine the energy poverty line (Boardman, 1991). This method was derived from the fact that relatively speaking poor households spent a higher percentage of their incomes on energy than wealthier ones, and spending more than a certain share of income may deprive them of other necessary goods. A cut-off point of 10 per cent of the total income has been used as the maximum share of energy expenditure allowed to remain non-poor (Barnes et al., 2011). One of the advantages of this approach is its insensitivity to price change. It is a relative energy poverty index allowing for heterogeneity in the poverty line by income classes and locations. The same authors have also developed another method which is similar to the expenditure method to define the energy poverty line. For the alternative method, they used a demand-based approach as the threshold point at which energy consumption begins to rise with an increase in household income. At or below this threshold point, households consume a bare minimum level of energy and should be considered energy poor. Some authors have also proposed a median approach, when income distribution is skewed to determine the energy poverty line.

A definition of energy poverty and determining the cut-off (the energy poverty line), however, need to be approached with caution. The conventional way of defining poverty and the poverty line does not serve this purpose. In the case of conventional goods, higher consumption means a higher level of welfare or lower level of poverty. But for energy goods, more consumption may not necessarily lead to higher welfare due to the fact that the demand for energy is a derived demand. Higher consumption of energy perhaps leads to lower welfare due to its repercussions on the environment, human health and budget claims. In this paper, we employ the multidimensional measure of energy poverty following the Nussbaumer et al., (2012) methodology.

3.2.4 Empirical Literature

In this section we briefly review some empirical studies conducted on energy poverty. The survey incorporates studies from different parts of the world even though it focuses on those from developing countries.

A review of various energy poverty measurements by Pachauri and Speng (2004) shows the status of the metric. The study presents a review of various measures of energy poverty using the economics and engineering perspectives. In an attempt to show a link between income poverty and energy poverty, the study found that there was a strong relationship between the two. The study also developed a two dimensional measurement of energy poverty and distribution. This measurement of energy poverty combines information on access to different energy carriers and quantities of energy consumed per capita. This is compared to a minimum energy requirement necessary to meet basic needs. The study further indicates that the developed two dimensional measure of energy poverty is a good complement to the consumption based poverty measurement. A further study by Pachauri et al. (2004) did an empirical assessment of energy poverty and distribution using Indian household survey data for 1983-2000. The results show a significant reduction in the level of energy poverty in India.

Similarly, Pachauri and Spreng (2011) did a detailed review of metrics used for measuring energy poverty. Their study compares existing energy poverty measurements and evaluates their applicability for consistent global comparison of the levels of energy poverty. The study recommends widening the scope of metrics of energy poverty to help appropriate designing and evaluation of policies and programs. It also acknowledges the multidimensionality of energy poverty and its measurements, though not explicit enough.

Barnes et al., (2011) employed demand based approaches to estimate the level of energy poverty in rural Bangladesh. In this approach the poverty line for measuring energy poverty is determined as a threshold point at which energy consumption begins to rise with an increase in household income. At or below the threshold, a household barely meets its basic needs and is thus considered energy poor. Using the 2004 compressive household survey in rural Bangladesh the study shows that the level of energy poverty was higher than the income poverty level. The findings of the study further indicate that rural electrification policies and the use of an improved biomass stove played a significant role in reducing energy poverty.

A study conducted by Pereira et al., (2011) shows that rural electrification played a significant role in reducing energy poverty and enhancing energy equity (fairness) in Brazil. The study re-scrutinized the existing energy poverty line to fit to the realities of Brazilian social and economic realities. It applied energy poverty measurements in the analytical framework of inequality and poverty analysis such as the Lorenz curve, poverty gap, squared poverty gap and Gini coefficient and the Sen Index to evaluate the effectiveness of the Brazilian government's energy poverty interventions.

In a same vein, Khandker et al., (2012) analyzed energy poverty using comprehensive cross-sectional data from a 2005 household survey which was a representative of both urban and rural India. The study defines the energy poverty line as the threshold point at which energy consumption started rising with an increase in household incomes. The aim of the study was to examine the relationship between income poverty and energy poverty. The study's empirical results show that the level of energy poverty was significantly higher than the income poverty level in rural areas. It suggests that besides policies for improving household incomes, energy related interventions and policies are also required to ameliorate the condition of energy poverty.

A ground breaking study by Nussbaumer et al., (2012) conceptualized the definition of energy poverty in a broader perspective. Their study did an intensive review of the existing metrics for energy poverty. It discusses their adequacies and applicability in measuring energy poverty. The study developed a multidimensional energy poverty index (MEPI) and applied it to many African countries to assess the extent and intensity of energy poverty. The results of the study show significant variations in the extent and intensity of energy poverty across Africa countries.

Groh (2014) developed and applied the concept of energy poverty penalty which states that people who are deprived of access to energy services spend more money relative to their income as compared to those who enjoy better access. It evaluated energy poverty from the end-use perspective using data from 342 households and micro-businesses in the rural areas of Arequipa, Peru. The results of the study show the prevalence of energy poverty penalty in the lower income segments. The study also shows the existence of a strong relationship between energy poverty, remoteness and development opportunities for people. The inevitable impact of energy penalty on energy poverty has an implication of leading to a trap in delaying rural development at the household level or hindering the development path for rural areas.

Treiber et al., (2015) tested the long standing energy ladder and energy stacking hypotheses in the context of energy sources and energy efficient cook stove use in Kenya. The study tested the existence of linear relationship between economic development and a transition to cleaner, more efficient and costly energy sources and energy use technologies. However, the results of the study shows that households tended to diversify energy use as incomes increased. The study indicates the existence of multifaceted demands in households which derive multiple demands for fuels and stoves. It concludes that broadening accessibility and availability of energy sources and energy conversion technologies may contribute to energy poverty alleviation.

Amidst increasing global attention on energy poverty, Wang et al., (2015) emphasize the importance of an appropriate measurement before making policies to alleviate energy poverty. Their study reviews previous literature on energy poverty and categorizes it under availability of energy services, the quality of energy services and satisfaction of energy demand for human survival. After evaluating the inadequacy of the existing measure of energy poverty for China, the study constructs a new energy poverty comprehensive evaluation index. The study also evaluated regional energy poverty and found that China's energy poverty showed an alleviating trend between 2000 and 2011. However, the results of the study show the persistence of different characterizations of energy poverty for different regions in the country over time and across dimensions. To ameliorate the situation of energy poverty, the study proposes several policy interventions such as increasing investments for energy infrastructure, a relative cost reduction of households' commercial energy consumption, expanding the energy management organization in rural areas; and boosting the utilization of modern, clean and efficient energy consumption equipment.

Day et al., (2016) revitalize energy use in the conceptual framework of Sen's capability approach. Their study defines energy poverty in the capability space which provides sound theoretical and coherent means of understanding the relationship between energy and well-being and thus conceptualizing the extent of energy deprivation. They propose a multidimensional measure of energy poverty which can be flexibly used under different social realities; this also opens another door for planning interventions for energy poverty alleviation which consider the multifaceted nature of the problem.

Similarly, a recent study by Sadath and Acharya (2017) employed the multidimensional energy poverty measurement derived within the framework of Sen's capability approach. This study presents a comprehensive assessment of the extent and socioeconomic implications of energy poverty in India. The study used the India Human Development Survey-II (2011-12) to analyze the multidimensional energy poverty index. The results of the study show that energy poverty was widespread in India and it also overlapped with other deprivations like income poverty and social backwardness.

A summary of some of the studies and the methodologies that they employ is chronologically presented in Table 3.3 to show past developments and the current state of research.

Table 3.3: Summary of empirical studies on energy poverty

No.	Author(s)	Year	Country	Energy poverty definition and analysis
1	Pachauri and Spreng	2004	India	Two-dimensional/Engineering method
2	Pachauri et al.	2004	India	Two-dimensional
3	Pachauri and Spreng	2011	General	Broader indicators of energy use
4	Barnes et al.	2011	Bangladesh	Demand based
5	Pereira et al.	2011	Brazil	Used the conventional analytical framework (Lorenz curve, Gini coefficient etc.)
6	Nassbaumer et al.	2012	Some African countries	Multidimensional Energy Poverty Index
7	Khandker et al.	2012	India	Demand based
8	Tchereni et al.	2013	Malawi	Energy expenditure
9	Edoumiekumo et al.	2013	Nigeria	Multidimensional Energy Poverty Index
10	Groh	2014	Peru	Energy poverty penalty concept
11	Treiber et al.	2015	Kenya	Energy ladder and energy stacking hypothesis
12	Wang et al.	2015	China	Energy Comprehensive Index
13	Bekele et al.	2015	Ethiopia	Multidimensional Energy Poverty Index
14	Day et al.	2016	General	Multidimensional Energy Poverty Index
15	Sadath and Acharya	2017	India	Multidimensional Energy Poverty Index

We can find vast literature on energy poverty for different countries. Our review and summary table shows that researchers have used various methods and the results of their analyses vary considerably. However, recent studies using the multidimensional approach have become prominent. Unfortunately, very few studies are available for sub-Saharan African countries despite the fact that energy poverty is a pressing issue for these countries. A study conducted by Tchereni et al., (2013) analyzed energy poverty levels for Malawi using energy expenditure to define energy poverty. Their results show that various socioeconomic variables determined the energy poverty status of households. Similarly, Edoumiekumo et al., (2013) employed the multidimensional measure of energy poverty to show the extent and determinants of energy poverty in Nigeria. The results of their multidimensional energy poverty show that the country had severe energy poverty with some regional variations. Moreover, their regression results from the multinomial logit model show that socioeconomic, geographic and demographic variables affected the probability of households falling into different energy poverty statuses.

For Ethiopia there is paucity of research on this issue. Very few studies are available and those which are available have limitations in terms of the area covered and the methodologies employed. Bekele et al., (2015) conducted a study on energy poverty employing the multidimensional approach. Their study used Addis Ababa as a case study and examined the extent and determinants of households' energy poverty. This study is geographically limited to only Addis Ababa. Therefore, it is expected that our paper will bridge this gap and provide a comprehensive measurement of the extent and intensity of energy poverty in Ethiopia using the multidimensional measure of energy poverty developed by Nussbaumer et al., (2012) in the framework of the family of decomposable measures of multidimensional poverty developed of Alkire and Foster (2007).

3.3 Data and Methodology

3.3.1 Data sources and types

The data used for this study is a combination of secondary data obtained from various sources. Primarily, the study relied on secondary data collected by the Central Statistical

Agency of Ethiopia and the World Bank (CSA and WB). It also used data from the International Energy Agency-World Energy Outlook database and two waves of data from the Ethiopian Socioeconomic Survey (ESS) which is a collaborative project between CSA and the World Bank's Living Standards Survey. The first wave of the data was collected in 2011 and the second in 2014 which was finally released in March 2015. The survey is very comprehensive and is multi-topic that can be flexibly used for welfare analyses using different attributes. The first wave of the survey covered almost all the rural parts of the country and also its small towns.

As part of the first survey, information was collected from 3,969 respondents in all regions of the country. In its second wave, the survey extended the sampling frame by including respondents from large urban areas including capital Addis Ababa. By doing this it tried to maintain the representativeness of the data collected from the sample respondents. The second round of the survey collected information from 5,262 respondents of which 3,776 were from the first wave. The two waves are expected to gradually form panel data where households are observed over time. The panel attrition rate between the two current waves is only 5 per cent or the two-year panel success rate is about 95 per cent which can be safely used for a simple panel data analysis following households' energy use behavior over time. As a result, our study uses information from 3,776 respondents in rural and small towns in Ethiopia which were covered in both the rounds of the survey (for a detailed description of the dataset see CSA and WB, 2013, 2015).

3.3.2 The multidimensional measure of energy poverty

The striking issue in measuring energy poverty is availability of detailed data on various dimensions of households' energy use. The selection of variables/indicators in constructing the multidimensional measure of the energy poverty index is subject to the availability of data. Besides, determining the relative importance of each variable in constructing MEPI is crucial. Following literature on the multidimensional measure of energy poverty and data availability, some attributes were identified as indicators of energy use status of households in rural and small towns in Ethiopia.

The index is composed of five indicators forming an index with four dimensions. The first indicator is type of energy sources used by households for cooking. It is clear that all households use energy for cooking their daily food. However, the type of energy sources they use to generate this heat affects their welfare. Use of traditional energy sources (firewood, charcoal, dung or crop residuals) cause many inconveniences and entail great opportunity costs (such as time allocated for collecting them). The second dimension is the extent of indoor air pollution. Dependence on traditional sources of energy and using inefficient energy use technologies exposes households to higher risks of indoor air pollution among other things. Indoor air pollution threatens the health and lives of many rural households in developing countries. Women and children are highly prone to externalities of cooking. This in turn creates health risks and reduces the welfare of the households (UNDP, 2014; WHO, 2002). As a result, including variables which can proxy this problem is very crucial in computing the multidimensional index of energy poverty.

Two variables were used to measure the risk and health burden of indoor air pollution: kitchen and type of stove used. The third indicator is type of energy used for lighting and finally ownership of entertainment and educational assets were used to construct the multidimensional measure of energy poverty. Details of the variables, indicators, weights used and deprivation cut-offs for computing MEPI are given in Table 3.4.

Table 3.4: Description of attributes, variables and their cut-off points for computing MEPI

No.	Dimension	Indictor	Variables (weight)	Deprivation cut-off (poor if…)
1	Cooking (Ci)	Modern cooking fuel	Type of cooking fuel (0.25)	Use traditional sources of energy[9] for cooking
2	Pollution (IPi)	Indoor air pollution	Kitchen is separate (0.15)	Use same residential house for cooking or no kitchen
			Type of oven/mited used for cooking (0.15)	Use traditional cook stove or use a three-stone cook stove
3	Lighting (HFi)	Energy for lighting	Type of energy used for lighting (0.25)	Household is deprived if it does not have electricity for lighting

[9] Traditional sources of energy in this context refer to biomass such as firewood, charcoal, dung and crop residuals while modern energy sources include electricity, kerosene, LPG and natural gas.

4	Entertainment & Education (EEi)	Entertainment or educational appliance ownership	Has a radio, tape, TV or satellite dish (0.20)	A household is considered poor/deprived if it has none of these assets

Multidimensional energy poverty was analytically constructed from the dimensions identified with weights estimated or assigned to show the level of energy deprivations that may affect households' welfare. The construction of MEPI followed the multidimensional poverty measure developed by scholars at the Oxford Poverty and Human Development Initiative (OPHI) (Alkire, 2007; Alkire and Foster, 2007, 2011; Alkire and Santos, 2014). Their initiative was influenced by Amartya Sen's ground breaking work on deprivations and capabilities with the central argument that human poverty should be considered as the absence of opportunities and choices for living a basic human life (Sen, 1990).

Our energy deprivation status of a household is constructed using four dimensions with five indicators. A household is said to be energy poor if the deprivation exceeds pre-defined cut-off points. Following Nussbaumer et al., (2012) we defined the multidimensional energy poverty status of households as: multidimensional energy poverty is measured in d variables for the sampled households (n). A vector $Y=\{y_{ij}\}$ represents the n×d matrix of achievements for i households across j variables. The value of $y_{ij}>0$, therefore, represents household i's achievement in the j^{th} variable. From these household level achievements using the dual cut-off approach we constructed the extent and severity of multidimensional energy poverty for each household and aggregated it to the population level.

A multidimensional energy poverty line of 0.33 was adopted. A household was energy poor if it was deprived of more than 33 per cent of the indicators. Hence, a household whose sum of weighted deprivations was greater than or equal to 0.33 was categorized as energy poor and a household whose sum of weighted deprivations was less than 0.33 was energy non-poor.

To be more clearly and formally drive the multidimensional energy poverty, let there be n individuals in all. Let M be the set of all households, m in number, and let n_i be the number of persons (or adult equivalent units) in household I (i=1,…, m), so that $\sum_{i \in M} n_i \equiv n$. Suppose there are d dimensions of deprivations in all, denoted by the running index j=1, …, d. Let D_{ij} be the deprivation status of household I (i=1, …, m) with respect to dimension j (j=1, …, d), with D_{ij} =1 if I is deprived in the j^{th} dimension, and D_{ij} = 0 otherwise.

If w_j (ϵ (0, 1)) is the weight attached to deprivation in the j^{th} dimension (with $\sum_{j=1}^{d} w_j = d$), then the deprivation score of household I can be written as:

(2) $S_i = \sum_{j=1}^{d} w_j D_{ij}$, i=1, …, m.

Let S* be the cutoff score for a household to be deemed multidimensionally deprived. Then, the set of deprived households is given by:

$R \equiv \{i \in M | S_i > S *\}$, and let the cardinality of the set R (that is to say, the number of multidimensionally deprived households) be denoted by r. Then, the number of multidimensionally deprived individuals, q, is obtained by summing the individuals over all deprived households:

$q \equiv \sum_{i \in R} n_i$. Further, the multidimensional headcount index of (energy) poverty is given by:

(3) $H \equiv \frac{q}{n}$.

Further, the level of multidimensional deprivation per poor household,$\bar{S}$, can be written as the average level of deprivation of the deprived households:

(4) $\bar{S} \equiv (1/r) \sum_{i \in R} S_i$.

Finally, the multidimensional energy poverty index is simply the product of H and $\bar{S}$:

(5) $MPI \equiv H\bar{S}$.

3.3.3 An econometric analysis of determinants of energy poverty

The index computed provides a measure of energy poverty. In line with literature, in the second step the households were classified as energy poor and energy non-poor. This allowed analyzing the multidimensional measure of energy poverty and its determinant using a panel logit model. In the logit model the dependent variable was MEPI. It was transformed into binary choice by using a specified deprivation cut-off point for the energy poverty index. If the index was greater than 0.33 the household was considered to be energy poor multidimensionally. The threshold was chosen based on the assumption of minimum required energy to satisfy the normal needs of a household considering the four dimensions described earlier.

3.3.4 Specification of the econometric model

The theoretical foundation for the specification of this model was driven from the latent variable approach. Suppose that a household's energy use is specified as:

$$y^*_{it} = x_{it}\beta + c_i + u_{it} \tag{6}$$

However, y^*_{it} is not observable by a researcher, what the researcher observes is whether the household under consideration is energy poor or not based on the threshold. As a result, the analyst can initiate specifications and estimations of binary choice models from the latent variable specification to identify and estimate the effects of the determinants of household energy poverty (Green, 2003):

$$y_{it} = \begin{cases} 1 \text{ if } y^*_{it} > 0 \\ 0, \text{ otherwise.} \end{cases} \tag{7}$$

Now the probability that y_{it} takes the value of one given the covariates and individual unobserved heterogeneity can be written as:

$$pr\left(y_{it} = 1 \mid x_{it}, c_i\right) = F\left(x_{it}\beta + c_i\right), \tag{8}$$

where F(.) is either the standard normal CDF (probit model) or the logistic CDF (logit model). From this non-linear model, individual heterogeneity (c_i) cannot be removed easily by differencing using within transformation or inclusion of the individual dummy variable to estimate (c_i) since it results in biased estimates unless t is very large. This will lead to the problem of incidental parameters (small T bias) (Cameron and Trivedi, 2005). Thus, we can estimate non-linear panel models with random effect or fixed effect logit or probit models. In our paper assuming the logistic distribution, we can specify our logit model as:

$$\begin{aligned} &\mathrm{pr}\left(y_{it} = 1 \mid x_{it}, c_i\right) = \Lambda\left(x_{it}\beta + c_i\right) \\ &\mathrm{pr}\left(y_{it} = 1 \mid x_{it}, c_i\right) = \frac{\exp\left(x_{it}\beta + c_i\right)}{1 + \exp\left(x_{it}\beta + c_i\right)} \end{aligned} \tag{9}$$

The traditional random effect logit model under the following assumption was used to estimate the determinants of multidimensional energy poverty in rural and small towns in Ethiopia. It requires strict exogeneity and zero correlation between the explanatory variables (x) and individual heterogeneity (c_i). The final estimable model for identifying and examining the effects of the determinants of multidimensional energy poverty in rural and small towns in Ethiopia used characteristics of a household's head (age, sex, education level, marital status); household characteristics (family size, expenditure on energy, total household expenditure and credit use); and nature of residential area (rural or small town). After the estimation of the random effect logit model, the log odds ratio and marginal effects were estimated to get interpretable results.

The odds ratio obtained from the logit model which shows the ratio of success to failure can be specified as:

(10)
$$\left(\frac{pr\left(y_{it}=1\mid x_{it},c_i\right)}{pr\left(y_{it}=0\mid x_{it},c_i\right)}\right)=\frac{\exp\left(x_{it}\beta+c_i\right)}{1+\exp\left(x_{it}\beta+c_i\right)}\Bigg/1-\frac{\exp\left(x_{it}\beta+c_i\right)}{1+\exp\left(x_{it}\beta+c_i\right)}$$
$$=\exp\left(x_{it}\beta+c_i\right)$$

If we take the log of the odds ratio we get the log odds ratio as:

(11)
$$\log\left(\frac{pr\left(y_{it}=1\mid x_{it},c_i\right)}{pr\left(y_{it}=0\mid x_{it},c_i\right)}\right)=\log\left(\exp\left(x_{it}\beta+c_i\right)\right)$$
$$=x_{it}\beta+c_i$$

Finally, the marginal effect for the determinants of energy poverty based on the logit model parameter estimates was obtained from the following relation:

(12)
$$\partial\Pr\left(y_{it}=1\mid x_{it},c_i\right)\Big/\partial x_{jit}=\beta_j\Lambda\left(x_{it}\beta+c_i\right)\left\{1-\Lambda\left(x_{it}\beta+c_i\right)\right\}$$

The odds ratio and marginal effects were among the generated results which were used for an interpretation. As we can see from Eqn. 12 the marginal effect of the x-variables based on the logit is non-linear. This implies that the interpretation of the logit model should be treated with caution. Depending on the test of panel versus pooled data results we have reported the pooled logit model results.

3.4 Results and Discussion

The first part of this section presents descriptive statistics of important variables to highlight and give a clear picture of the data used for the study. It starts with a presentation and discussion of the demographic characteristics of the respondents. It then extends to a description of the socioeconomic characteristics of the households. It finally presents the status of households in energy related activities with due emphasis on the variables used for constructing the multidimensional energy poverty index. This part also gives energy access and energy use technology ownership status of the households. As such it shows the energy poverty status of the households qualitatively or gives the dashboard indicator of households' deprivation levels. In the second part, it does an analysis of energy poverty using a multidimensional approach in detail. It then presents the econometric results to examine the determinants of multidimensional energy poverty in rural and small towns in Ethiopia.

3.4.1 Descriptive statistics of the demographic characteristics

The demographic characteristics of the households and their heads for the two waves of the data are presented in Table 3.5.

Table 3.5: Household size, age and sex of head (by year)

	Year			
	2011		2014	
Variable	Mean	Std. Dev	Mean	Std. Dev.
Household size (in number)	4.86	2.38	5	2.39
Household head's age (in years)	44.24	15.64	45.84	15.32

Source: Researcher's computation.

As can be seen from Table 3.5, the family size of the sample respondents was about 4.86 in 2011 with a standard deviation of 2.38. In the second round of data collection the mean family size was slightly higher than it was in the first round. In 2014 average family size of the respondents was five persons per household with a standard deviation of 2.39. This may tell us that family planning needs to be reconsidered if the country wants to keep population growth within reasonable dynamics. Further, Table 3.5 shows that the average age of the household head was about 44.24 and 45.84 years in 2011 and 2014 respectively. It shows that the average age of the head of the household was slightly higher in 2014 as compared to 2011.

Table 3.6: Percentage of sex, religion and marital status of the head of household (by year)

	Year	
	2011	2014
Variable	Percentage	Percentage
Household head's sex: Male (per cent)	75.48	74.12
Household head's sex: Female (per cent)	24.52	25.88
Household head's religion: Orthodox (per cent)	43.83	43.77
Household head's religion: Muslim (per cent)	32.79	33.23
Household head's religion: Protestant (per cent)	19.65	19.70
Household head's religion: Others (per cent)	3.73	3.30
Single	3.83	3.36
Married	76.28	74.49
Divorced	5.47	6.83
Separated	1.19	1.36
Widowed	12.52	13.96

Source: Researcher's computation using ESS 2011 and 2014 data.

A detailed exploration of the data in Table 3.6 shows that there was not much variation in the headship and religion of the head of the household in the two rounds of the survey. The headship role was predominantly played by males which may call for various policies to empower women and their roles in resource use and decisions in the household. Besides, the religion of the head of the household showed a slight variation in the two survey periods.

The marital status of the head of the household shows that a majority of the respondents were married (about 76.28 per cent and 74.49 per cent in 2011 and 2014 respectively). Table 3.6 further shows that a very low proportion of the respondents was single or separated in both rounds of the survey.

Table 3.7 presents the expenditure patterns of households on different items in 2011 and 2014. There is an observable variation in expenditure patterns in the survey years. In the first round food and energy expenditures were on average higher than in 2014. But expenditure on non-food items shows slightly higher value on average in 2014 as compared to 2011. Moreover, the pattern of expenditure shows that there was wider dispersion which indicates the extent of inequalities in the study area and hence implies relevant policy interventions to improve the situation.

Table 3.7: Descriptive statistics of important variables (by year) (per adult equivalence)

	Year			
	2011		2014	
Variable	Mean	Std. Dev	Mean	Std. Dev
Annual food expenditure	8,843.56	48,391.32	6,723.93	10,573.76
Annual energy expenditure	665.97	6,179.88	642.35	2,067
Annual non-food expenditure	1,439.25	8879.73	1,631.07	3,070.07
Annual non-food expenditure (fixed assets)	2,224.09	13,886.54	2,964.07	5,356.31
Annual total expenditure	12,506.91	53,249.59	11,319.07	141,001.73

Source: Researcher's computation.

3.4.2 Descriptive statistics of energy sources and technology use of households

The data from the two rounds of the survey contain important information about the energy use status of households. Residents in most developing countries, especially in rural parts, relied on inefficient energy use technologies and energy sources to meet their daily needs. This was partly due to the non-availability of alternative sources and due to their non-affordability. As we can see from Table 3.8, a majority of the households used biomass as a source of energy for cooking. Firewood (either collected or purchased) was the major source of energy for cooking for about 87 per cent of the households in rural and small urban areas. This predominance of firewood for cooking has significant implications for health, time use and negative environmental impacts. Very few households used modern energy sources as a major source of cooking energy.

Table 3.8: Main sources of cooking fuel (by year)

	Year	
	2011	2014
Variable	Percentage	Percentage
Collect firewood	78.04	77.62
Purchase firewood	9.80	9.71
Charcoal	1.61	1.52
Crop residuals/leaves	3.24	5.30
Dung/manure	5.01	5.30
Sawdust	0.08	0.03
Kerosene	0.62	0.69
Butane/gas	0.03	0.11
Electricity	0.13	0.64
Solar	0.03	0.00
Other sources	1.42	1.1

Source: Researcher's computation.

Table 3.8 shows that electricity, solar, kerosene and butane/gas made an almost insignificant proportion of energy sources for cooking among the respondents in rural and small towns in Ethiopia. This requires an aggressive energy policy and interventions to ameliorate the situation.

Table 3.9: Main source of energy used for lighting by households (by year)

	Year	
	2011	2014
Variable	Percentage	Percentage
Electricity meter- private	7.64	7.90
Electricity meter- shared	9.65	12.35
Electricity from generator	0.45	0.50
Solar energy	0.13	3.05
Electric battery	0.29	0.50
Light from dry cell with switch	17.29	25.64
Kerosene light lamp (imported)	9.75	5.78
Kerosene light lamp (local kuraz)	41.23	33.54
Candle/wax	0.24	0.08
Firewood	12.99	9.68
Other sources	0.32	0.98

Source: Researcher's computation.

Table 3.9 shows the status of energy sources for lighting in rural and small towns in Ethiopia. A further look at the data shows that the primary energy source for lighting was kerosene light (local kuraz) which accounted for about 41 per cent and 35 per cent in 2011 and 2014 respectively. About 17 and 20 per cent of the respondents used electricity from different sources for lighting in 2011 and 2014 respectively. Light from dry cells with switches, firewood and imported kerosene lamps contributed significantly to households' sources of energy for lighting. Despite the fact that Ethiopia is a country with sunshine throughout the year, the solar energy source contributed a very small proportion of households' sources of energy for lighting. This could signal that solar energy as an alternative source of energy for the country is poorly developed which calls for appropriate policy interventions.

Table 3.10: Type of kitchen used by households for preparing food

	Year	
	2011	2014
Variable	Percentage	Percentage
A room used as a modern kitchen outside	0.35	0.56
A room used as a modern kitchen inside	0.32	0.64
A room used as a traditional kitchen outside	32.7	36.4
A room used as a traditional kitchen inside	23.27	28.95
No kitchen	43.36	33.46

Source: Researcher's computation.

Indoor air pollution is a very severe problem in developing countries which predominantly use traditional sources of energy for preparing their daily food (see Table 3.10). Besides the type of energy used, the type of kitchen and energy use technologies also play a crucial role in reducing indoor air pollution. Energy use technology has an immense role in reducing indoor air pollution through the quantity of energy used for cooking or lighting and saving time for households. Cooking in most of the developing countries demands a lot of time and uses considerable energy and claims a higher resource budget of poor households. As a result, improving energy use efficiencies of these technologies and promoting technologies reduces energy use related burdens on the environment and enhances households' welfare to a greater extent. As can be seen from Table 3.11 about 97 per cent of the households used traditional stoves for cooking. This does not show any improvement in the 2014 survey.

Table 3.11: Primary type of stove (mitad) used - baking enjera

	Year	
	Percentage	Percentage
Variable	2011	2014
Traditional mitad (removable)	68.68	72
Traditional mitad (not removable)	28.33	25.24
Improved energy saving mitad (rural tech.)	2.7	1.9
Electric mitad	0.29	0.93

Source: Researcher's computation.

3.4.3 Extent of energy poverty in rural and small towns in Ethiopia

The results of the deprivation analysis show that the sample households were severely deprived of modern energy sources and hence we see evidence of widespread energy poverty in rural and small towns in Ethiopia. The headcount measure of the deprivation status of households when it comes to energy services is presented in Table 3.12.

Table 3.12: Incidence of energy poverty by year (headcount energy poverty, H)

Year	Values	Type of cooking fuel	Kitchen is separate	Type of oven/mited used for cooking	Type of energy used for lighting	Has a radio, tap, TV or satellite dish	Incidence of energy poverty (H)
	Weights	0.25	0.15	0.15	0.25	0.20	1.00
2011	Per cent	99.21	66.92	97.03	82.28	63.80	
	Weighted value	24.80	10.04	14.55	20.57	12.76	82.72
2014	Per cent	98.57	62.42	97.17	76.22	68.54	
	Weighted value	24.64	9.36	14.58	19.06	13.71	81.35

Source: Researcher's computation.

As can be seen from Table 3.12 the dashboard approach shows the extent of deprivation of energy sources or services by each indicator. A further look at the results shows that there was some improvement in deprivation levels in 2014 as compared to 2011. However, the change was not very impressive which suggests that the sector needs concerted policy interventions. The results also show that about 82.72 and 81.35 per cent of the households were below the energy poverty line in 2011 and 2014 respectively.

Table 3.13: Multidimensional indices of energy poverty (the Alkire and Foster, AF 2007 method) by year and sex

	H	Mo	A
Over all	0.986	0.817	0.828
2011	0.986	0.824	0.836
2014	0.986	0.811	0.823
Male	0.986	0.809	0.820
Female	0.986	0.839	0.851

Source: Researcher's computation.

Energy poverty is prevalent in most of the developing countries. The case is peculiar for rural parts of SSA countries where most of the population is deprived of access to modern energy sources. Modern energy sources are both physically and economically not accessible in rural parts. Physical accessibility means the availability of energy sources in the area. For example, the rate of rural electrification is very low which implies that rural residents do not have physical access to electricity. More importantly, economic accessibility is challenging for rural residents for switching to modern energy and improved energy technologies. Low income/poor households cannot afford to pay for modern energy and improved technologies which forces them to use traditional sources of energy and energy use technologies.

The case is acute for rural and small urban areas in Ethiopia. As we can see from Table 3.13, the multidimensional measure of energy poverty shows the existence of severe energy poverty. About 82 per cent of the households were multidimensionally energy poor in 2011 while there was only a slight decline in the second round of the survey. The results of our study show a slight improvement in multidimensional energy poverty as compared to the 90 per cent result obtained by Nussbaum et al., (2011). Female headed households were more energy poor as compared to male headed households in both the years. MEPI's sensitivity to the weights attached was simulated for different weighting schemes. Equal weight for each indicator produced similar results except for dimensional contributions.

Table 3.14: Relative contribution of dimensions to Alkire and Foster (AF) MEP indices estimated as population share (in per cent)

	Year		**Sex**	
	2011	2014	Male	Female
Dimensions	Mo	Mo	Mo	Mo
Type of cooking fuel	0.298	0.302	0.303	0.292
Type of kitchen used	0.122	0.115	0.115	0.126
Type of stove used	0.176	0.179	0.180	0.173
Source of energy for lighting	0.250	0.235	0.248	0.226
Ownership of educational/entertainment appliances	0.155	0.169	0.154	0.183

Source: Researcher's computation.

Table 3.14 shows the contribution of each dimension to the multidimensional index of energy poverty for households. For instance, deprivation in the cooking energy dimension contributed about 29.8 per cent to the overall multidimensional energy poverty in 2011 whereas it contributed about 30.2 per cent in 2014. Source of energy for lighting was the second highest contributor to households' energy poverty levels. Gender wise, deprivation in cooking fuel contributed about 30.3 per cent multidimensional energy poverty for male headed households while its contribution was slightly lower for female headed households. This information can be used for targeting each dimension if one wants to reduce energy poverty in the study area. The dimensional deprivation shows that any attempts to solve the problem of energy poverty in the study area should target each dimension with varying degrees of emphasis.

3.4.4 Determinants of MEPI in rural and small towns in Ethiopia

Once we had examined the extent of energy poverty in the study area, the next step was to examine the factors that were responsible for this level of energy poverty for the households. Using the random effect logit model, we examined the determinants of multidimensional energy poverty for households in rural and small urban areas in Ethiopia. The regression results using socioeconomic characteristics, household head's characteristics and community characteristics are given in Table 3.15. Before running the regression, we conducted a series of diagnostic tests to see whether the data fulfilled some desirable properties. The presence of multi-collinearity, normality of the variables and specification tests were conducted using appropriate tools. The pair-wise correlation coefficient showed that there was no significant correlation between the independent variables. To correct for unknown forms of the hetroscedasticity problem that may reduce efficiency of the estimated coefficients we used White's hetroscedasticity consistent standard error (robust estimation). The results of the random effect logit model and marginal effects after logit are given in Tables 3.15 and 3.16 respectively.

Table 3.15: Logit regression results of MEPI's determinants

MEPI_index	Coefficients	Std. Err	P-value
Household's size	0.17	0.06	0.007
Sex of HH head (male=1, female=0)	0.40	0.32	0.207
Household head's age	-0.02	0.01	0.047
Literacy (1 literate, 0 otherwise)	1.62	0.38	0.000
Area of residence (1 rural, 0 otherwise)	1.80	0.27	0.000
Credit use (1 if used, 0 otherwise)	-0.26	0.30	0.384
HH energy expenditure (log)	-0.05	0.10	0.654
HH total expenditure (log)	-0.72	0.15	0.000
Marital status (married=1 or 0 otherwise)	0.82	0.41	0.045
Marital status (divorced=1 or 0 otherwise)	1.48	0.60	0.013
Marital status (separated=1 or 0 otherwise)	0.53	1.10	0.631
Marital status (widowed=1 or 0 otherwise)	1.37	0.64	0.032
Constant	8.13	1.22	0.000

Note: N=6,533, Log likelihood = -366.85, Pseudo R^2= 0.29, Wald chi^2 (13) = 3356.71***.

Since the logit model's results are not directly interpretable we have to compute either the log odds ratio to interpret the estimated results as the effect of independent variables on the probability of success to failure ratio, or alternatively we can compute marginal effects after logit and interpret the results directly as the effect of covariates on the probability of being energy poor. We prefer the results of the marginal effect after logit since these give us the effect of covariates on the probability of being multidimensionally energy poor.

Table 3.16: Marginal effect after the logit model

Variable	dy/dx	Std.Err	P> |z|
Household's size	0.0004	0.0002	0.028
Sex of HH head (male=1, female=0)	0.0024	0.0014	0.093
Household head's age	-0.00005	0.00003	0.058
Literacy (1 literate, 0 otherwise)	0.005	0.0011	0.000
Area of residence (1 rural, 0 otherwise)	0.011	0.0034	0.001
Credit use (1 if used, 0 otherwise)	-0.00074	0.00086	0.385
HH energy expenditure (log)	-0.00013	0.0002	0.655
HH total expenditure (log)	-0.002	0.0005	0.000
Marital status (married=1 or 0 otherwise)	0.003	0.002	0.135
Marital status (Divorced=1 or 0 otherwise)	0.002	0.0007	0.001
Marital status (Separated=1 or 0 otherwise)	0.001	0.0018	0.52
Marital status (Widowed=1 or 0 otherwise)	0.002	0.0009	0.008

The results in Table 3.16 show that as household size increased by one member the probability of the household falling into multidimensional energy poverty increased by 0.0004 which was significant at the 5 per cent level of significance. Male headed households had about 0.0024 higher probability of becoming multidimensionally energy poor as compared to female headed households. A one-year increase in the age of the head of the household decreased the probability of the household becoming multidimensionally energy poor by 0.00005 and was significant at the 10 per cent level. Access to credit and higher household total expenditure significantly reduced the probability of a household falling into energy poverty.

3.5 Conclusions and policy implications

This study examined in detail the extent and determinants of energy poverty in rural and small towns in Ethiopia. The study used two rounds of overlapping data from a survey conducted in a joint project of the Central Statistical Agency of Ethiopia and the World Bank as part of the World Bank's Living Standards Survey. With the primary objective of analyzing the extent and determinants of multidimensional energy poverty in the study area, the paper highlighted the status of households with regard to energy use and energy use technologies in the area. The descriptive statistics' results clearly reveal the energy use status of the respondents in both the survey years.

The study also examined the extent of energy poverty in the area using the multidimensional measure following the Nussbaumer et al., (2012) methodology adopted from Alkire and Foster (2007) as the multidimensional measure of poverty. The results of the multidimensional energy poverty index show that about 82.4 and 81.1 per cent of the respondents were multidimensionally energy poor in 2011 and 2014 respectively. The results also show that there was no significant improvement in the energy poverty status of the households in the survey periods with a three-year difference. The relative contribution and decomposition of multidimensional energy poverty by dimension can help policymakers and development planners to direct resources and efforts in appropriate intervention areas. Specifically, policy interventions for improving households' energy poverty should consider each attribute and design appropriate tools for public intervention.

The results of the random effect logit model show the determinants of the MEP status of the households. Households with larger family size, married, widowed or divorced household heads and located in rural areas had a higher probability of being multidimensionally energy poor. On the contrary, higher age of the head of the household, access to credit and higher total household expenditure (proxy for income) reduced the probability of households being multidimensionally energy poor. As noted in the literature as well as confirmed by the positive coefficient of income on energy poverty from the regression results of this study, energy poverty is highly correlated with income poverty. As income increases, the energy poverty level decreases which imply that affordability of energy sources and energy use technologies require a series of policy interventions. Policies promoting clean energy technologies and clean energy sources should be supported to enhance households' incomes. Moreover, the results of the study show that the Government of Ethiopia has a long way to go still to realize access to rural clean energy regardless of the relentless efforts that have been made so far. More efforts are required for promoting rural clean energy and energy use technologies (for example, through rural electrification and promoting solar energy) coupled with an appropriate pricing mix (subsidy) to reach the poor thus reducing energy poverty.

It is undeniable that poverty is the most fundamental realities of developing countries. Energy poverty is a new dimension of poverty. Most incidences of energy poverty emanate from lack of access to clean, affordable and modern energy services. Unlike income poverty, energy poverty can be improved through price reduction, improvements in energy efficiency, expanding modern energy sources and increasing household incomes. Energy efficiency plays a prominent role in reducing energy poverty. It will make energy necessary for basic needs become affordable at a lower expenditure. It also has double dividend benefits as it makes the energy required for basic life to be affordable at a lower cost and also helps in mitigating global warming through reducing emissions related to energy use. Reducing energy poverty provides enormous welfare benefits to poor households. It contributes to reducing poverty through improvements in health -- lower indoor air pollution means lower respiratory diseases and lower health expenditures. Moreover, use of modern energy and technologies increases productivity and new opportunities for additional income and reduces time and labor spent on household activities. Modern technologies for energy use, especially in rural parts in developing countries, contribute to reducing poverty, improving health and education and promoting development. Policymakers can use the results of this study for finding synergies between poverty reduction and energy poverty reduction policies. The results can also be used for aligning international goals like SDGs to national realities.

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Chapter Four: Analysis of households' preferences and willingness to pay for improved cook stoves in Ethiopia: Evidence from discrete choice models[10]

Abstract

This paper examines households' preferences, willingness to pay and determinants of improved cook stove use in rural Ethiopia. The study uses primary data collected from 307 households randomly selected from three districts in Ethiopia's Oromia national regional state with 1,842 observations (six choices for each household). The double-bounded value elicitation format was used to estimate willingness to pay using a contingent valuation, while a choice experiment was used for generating data on trade-offs among different attributes of the proposed improved cook stoves. A choice experiment design was done using the R software to efficiently generate an attribute and level combination for the improved cook stoves using the fractional factorial design. Data was analyzed using discrete choice models including the multinomial logit model, mixed logit model, latent class model, generalized multinomial logit model and interval data model. The findings show that sample households were aware of the effects of using traditional cook stoves and the benefits of using improved cook stoves. However, they were constrained by the availability of the new technology and discouraged by the low-quality products that they had used so far. Moreover, the mean willingness to pay estimates from different models show that rural society is ready to buy the improved cook stoves with prices in the range of about 150 to 350 Birr. Emission reduction, reducing fire risks and the durability of the cook stove positively and significantly affect its adoption while price discourages this use. Higher levels of education, higher incomes, non-farm employment and having one more livestock increase the probability of adopting the improved cook stoves. The study tested the stated attribute non-attendance for choice experiment and cheap-talk for hypothetical bias reduction in contingent valuation. Models accounting for scale and preference heterogeneity performed well in this choice exercise. The mean willingness to pay and marginal rate of substitution for the attributes of the improved cook stoves from this study can be used for product design and pricing policy to make effective policy interventions.

Keywords: Contingent valuation, choice experiment, cook stove, energy efficient technology, Ethiopia, MNL, MXL, GMML

JEL Classification Codes: C25; D12; Q51

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4.1. Introduction

Energy is an important developmental tool currently at the forefront of the global economic and political agenda. Energy related policies and strategic interventions have become a venture that is seeking increasing global attention. Today, global environmental problems are largely related to energy use at different levels. Consequently, we observe growing efforts directed towards formulating and intervening in energy policies. Maintaining energy security, expanding access to renewable energy, disseminating energy efficient technologies and improving energy use efficiency are some of these policy interventions. However, the effectiveness of any policy intervention depends on societal readiness and support for the intervention (Ruiz-Mercado et al., 2011).

Expanding access to modern energy is tantamount to liberating 2.7 billion people globally who rely on traditional energy sources from the captivity of inefficient and traditional energy uses. Access to affordable and reliable energy services in developing countries is fundamental for reducing poverty, improving health, increasing productivity, enhancing competitiveness, reducing environmental problems and promoting economic growth. Modern energy and efficient energy use technologies have multiplier effects in development. They play substantial roles in the provisioning of clean water, sanitation and healthcare and providing reliable and efficient lighting, heating, cooking, transport, and telecommunication services. Despite this, in recent years nearly 1.2 billion people (about 16 per cent of the global population) in poor countries lacks access to electricity and about 2.7 billion people (38 per cent of the world's population) relies on inefficient sources of energy for cooking and household needs. Most of the electricity-deprived population is living in Sub-Saharan Africa (SSA) and South Asia[11] (Bhojvaid et al., 2014; Ruiz-Mercado et al., 2011; UNDP and WHO, 2009; WEO, 2016).

Even though Ethiopia has been registering impressive economic growth for the last decade or so, it is suffering from an unsustainable use of energy. The energy reality of the country shows that biomass accounts for most of the residential energy use. The country has one of

[11] http://www.worldenergyoutlook.org/resources/energydevelopment/energyaccessdatabase/ (accessed on 22 January 2017).

the lowest rates of diversified modern energy services; it also has the lowest rate of access to these services. About 92 per cent of the energy sources in the country come from biomass while oil accounts for about 7 per cent and hydropower for about 1 per cent. Moreover, the energy use pattern of the country shows that households (including agriculture) account for 88 per cent of the total energy consumption followed by industry (4 per cent), transport (3 per cent), services and others (5 per cent).[12] In spite of Ethiopia's high potential for the production of modern energy, which could be a power hub for Africa, only about 25 per cent of its population has access to electricity (Dawit, 2012; WEO, 2013, 2016).

On the other hand, the energy sector is one of the major contributors of greenhouse gas emissions. Further, indoor air pollution threatens health and claims lives of a substantial number of people in developing countries due to reliance on biomass fuels (WHO, 2002). According to WEO (2016) each year, around 3.5 million premature deaths are attributable to household air pollution resulting from the traditional use of solid fuels such as fuel wood and charcoal. The problem is more serious for rural households in Ethiopia who rely more on biomass fuels. Lack of access to clean energy sources; health problems due to indoor air pollution; environmental degradation because of reliance on nature to collect energy sources; and inefficiency of energy use technologies are well known issues for most rural households in Ethiopia. According to a WHO (2007) report, more than 50,000 deaths per year and 5 per cent of the disease burden of the country were attributable to indoor air pollution.

In response to the challenges of development and the country's aspirations of sustainable development, the Government of Ethiopia has launched ambitious medium term development plans, the latest of which is the Growth and Transformation Plan (GTP) which was launched in 2011. The country has a target of attaining lower middle income status by 2025 and its growth path is aligned with the climate resilient green growth as set out in the Climate Resilient Green Economy strategy (CRGE). In line with this plan, the country has embarked on expanding its modern energy sources and the energy sector is considered an important pillar for realizing green growth and accelerating the development of the country. Through its CRGE strategy Ethiopia has

[12] https://energypedia.info/wiki/Ethiopia_Energy_Situation (accessed on 21 February 2017).

clearly indicated the importance of addressing households' energy demands including expanding renewable energy resources and promoting clean energy technologies (for example, dissemination of 9 million efficient cook stoves by 2015 and about 31 million by 2030). Promoting efficient stoves is part of the fast track initiatives aimed at reducing greenhouse gas emissions by about 50Mt CO_2e by 2030 and is also an ingredient for implementing a strategy for reducing emissions from deforestation and forest degradation (REDD+) (FDRE, 2011a, 2011b).

Nevertheless, the effectiveness of any policy intervention aimed at a specific target is highly susceptible to consumers' preferences and willingness to pay for the improvements and their readiness to adapt to a new environment. Unless society accepts and continues using the innovation in the long term, the improved cook stove dissemination policy intervention will be less effective (Ruiz-Mercado et al., 2011). In line with this, this study analyzes the effectiveness of the cook stove dissemination policy of the Government of Ethiopia for supporting its green growth initiative and gives relevant product related attributes which will affect households' preferences and willingness to pay for the improved cook stoves.

There is vast literature which evaluates households' preferences and willingness to pay for energy related interventions. But there is dearth of literature on these issues for developing countries. A few studies that are available focus on willingness to pay for electricity connections, improved cook stoves adoption and different types of fuel for Kenya, India and Ethiopia (Abdullaha and Jeanty, 2011; Bhojvaid et al., 2014; Kooser, 2014; Kroon et al., 2014; Takama et al., 2011). However, the study for Ethiopia is limited geographically to urban areas and methodologically it is unable to account for preferences as well as scale heterogeneity in estimating willingness to pay for improved cook stoves. Further, the problem is less studied in rural areas where a majority of the households in developing countries reside with very different livelihood set-ups. Besides, however rational the people might be, they make purchase decisions for a commodity on the basis of some features of the commodity. In this case, the decision makers' claim 'attributes non-attendance.' Attribute non-attendance is when respondents ignore a given attribute and its associated level while evaluating alternative packages of attributes. These are behavioral responses and ignoring them in the analysis would bias the estimated mean willingness to pay (Campbell et al., 2011; Hensher and Greene, 2010).

Therefore, the main contributions of this study to the limited but growing literature in this area include extending the study to rural areas, incorporating more attributes of improved cook stoves which fit rural housing realities, using a combination of choice experiment and contingent valuation survey, examining the attribute non-attendance, testing different tools for reducing hypothetical bias and methodologically employing discrete choice models which account for preference heterogeneity as well as scale heterogeneity (mixed logit, latent class and generalized mixed logit model).

In doing so, the study addresses the following research questions:

- To what extent are rural households aware of the negative effects of using traditional cook stoves and prefer the improved cook stoves?
- What are the cook stoves' specific attributes and socioeconomic determinants of the adoption of these improved stoves?
- Can a rural household afford to buy an improved cook stove at the current price?
- Do rural households show preference heterogeneity in choosing the improved cook stoves in Ethiopia?
- Does a household reveal attribute non-attendance in choosing an improved cook stove?

To address these research questions the study focuses on examining the preferences, willingness to pay and determinants of the use of the improved cook stoves among rural households in Ethiopia and gives relevant information for rural energy planning and policy.

The rest of this chapter is organized as follows. Section 4.2 presents a review of previous works on the theory of non-market valuation techniques, cost-benefit analyses, the non-market valuation method and a theoretical framework of the choice models. It shows the gap in literature on the valuation of the improved cook stoves and willingness to pay estimations. Section 4.3 gives details of the methodology used. Section 4.4

discusses the results of the study while the final section gives a conclusion and policy recommendations.

4.2. Literature Review

4.2.1 Theory of non-market valuation and cost-benefit analysis

Non-market valuation methods have become an important toolkit for valuing goods and services where the conventional market does not reflect their true values. In fact, when there is market failure, the market price provides wrong signals about the economic value of a good or service under consideration. The market fails due to the existence of the perverse effect of production and consumption, information asymmetry, lack of well-defined property rights and existence of public goods. On the other hand, a market for some goods and services does not exist (for example, environmental goods) and thus it is difficult, if not impossible, to estimate the values of such goods. Often many analytical approaches of project appraisal, be it a private project or a social project or setting environmental standards, require some considerations for estimating values in terms of costs and benefits. A peculiar aspect of the cost-benefit analysis, as contrasted with other analytical approaches, is that it requires that the advantages and disadvantages of a project be reduced to numbers. It is this part, coupled with market failure or a market's non-existence that complicates the valuation of intended action in pecuniary terms. Costs of any project are easier to estimate. A more daunting task is estimating economic benefits. Economists have an important toolkit (non-market valuation techniques) in this respect (Ackerman and Heinzerling, 2002; Haab and McConnell, 2002).

Non-market valuation methods are generally categorized under two methods: stated preference and revealed preference methods. In stated preference methods, we ask people what they would like to pay or accept for a particular change to happen or not to happen. It is a direct method where people are asked to state their willingness to pay or their choice of a given proposed change. Stated preference methods can be used for preference/choice evaluation, demand analysis and forecasting. The most frequently used methods here are contingent valuation, choice experiment, contingent ranking and contingent rating.

Revealed preference methods are indirect non-market valuation methods. These are used to derive economic value for non-market goods/services indirectly from the behavior of individual decisions. They encompass the travel cost method, hedonic pricing method, and hedonic wage method and averting behavior method. The contingent valuation method asks a sample of individuals about their willingness to pay for a hypothetically designed project. A choice experiment requires a sample of respondents to make a series of choices from experimentally designed choice sets from which trade-offs between attributes and marginal rate of substitution are estimated. Applications of choice experiment today include environmental economics, health economics, transport economics, marketing and energy economics (Adamowicz et al., 1998; Aizak and Nishimura, 2008; Haab and McConnell, 2002; Hensher et al., 2005).

4.2.2 Theoretical framework and valuation techniques

The underlying theoretical modeling of a choice experiment rests in the traditional microeconomic theory of choice and decision theory. A rational consumer is assumed to maximize utility subject to budget constraints. The choice experiment approach combines the characteristic theory of value (Lancaster, 1966) and the random utility theory (McFadden, 1974). In the characteristic theory of value it is assumed that consumers derive satisfaction not from the goods themselves but from the attributes that they possess. According to the characteristic theory of value, the probability of choosing a specific alternative is a function of the utility linked to the same alternative. Moreover, the utility derived from each alternative is assumed to be determined by preferences over the levels of the attributes provided by that alternative. The assumption that individuals derive utility from the characteristics of a good rather than from the good itself implies that a change in one of the characteristics (such as the price) may result in a discrete switch from one good to another which will affect the probability of choosing that specific commodity on the margin (Hanley et al., 1998; Lancaster, 1966).

In the choice experiment, where the respondent is asked to choose the most preferred among a set of alternatives, the random utility theory is appropriate for modeling the choices as a function of attributes and attribute levels. In the random utility theory, an individual is assumed to make choices based on the attributes of the alternatives with some degree of randomness. The theory says that the utility derived by individuals from their choice is not directly observable, but an indirect determination of preferences is possible and it decomposes the utility function into a deterministic or systemic part (V) and a stochastic part (ε). The stochastic part is assumed to follow a pre-determined distribution (Brown and Walker, 1989; Hanley et al., 2001; McFadden, 1974).

4.2.3 Empirical review

One can find vast empirical literature on issues related to energy use, adoption of energy efficient technologies and households' preferences and willingness to pay for energy efficient technology in different parts of the world. Since energy plays a crucial role in economic development and improving social welfare this area has been and will be one of active inquiry. Most of the studies available so far focus on the effectiveness of interventions, factors affecting energy use technology adoption and the energy, poverty and environment nexus (Akpalu et al., 2011; Alem et al., 2014; Amigun et al., 2010). Existing literature also shows that preferences and tests of individuals matter for the effectiveness of policy to promote energy efficient technologies and a considerable amount of available work employs stated preference methods to estimate the value of the improvements.

Using the contingent valuation methodology Abdullaha and Jeanty (2011) analyzed rural households' willingness to pay for electricity connections in Kenya. Similarly, Takama et al., (2011) analyzed households' willingness to pay and preferences in Ethiopia, Tanzania and Mozambique for improved cook stoves. A comprehensive study by Bhojvaid et al., (2014) in rural India shows that households' mean willingness to pay for improved cook stoves varied significantly by stove related attributes. Kroon et al., (2014) studied households' preferences for fuels and willingness to pay for alternative cook stove technologies in Kenya. Kooser (2014) examines Ethiopian households' preferences and willingness to pay for an improved cook stove. This study showed that adoption of the improved cook stove was affected by various cook stove specific attributes and socioeconomic characteristics.

A study by Jagger and Jumbe (2016) in rural Malawi shows households' preferences and willingness for adopting the locally produced improved cook stove. The study used the discrete choice experiment on 383 households randomly selected in rural Malawi for getting their preferences for the locally produced improved cook stove or a package of sugar and salt with equivalent value. Their study shows that availability of large crop residual, long time devoted to the collection of fuel wood, awareness about the environmental impact of wood fuel and peer-effect at the village level increased the odds of choosing the improved cook stove while availability of a large labor force for fuel wood collection and experience with non-traditional cooking facilities decreased the odds of choosing the improved cook stove.

In another study using data from rural Guatemala, Bielecki and Wingenbach (2014) show the importance of cultural and social perceptions in adopting the improved cook stove. Beyond the 'triple benefits' of the improved cook stove: health benefits, preserving the local ecosystem and greenhouse gas reduction, the study argues that the adoption of the improved cook stove is influenced by other benefits of the stove such as lighting, heating and becoming a social gathering point for families. The study concludes that to enhance the effectiveness of the dissemination of the improved cook stove, adoption programs should account for these cultural and social needs of users.

A handful of studies have applied the stated preference methodology for estimating households' willingness to pay for improved cook stoves. However, these studies came up with conflicting results. For instance, a study by Jeuland et al., (2015) using data from rural households in North India shows that households had strong base line preferences for the traditional cook stove which would be an inhibiting factor for a wider adoption of the improved cook stove. The study recommends the need for a reinvigorated supply chain with complementary infrastructure investment, appropriate incentives for consumers, continued applied research and knowledge generation to scale up the distribution of the improved cook stove.

Existing literature on the adoption of improved cook stoves reveals the importance of stove specific attributes. It also shows that a mix of these attributes greatly affects the adoption of improved cook stoves in addition to socioeconomic characteristics of the adopters. However, the problem is less studied in rural areas where a majority of the households in developing countries reside. Moreover, to the best knowledge of the researcher, non-attendance of one or more attributes in making a choice for an improved cook stove has not been studied in Ethiopia. Attribute non-attendance, where respondents ignore a given attribute and its associated level while evaluating alternative packages of attributes are behavioral responses and hence ignoring them in an analysis will bias the estimated mean willingness to pay (Campbell et al., 2011; Hensher and Greene, 2010, Scarpa et al., 2009).

This paper contributes to existing literature by extending the study to rural areas, incorporating more attributes of the improved cook stoves which fit in rural housing realities and tests the existence of attribute non-attendance. It methodologically uses mixes of different models (multinomial logit model, mixed logit model, latent class model and generalized mixed logit model) to account for preferences and scale heterogeneity in choice decisions.

4.3. Methodology of the study

4.3.1 Description of the study area

The study was conducted in three selected zones of the Oromia national regional state which is one of the nine regional states in the Federal Democratic Republic of Ethiopia. The selected zones are in the center of the country and in the central part of the region. The selection of these three zones was based on convenience and also for maintaining the heterogeneity of the respondents in terms of socioeconomic characteristics, agro-climatic features and forest coverage. These selection criteria were used to account for various respondents who had different levels of access to forest resources which is important for biomass fuel use. The selected zones are North Showa, South West Showa and Finfinne Surrounding Oromia Special Zone. One district was randomly selected from each selected zone. The selected districts were Sebetahawas, Bacho and Wachale. Eight kebeles[13] were selected from these districts using cluster sampling to include people with different socioeconomic, demographic and agro-climatic conditions in the sample.

[13] *Kebele is the smallest administrative unit, equivalent to a neighborhood, in Ethiopia. It is accountable to the district and believed to have a minimum of about 500 households.*

4.3.2 Data sources and sampling procedure

Primary data was generated using a survey of 307 households by employing a multi-stage random sampling technique. Random sampling and sampling proportion to size were used to select households from the selected kebeles. Finally, 307 households were selected employing the sample proportion to size method. To collect information from selected households' face-to-face interviews were conducted with selected respondents. Moreover, before doing the final survey a pilot study was conducted to evaluate the appropriateness and clarity of instruments and for determining the initial bid (price) used in the final survey. Feedback from the pilot study was incorporated and the final instrument was developed. Five well-trained and experienced enumerators closely monitored by two supervisors were involved in the data collection process. The collected data was encoded using the SPSS software and it was then transferred to different versions which are compatible with Stata and Nlogit used for data analysis in this paper.

4.3.3 Survey techniques and experimental design

A. Survey techniques

Data for this study was collected using the stated preference methodology. It employed two stated preference techniques: contingent valuation and choice experiment. For contingent valuation, a scenario in a carefully structured hypothetical market for an energy efficient cook stove was designed and households' willingness to pay for such a case was generated using the double-bounded value elicitation format. This elicitation format was preferred as it fits marketing realities in developing countries where bargaining is common. A respondent was provided with a randomly selected initial bid (proposed price of an improved cook stove) from three bid levels 75, 150 and 250 Birr which was determined from a pilot survey and expert consultations. Depending on a response to the initial bid, a Yes or No, the next bid was increased (decreased) by 50 per cent. Following the final response (Yes or No), the respondents were asked to state their maximum willingness to pay for the proposed improved cook stove, if any.

The study also used the choice experiment technique for a hypothetically designed improved cook stove scenario. The choice experiment was used for identifying households' preferences for the different attributes of energy efficient stoves. The respondents were asked to make a series of improved cook stove choices with different combinations of attributes which were mutually exclusive. Detailed information on both attribute specific and socioeconomic characteristics was generated. In designing a choice experiment, one should consider various factors which can affect the choice of any specific cook stove. Generally, we can categorize these under three headings. The first category is stove specific characteristics like durability, start-up time, heat energy delivered, ease of use, and the price of the stove and the convenience of use. The second group is related to the risks associated with the use of technology such as risk of explosion and air pollution levels. The final group could be reliability of use due to different constraints like sustainable supply or availability of energy. Different types of energy efficient cook stoves exist in Ethiopia albeit with low penetration rates. The Mirt cook stove, the Tikikil cook stove, the Lakechi cook stove, the Gonze cook stove and the traditional three-stone cook stove were considered for the design of the experiment.

From the cook stoves available in the country, the study primarily focused on the cook stove used for baking enjera since it uses about 50 to 60 per cent of a household's energy use (Bizzarri, 2010). For the selected cook stove different attributes like risk of use, indoor smoke levels, saving in fuel consumption, durability and the price of the cook stove were considered. The final choice of attributes and their levels was made in consultation with cook stove designers, experts, a literature survey, focus group discussions and a pilot survey in the selected area.

B. Choice Experiment Design

Stated preference exercises pass through a series of steps. One of the vital steps in a choice experiment survey is determining the number of alternatives, attributes, attribute levels and values to be assigned. Traditionally, a stated preference survey relies on a binary choice to reduce the burden of choice making. Even though it is simple to handle, the binary choice approach is far from reality and has less policy relevance and pragmatism. Thus, extending the number of alternatives and attribute levels improves response quality; it increases the realism of responses; and has room for masking the aim of the study to avoid strategic bias (Hanley et al., 2001).

Hence, to estimate households' willingness to pay and preferences for the improved cook stove in rural Ethiopia, different attributes of the improved cook stove were selected based on a literature survey, focus group discussions, pilot study and expert consultations. Various attributes of the improved cook stove were identified. However, due to the complexity of the experimental design and households' limited cognitive ability in making choices we limited the attributes included in the experiment to reducing indoor smoke/emissions, reducing risks of a fire, saving fuel, durability and the price of the improved stove. The proposed improvements to the cook stove were done in such a way that it became a multipurpose stove. It can be used for baking enjera, cooking wat, boiling coffee etc. So far this model has not been developed and distributed in Ethiopia. But making the stove multipurpose is meant to increase energy use efficiency and increase economies of scale advantages in fuel wood use (see Figure 4.1 and 4.2).

Figure 4.1. Traditional three stone stove

Figure 4.2. The proposed multipurpose improved stove

Along with selecting the attributes for the improved cook stove it was necessary to determine different levels corresponding to each attribute. Three levels were selected for each attribute of the improved cook stove. A detailed description of the attributes and levels for the proposed management plan are now given. The starting points for level selection for each attribute were driven from empirical studies on the topic (Beyene et al., 2015).

1. ***Indoor smoke or emission reduction***: indoor smoke is an acute health problem that rural households face because they rely on traditional cook stoves and traditional

energy sources. Cooking and heating with open fires releases indoor air pollution which is equivalent to smoking two packets of cigarettes a day. High indoor emission levels expose households to different health risks such as respiratory diseases, asthma symptoms, throat irritation, flu, irritation of the eyes and nose, allergic reactions and even cancer. Thus, this program is designed to reduce the problems of indoor smoke from using the traditional three-stone cook stove. The program integrates different packages to the improved cook stove to reduce emission levels. Under different packages it will reduce emission by 40, 65 or 90 per cent.

2. ***Risk of use*****:** this plan was designed in response to the different hazards of using the traditional cook stove. It involves designing a cook stove such that it reduces risks of a fire, burning and explosions. It makes households safer while cooking and reduces related costs for prevention and curatives.
3. ***Fuel saving*****:** shortage of fuel wood, higher costs of fuel and its environmental effects through deforestation are some of the crucial problems related to firewood collection and use. This program is meant to improve efficiency of the stove and reduce fuel wood usage by 25, 45 or 65 per cent as compared to the three-stone cook stove.
4. ***Durability of the stove****:* frequent breakage of the stove exposes a household to unnecessary costs. This program aims at producing a stove which can serve a household for different durations -- for about 5 years, 15 years or 20 years depending on the material used for its production.
5. ***Price of the stove:*** it is unquestionable that price affects the demand for a product. As the law of demand states as price increases demand for the product declines other things remaining constant. Three price levels of 75 Birr, 150 Birr and 250 Birr were used in the survey to examine the effect of price on the demand for the stove and for the computation of marginal willingness to pay for each attribute. These starting bids were selected on the basis of literature review, pilot survey and focus group discussion with experts. The summary of attributes and levels is presented in Table 4.1.

Table 4.1: Attributes and levels of the proposed improved cook stove

Attributes/Stove type	Levels	Traditional stove
Indoor smoke/emission reduction	40, 65 and 90 per cent	Status quo
Risk of use	Low, Moderate, High	Status quo
Fuel wood saving	25, 45 and 65 per cent	Status quo
Durability of the stove (in years	5, 15, 20	Status quo
Price of the improved stove (in Birr)	75, 150, 250	Status quo

Source: Developed by the author.

Five attributes were used with three levels each for constructing the choice sets. The algorithm of experimental design (AlgDesign) of R software in discrete choice experiment (DCE) was used for the experimental design and for testing the efficiency of the design. SAS software was used to supplement the experimental design and for testing the efficiency of the choice experiment design. With a D-efficiency of 97.8 per cent, the orthogonal fractional factorial design was developed for the first alternative, reducing the original full factorial design of 243 (3^5) possible combinations to just 18. The full factorial design with all the possible treatment combinations is not feasible for presenting as choice tasks. As a result, only a fraction of the total number of treatment combinations using fractional factorial design was selected. Optimum treatment combinations were selected such that all the attributes were statistically independent of each other (orthogonal). Finally, the 18 treatment combinations selected using the orthogonal fractional factorial design were blocked into three versions avoiding dominant selection so that inefficient selection was minimized due to the cognitive burden of the respondents in multiple choice tasks.

In this regard, the discrete choice experiment provides a panel of six choice sets for everyone from a given version (Table 4.2). Each choice set consists of two experimentally designed alternatives – labeled ‘Option 1’ and ‘Option 2’ – and a status quo alternative – labeled ‘No action’ – which portrays all the attributes of the currently in-use cook stove (the three-stone stove) with no additional payment as compared to the price of the conventional stove.

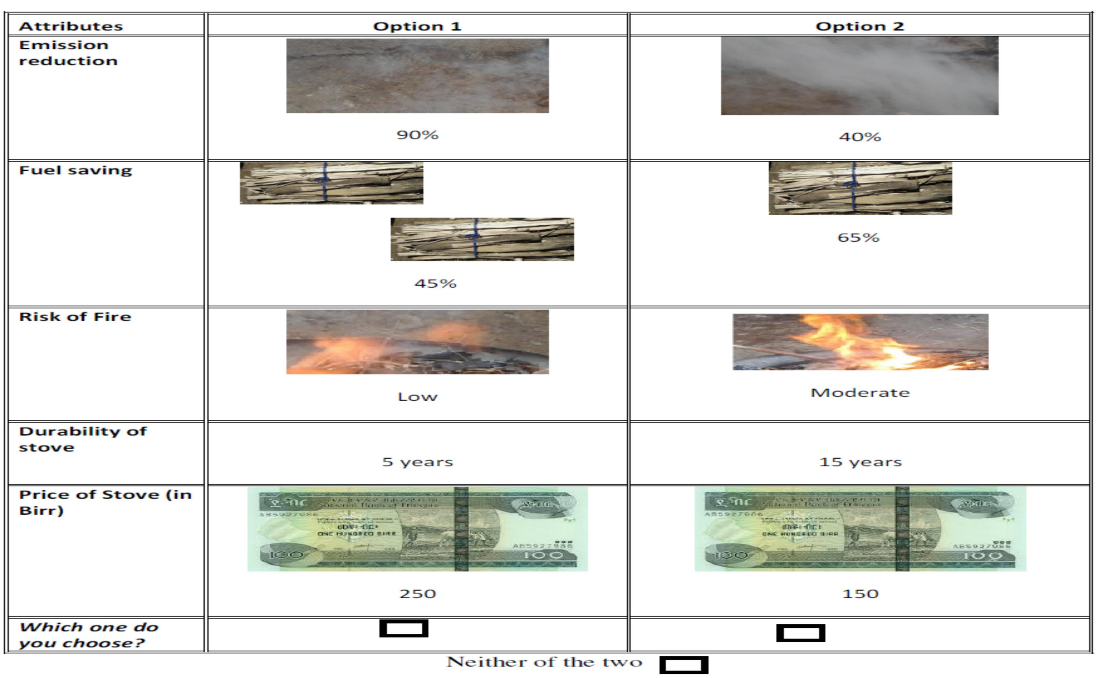
Table 4.2: Sample choice set used for the survey

Attributes	Option 1	Option 2	Option 3
Emission reduction	90 per cent	40 per cent	Status quo
Fuel saving	45 per cent	65 per cent	Status quo
Risk of Fire	Low	Moderate	Status quo
Durability of the stove	5 years	15 years	Status quo
Price of the stove (in Birr)	250	150	Status quo
Which one will you choose?	☐	☐	☐

Source: Designed by the author in 2016.

As we can see from Table 4.2, understanding improvements for each attribute in the choice set could be difficult for some respondents. As the survey was conducted in rural areas where a majority of the respondents have low levels of education it was necessary to supplement the choice sets by a choice card which is a diagrammatical representation of the choice sets. To assist respondents and to make the choice task as simple as possible choice cards were prepared for each choice set and presented to the respondents. A sample choice card used is provided in Figure 4.3.

Figure 4.3. Sample choice card



Source: Designed by the author in 2016.

4.3.4 Econometric model specifications and estimation methods

A. Multinomial logit, mixed logit, latent class and generalized mixed logit model specifications

Models of discrete choice data are grounded in the theoretical underpinnings of the characteristic theory of value (Lancaster, 1966) and the random utility theory (McFadden, 1974). An individual makes a choice for an improved cook stove since he/she values the attributes of the product. Here we assume utility as a latent construct that underlies observed choices reflecting the demand for a good. Respondent n is assumed to consider the full set of offered alternatives *i* and choosing the alternative with the highest utility. As implied by the characteristic theory of value, utility of option *i* for individual *n* (U_{in}) is assumed to depend on attributes of the good to be valued (Z_i) and the socioeconomic characteristics of individual users (S_n). This utility is decomposed into deterministic and stochastic components as:

(1) $$U_{in} = V_{in} + \varepsilon_{in}$$

where U_{in} is the latent, unobserved utility of consumer *n* for choice alternative *i*, V_{in} is the deterministic/observable part of the utility that individual *n* has for choice alternative *i* and ε_{in} is the random or unobservable portion of the utility that consumer *n* has for choice alternative *i*.

Employing the rationality assumption, that is, individuals are utility maximizers, the probability that individual n will choose option i over another option j is given by:

(2) $$\begin{aligned} Prob(i \mid R) &= Prob(U_{in} > U_{jn}) \\ &= Prob(V_{in} + \varepsilon_{in} > V_{jn} + \varepsilon_{jn}) \text{ for } j \in R \text{ and } i \neq j \end{aligned}$$

where R is the complete choice set available to the individual. This probability is estimable under the assumption that the error terms are independently and identically distributed with extreme-value distribution. This assumption gives rise to the specification of the multinomial logit model (MNL) that determines the probabilities of choosing alternative i over j (Hanley et al., 2001):

(3) $$\operatorname{Prob}\left(U_{in} > U_{jn}\right) = \frac{\exp\left(\mu V_i\right)}{\sum \exp\left(\mu V_j\right)}; \forall j \neq i$$

where $V_i = V(Z_i, S_n)$, is the indirect utility function, Z_i is a vector of the energy efficient cook stove's attributes, S_n is a vector of users' socioeconomic characteristics and μ is a scale parameter inversely related to the standard deviation of the error term and not separately identifiable in a single dataset. The implication of this is that the estimated βs cannot be directly interpreted as to their contribution to utility since they are confounded with the scale parameter. The MNL model must satisfy the independence from irrelevant alternatives (IIA) property, which means that the addition or subtraction of any alternatives from the choice available to the respondent will not affect the relative probability of individual n choosing any other alternative (Hausman and McFadden, 1984). The deterministic utility function from the MNL model can be presented by V_{ij} which is assumed to have an additive structure and is given by:

(4) $$V_{ij} = ASC + \sum_{k=1}^{k} \beta_k Z_k + \sum_{m=1}^{m} \beta_m S_m$$

where ASC (alternative specific constant) captures systematic variations in choice observations which are associated with alternatives that are not explained either by the attribute's variation or respondents' observed socioeconomic characteristics (Ben-Akiva and Lerman, 1985). It accounts for the effects of any attribute not included in the choice set on utility (Agimas and Mekonnen, 2011). β_k is a vector of coefficients corresponding to $Z's$ attributes from the choice sets and β_m is a vector of coefficients corresponding to S_m socioeconomic characteristics of the respondents. To improve the efficiency of the estimated coefficients of the MNL model and WTP the study used bootstrap methods (Cameron and Trivedi, 2010; Takama et al., 2011). Once multinomial logit model estimations are obtained, the marginal value of each attribute and the corresponding marginal rate of substitution are estimated. Besides, a measure of welfare change (compensating surplus) that conforms to the demand theory can be derived from the proposed changes in the improved cook stove's attributes. The marginal rate of substitution - part-worth - for each attribute is estimated following Hanley et al., (2001):

(5) $$WTP = b_y^{-1} \ln \left\{ \frac{\sum_i \exp\left(V_i^1\right)}{\sum_i \exp\left(V_i^0\right)} \right\}$$

where V_i^0 represents the utility of the initial state and V_i^1 represents the utility of the alternative state. The parameter b_y is the coefficient of price attribute which measures the marginal utility of income. For the linear utility index representation, WTP is simply the ratio of the coefficient of an attribute to the coefficient of payment (price). This ratio is called part-worth/implicit price or marginal willingness to pay for the attribute. It is estimable in Nlogit using the Krinsky and Robb method (Hensher et al., 2005):

(6) $$WTP = -\frac{\beta_{attribute}}{\beta_{payment}}$$

The assumption of IIA in the multinomial logit model (MNL) is hard to meet in real choice models. If assumption of IIA is violated which can be tested using the Hausman and McFadden (1984) procedure, we have to resort to models which would relax this assumption. One such model is the random parameter logit model (RPL) also known as the mixed logit model (Train, 1998). The mixed logit model (MLM), as opposed to the multinomial logit model, allows for high flexibility by specifying taste coefficients to be randomly distributed across individuals and it accounts for unobserved heterogeneity of households in decision making (Campbell et al., 2011; Hensher and Greene, 2003; Kroon et al., 2014). It also allows for interdependence of the choice situation by allowing the AR(1) process. MLM generalizes a standard MNL by allowing its parameters associated with the observed variable to vary with a known population distribution across individuals. It also assumes continuous joint distribution and is specified as:

(7) $$p_{iqt} = \frac{\exp\left(\alpha' + \beta' X_{iqt} + \varphi' F_{iqt}\right)}{\sum_{j=1}^{J} \exp\left(\alpha' + \beta' X_{jqt} + \varphi' F_{jqt}\right)}$$

where α’ is a vector of fixed or random alternative-specific constants (ASCs) associated with i = 1, . . . , J alternatives and q = 1, . . . ,Q individuals and one of these ASCs should be identified as 0. β’ is a parameter vector that is randomly distributed across individuals. φ’ is a vector of non-random parameters. X_{iqt} is a vector of individual-specific characteristics and alternative-specific attributes at observation t and is estimated with random parameters. F_{iqt} is a vector of individual-specific characteristics and alternative specific attributes at observation t and is estimated with fixed parameters. As an alternative to the mixed logit model which assumes continuous joint distribution of the sources of individual preference heterogeneity, we also use the latent class model which assumes discrete distribution of preference heterogeneity. A latent class model is used to analyze the behavior of different classes in choosing energy efficient cook stoves following Boxall and Adamowicz (2002) and Greene and Hensher (2003). Here a consumer shows discrete preference heterogeneity for goods and services. This consumer preference heterogeneity must be accounted for while estimating the consumer’s WTP. The latent class model specification stands on the theory that individual behavior depends on observable attributes and on latent heterogeneity that varies with factors that are unobserved by an analyst (Greene and Hensher, 2003; Shen, 2009). This heterogeneity can be analyzed by the model of discrete parameter variation. The central assumption here is that individuals are implicitly sorted into a set of Q classes and the analyst has no prior information about the class to which an individual belongs. Following Greene and Hensher (2003), the latent class model can be extended from the central behavioral model of multinomial logit model for discrete choice among J_i alternatives by individual i observed in T_i choice situations:

(8) Prob[that individual i choices j in choice situation t|class q] = $\dfrac{\exp\left(x'_{it,j}\beta_q\right)}{\sum_{j=1}^{J_i}\exp\left(x'_{it,j}\beta_q\right)} = F(i,t,j\,|\,q)$

Consequently, the probability for the specific choice made by an individual i given the class to which the individual belongs can be specified as:

(9) $$P_{it|q}(j) = \Pr ob\left(y_{it} = j \,|\, class = q\right)$$

In this formulation, for the given class assignment the contribution of individual i to the likelihood would be the joint probability of the sequence $y_i = \left[y_{i1}, y_{i2}, ..., y_{iT}\right]$ given as:

(10) $$P_{i|q} = \prod_{t=1}^{T_i} P_{it|q}$$

The class assignment is not known, but if H_{iq} denote the prior probability for class q for individual i, it can conveniently be presented as the multinomial logit as:

(11) $$H_{iq} = \frac{\exp^{(z_i' \theta_q)}}{\sum_{q=1}^{Q} \exp^{(z_i' \theta_q)}}, \ q = 1, ..., Q, \ \theta_Q = 0$$

where z_i's are a set of observable characteristics which enter the model of class membership. To enable identification of the model the Qth parameter is normalized to zero. The likelihood of individual i is the expectation (over classes) of the class specific contributions given as:

(12) $$p_i = \sum_{q=1}^{Q} H_{iq} P_{i/q}$$

Finally, the log likelihood function for the sample can be specified as:

(13) $$\ln L = \sum_{i=1}^{N} \ln p_i = \sum_{i=1}^{N} \ln\left[\sum_{q=1}^{Q} H_{iq}\left(\prod_{t=1}^{T} p_{it|q}\right)\right]$$

Through maximizing the likelihood function, the coefficients are estimated for all classes. However, the determination of the number of classes for the latent class model is not straightforward. This study examines the optimum class size using the information criteria and comes up with two classes to estimate this model.

Currently researchers in preference analysis and discrete choice models have come up with more sophisticated and advanced models which account for both preference heterogeneity and scale heterogeneity. The generalized multinomial logit model (G-MNL) is one such model. Following Fiebig et al., (2010), the G-MNL model for a sample of N respondents with the choice of J alternatives in T choice situations represents the probability of respondent i choosing alternative j in choice situation t as:

(14) $$\Pr\left(\text{choice}_{it} = j \mid \beta_i\right) = \frac{\exp\left(\beta'_i x_{itj}\right)}{\sum_{k=1}^{J} \exp\left(\beta'_i x_{itj}\right)}, \quad i = 1,\ldots, N;\ t = 1,\ldots,J$$

where x_{itj} is a vector of observed attributes of alternative j and β_i is a vector of individual-specific parameters defined as:

(15) $$\beta_i = \sigma_i \beta + \{\gamma + \sigma_i (1-\gamma)\} \eta_i$$

Here the specification of β_i is central to G-MNL. It depends on a constant vector β, a scalar parameterγ, a random vector η_i distributed MVN (0, Σ) and σ_i, the individual-specific scale of the idiosyncratic error. The value of γ ranges from [0, 1], at extreme values of γ we get *G-MNL* type I or II. G-MNL is able to account for 'extreme' consumers with nearly lexicographic preferences. It is able to explain consumers who exhibit very 'random' behavior. As per these developments, this paper extended the analysis for the improved cook stove chosen to the generalized mixed logit model.

B. Estimating WTP distribution and attribute non-attendance

Estimating WTP for goods and services serves several purposes and hence it has been used in different areas. There are several methods for estimating WTP. The first and simplest method is to directly ask respondents their willingness to pay for the good/service under consideration. However, this method has several problems: respondents may face cognitive difficulties and they may behave strategically to respond to different incentives (Hole and Kolstad, 2012). It can be estimated either in the preference (utility space) or in the WTP space. The distribution of WTP in the utility space can be specified. The utility of household n derives from the use of cook stove j under situation t specified as a function of income of the household w_{njt} and other non-income attributes of the stove x_{njt}:

(16) $$U_{njt} = \alpha_n w_{njt} + \beta'_n x_{njt} + \varepsilon_{njt}$$

From Eqn. 16 α_n and β_n indicate individual-specific coefficients for income and the other attributes of the improved cook stove chosen and ε_{njt} is a random term. We assume that ε_{njt} is extreme value distributed with variance given by $\mu_n^2\left(\frac{\pi^2}{6}\right)$, where μ_n is an individual-specific scale parameter. Train and Weeks (2005) show that dividing Eqn. 16 by μ_n does not affect behavior and results in a new error term which is IID extreme value distributed with variance equal to $\frac{\pi^2}{6}$ and we get a new equation:

(17) $$U_{njt} = \frac{\alpha_n}{\mu_n} w_{njt} + \frac{\beta_n'}{\mu_n} x_{njt} + \varepsilon_{njt}$$, which can be written as:

(18) $$U_{njt} = \lambda_n w_{njt} + c_n' x_{njt} + \varepsilon_{njt}$$

Eqn. 18 is a specification of WTP in preference space (Train and Weeks, 2005). Moreover, decision makers are highly influenced by one characteristic of a product during purchase decisions. In the choice experiment exercise, it is known as 'attribute non-attendance.' Attribute non-attendance – an attribute not being considered or being ignored by decision makers while making a choice - has occupied prominent place in discrete choice models (Hensher et al., 2012). Our study examined the presence of attribute non-attendance in the improved cook stove choice decision for the study area. It employed attribute non-attendance where respondents were asked to state to what extent they had attended to each attribute after the choice exercises were completed.

C. Interval data model for estimating double-bounded CVM data

An analysis of the double-bounded response data from the contingent valuation survey uses the interval data model. In this case the information which is directly elicited is a dichotomous response taking a value of zero if the individual says No and 1 if the individual answers Yes for the initial as well as follow-up questions. The response of individual i depends on the value of price (bid) with the improvement in the good proposed to be provided. Let us assume that an individual is asked if he is willing to pay t_i for a given change in the good proposed to be provided. If the response of that individual is No, then we can say his willingness to pay is between zero and t_i, that is, 0

$\leq$ WTP $\leq t_i$ and if he answers Yes his willingness to pay is $t_i \leq$ WTP $< \infty$. In order to get an accurate estimate for WTP we need a relatively larger sample size which is hardly attainable in such a survey.

Alternatively, the double-bounded methodology proposed by Hanemann et al., (1991) can be used to efficiently estimate WTP. In this case, a respondent is given a follow-up question after he responds Yes or No to the first bid question. If the individual answers Yes to the first question he is provided with a higher bid. On the other hand, if the individual answers in the 'negative' to the first bid question then he is offered a lower bid. To examine the distribution of the WTP of the respondent in this case following Lopez-Feldman's (2012) explanation we can denote the first bid price by t^1 and the second bid price by t^2. In this regard, each respondent will fall in one of the following categories:

1. An individual answers Yes to the first bid question and No to the second bid question, then $t^2 > t^1$. In this case, we can say that $t^1 \leq$ WTP $< t^2$.
2. An individual answers Yes to both the questions, then we have $t^2 \leq$ WTP $< \infty$.
3. An individual answers No to the first question and Yes to the second one so that $t^1 > t^2$, so that we have, $t^2 \leq$ WTP $< t^1$.
4. Finally, if an individual answers No to both the first and second questions, we have, $0 <$ WTP $< t^1$.

These four cases can be estimated by the double-bounded or interval data model as specified below. To specify the model let us denote the answer to the first and second response questions by dichotomous variables y_i^1 and y_i^2. The probability that an individual answers Yes to the first question and No to the second question is given as: $\Pr(y_i^1 =1, y_i^2=0|z_i) = \Pr(yes, no)$. Specifying this probability distribution works under the assumption that $WTP_i (z_i, u_i) = z_i'\beta + u_i$ and $u_i \sim N(0,\sigma^2)$, then the probability distribution of the four choices is given as:

Case 1: $y_i^1 =1$ and $y_i^2 =0$

$$
\begin{aligned}
\Pr(\text{yes},\text{no}) &= \Pr\left(t^1 \le WTP < t^2\right) \\
&= \Pr\left(t^1 \le z_i'\beta + u_i < t^2\right) \\
&= \Pr\left(\frac{t^1 - z_i'\beta}{\sigma} \le u_i < \frac{t^2 - z_i'\beta}{\sigma}\right) \\
&= \Phi\left(\frac{t^2 - z_i'\beta}{\sigma}\right) - \Phi\left(\frac{t^1 - z_i'\beta}{\sigma}\right)
\end{aligned} \tag{19}
$$

where the last expression follows that Pr(a ≤ X < b) = F(b) - F(a). Therefore, using symmetry of the normal distribution we have:

$$
\Pr(\text{yes},\text{no}) = \Phi\left(z_i'\frac{\beta}{\sigma} - \frac{t^1}{\sigma}\right) - \Phi\left(z_i'\frac{\beta}{\sigma} - \frac{t^2}{\sigma}\right) \tag{20}
$$

Case 2: y_i^1=1 and y_i^2=1

$$
\begin{aligned}
\Pr(\text{yes},\text{yes}) &= \Pr\left(WTP > t^1, WTP \ge t^2\right) \\
&= \Pr\left(z_i'\beta + u_i > t^1, z_i'\beta + u_i \ge t^2\right)
\end{aligned} \tag{21}
$$

Using Baye’s rule, which says that P(A,B) = Pr(A|B)*Pr(B) we have:

(22)

$$
\Pr(\text{yes},\text{yes}) = \Pr\left(z_i'\beta + u_i > t^1 \mid z_i'\beta + u_i \ge t^2\right) * \Pr\left(z_i'\beta + u_i \ge t^2\right)
$$

Here by definition $t^2 > t^1$ and then $\Pr\left(z_i'\beta + u_i > t^1 \mid z_i'\beta + u_i \ge t^2\right) = 1$

which implies

$$
\begin{aligned}
\Pr(\text{yes},\text{yes}) &= \Pr\left(u_i \ge t^2 - z_i'\beta\right) \\
&= 1 - \Phi\left(\frac{t^2 - z_i'\beta}{\sigma}\right)
\end{aligned}
$$

So by symmetry we have:

$$
\Pr(\text{yes},\text{yes}) = \Phi\left(z_i'\frac{\beta}{\sigma} - \frac{t^2}{\sigma}\right) \tag{23}
$$

Case 3: y_i^1 = 0 and y_i^2 = 1

$$(24)\quad \begin{aligned} \Pr(no, yes) &= \Pr\left(t^2 \le WTP < t^1\right) \\ &= \Pr\left(t^2 \le z_i'\beta + u_i < t^1\right) \\ &= \Pr\left(\frac{t^2 - z_i'\beta}{\sigma} \le \frac{u_i}{\sigma} < \frac{t^1 - z_i'\beta}{\sigma}\right) \\ &= \Phi\left(\frac{t^1 - z_i'\beta}{\sigma}\right) - \Phi\left(\frac{t^2 - z_i'\beta}{\sigma}\right) \\ \Pr(no, yes) &= \Phi\left(z_i'\frac{\beta}{\sigma} - \frac{t^2}{\sigma}\right) - \Phi\left(z_i'\frac{\beta}{\sigma} - \frac{t^1}{\sigma}\right) \end{aligned}$$

Case 4: $y_i^1 = 0$ and $y_i^2 = 0$

$$(25)\quad \begin{aligned} \Pr(no.no) &= \Pr\left(WTP < t^1, WTP < t^2\right) \\ &= \Pr\left(z_i'\beta + u_i < t^1, z_i'\beta + u_i < t^2\right) \\ &= \Pr\left(z_i'\beta + u_i < t^2\right) \\ &= \Phi\left(\frac{t^2 - z_i'\beta}{\sigma}\right) \\ \Pr(no, no) &= 1 - \Phi\left(z_i'\frac{\beta}{\sigma} - \frac{t^2}{\sigma}\right) \end{aligned}$$

For these four models we have to construct the likelihood function to directly obtain β and σ through the method of maximum likelihood estimation. To be maximized to find the parameters of the model the likelihood function can be constructed as:

$$(26)\quad \sum_{i=1}^{N}\left[\begin{array}{l} d_i^{yes,no}\ln\left(\Phi\left(\frac{t^2-z_i'\beta}{\sigma}\right)-\Phi\left(\frac{t^1-z_i'\beta}{\sigma}\right)\right)+d_i^{yes,yes}\ln\left(\Phi\left(\frac{t^1-z_i'\beta}{\sigma}\right)\right) \\ +d_i^{no,yes}\ln\left(\Phi\left(z_i'\frac{\beta}{\sigma}-\frac{t^2}{\sigma}\right)-\Phi\left(z_i'\frac{\beta}{\sigma}-\frac{t^1}{\sigma}\right)\right)+d_i^{no,no}\ln\left(1-\Phi\left(z_i'\frac{\beta}{\sigma}-\frac{t^2}{\sigma}\right)\right) \end{array}\right]$$

where $d_i^{yes,no}$, $d_i^{yes,yes}$, $d_i^{no,yes}$, $d_i^{no,no}$ are indicator variables that take values of one or zero depending on the relevant case for each individual whereby each individual will only appear once in the likelihood function. Using this likelihood function estimating the parameters ($\hat{\beta}$ and $\hat{\sigma}$) is straightforward. Doubleleb Stata command is used to estimate this interval data model after adding the ado developed by Lopez-Feldman (2012) on Stata Version 12.

Finally, this paper tested one method of reducing a hypothetical bias in the contingent valuation survey. Biases in contingent valuation studies abound. People's intentions and actions deviate in the real world. Sources of such biases can be strategic bias, hypothetical bias and starting point bias. In contingent valuation literature several methods are proposed and implemented to reduce these biases. Hypothetical bias is broadly defined as a difference between stated WTP and revealed WTP. It is a systematic divergence between welfare estimates obtained through stated preference and revealed preference choice instruments. Usually, individuals' stated WTPs often exceed their real-money WTPs (List and Gallet, 2001; Murphy et al., 2005). This paper used cheap-talk to test its impact on reducing the hypothetical bias in the contingent valuation survey.

4.4 Results and Discussion

4.4.1 Descriptive statistics' results and discussion

This section presents some descriptive statistics from responses to some of the questions in the survey. In particular, it briefly presents respondent perceptions, awareness, socioeconomic characteristics and ownership status. It is hoped that it gives readers some clues about the nature of the data and its distribution. Table 4.3 gives summary statistics for some of the continuous variables.

Table 4.3: Descriptive statistics of continuous variables

Variables	Mean	Std. Dev.
Age of respondent (in years)	42.82	12.90
Education level of respondent (in years)	2.96	3.57
Household size (in number)	6.35	2.44
Adult male equivalence hh size	5.05	2.05
On-farm employed members	2.1	1.49
Off-farm employed members	0.14	0.37
Land owned in local units (kert)	7.27	6.54
Land cultivated in local units (kert)	9.39	8.23
Land rented in in local units (kert)	3.28	6.03
Land rented out in local units (kert)	0.34	1.42

Number of oxen owned	2.01	1.56
Livestock owned (in TLU)	5.25	3.91
Expenditure of households per month(in Birr)	1541.68	980.79
Income of household per month (in Birr)	2115.57	1661.49

Source: Author's computation from the 2016 survey data.

As can be seen from Table 4.3, on average the age of respondents is 42.8 with a standard deviation of 12.8 years. Household heads in the study area on average achieved Grade 3 and family size was about six which is relatively higher than the family size in rural Ethiopia. On average, sample households' monthly income was about 2,115 Birr and monthly expenditure was slightly lower than the income at about 1,541 Birr per month. Off-farm employment was not common in the study area. Respondents' land ownership status shows that on average a household possessed about 7.27 kert (less than 2 hectares). It seems that landholding in the study area did not meet the land demands of a majority of the farmers as they were, on average, net renters-in. Oxen were predominantly used as a source of power for plowing. On average, a household owned two oxen and about 5.25 livestock in terms of tropical livestock units.

Table 4.4: Frequency of categorical variables

Variables	Category	Frequency	Percentage
Access to credit	Yes	116	37.79
	No	191	62.21
Respondent's sex	Male	207	67.43
	Female	100	32.57
Can read and write	Yes	183	59.61
	No	124	40.39
Own a private tree	Yes	265	86.32
	No	42	13.68
Marital status	Married	274	89.25
	Otherwise	33	10.75

Source: Author's computation from the 2016 survey data.

Table 4.4 shows that close to two-third of the respondents did not have access to credit. Regarding gender of household heads, about 67 per cent of the households were male headed. The penetration rate of education in rural part in developing countries in general and in Ethiopia in particular is very low. In case one wants to talk about education in these areas it would make sense to talk about literacy rates. About 60 per cent of the household heads in the study area could read and write.

Table 4.5: Frequency and distribution of use, health effects and information about the cook stove

Variables	Category	Frequency	Percentage
Have you experienced any health related injury when you cook on a traditional stove?	Yes	195	63.52
	No	112	36.48
Have you heard about the improved cook stove?	Yes	290	94.46
	No	17	5.54
Are you currently using any improved cook stove?	Yes	79	25.73
	No	228	74.27
Do you use the same type of stove for all meals?	Yes	184	59.93
	No	123	40.07

Source: Author's computation from the 2016 survey data.

More than half the respondents' had experienced different health problems as a result of their current cook stove usage (Table 4.5). Physical burns, respiratory diseases, symptoms of asthma and irritation in the eyes and nose were some of the problems that they had experienced. The results in Table 4.5 show that a majority of the respondents (about 95 per cent) had information about the improved cook stoves. Their sources of information included health extension workers in the area, agricultural development workers, friends, the radio and local community organizations like Idir and Iqub. Despite this information the penetration rate of an improved cook stove was very low. Only about 26 per cent of the respondents were using the improved cook stove. From the responses to a follow-up question, it was seen that the respondents' were conservative in using the product due to a bad experience and also that they had very little information about using the product.

Table 4.6: Households' perceptions about the improved cook stove

Variables	Strongly agree (in per cent)	Agree (in per cent)	Undecided (in per cent)	Disagree (in per cent)	Strongly disagree (in per cent)
Use of the improved cook stove improves your families' health	62.54	30.62	6.84	0	0
Use of the improved cook stove saves time	62.540	32.25	5.21	0	0
It is easy to buy the improved cook stove in your area	54.40	20.85	6.19	13.36	5.21
Fixing the improved cook stove is easy	39.41	37.46	13.68	8.47	0.98
Use of the improved cook stove should be mandatory in Ethiopia	61.24	29.97	5.86	2.93	0

Source: Author's computation from the 2016 survey data.

The results in Table 4.6 give a clear picture of respondents' perceptions about using the improved cook stove. Use of the traditional cook stove has tremendous negative health effects. Indoor air pollution, physical burning and damage to different body parts due to fire and smoke are common health effects of using the traditional cook stove. In line with this, households strongly believed that use of the improved cook stove will reduce these problems. About 62 per cent of the respondents strongly agreed that use of the improved cook stove will improve the health of household members. A majority of the respondents also agreed that the improved cook stove saved time. They also agreed that use of the improved cook stove should be mandatory in Ethiopia to alleviate the problems surrounding the use of the traditional cook stove (three-stone stove).

Table 4.7: Responses on distribution and the price of the stove (bid)

Bid	No	Yes	Total
75	26	79	105
150	50	50	100
250	62	40	102
Total	138	169	307

Source: Author's computation from the 2016 survey data.

Theoretically as price increases demand for a product decreases, other things remaining constant. As presented in Table 4.7, the proportion of respondents who accepted the offered price of the stove (bid) decreased as its price increased.

Table 4.8: Stated attribute non-attendance

	Attended to attribute (percentage of respondents)				
Attributes	Always	Often	Sometimes	Rarely	Never
Emission reduction	36.16	21.17	28.34	12.7	1.63
Fuel wood saving	27.69	18.24	33.88	19.22	0.98
Reducing risk of fire	48.53	21.17	24.76	4.56	0.98
Durability of the stove	50.49	20.85	21.5	6.51	0.65

Source: Author's computation from the 2016 survey data.

It is evident from Table 4.8 that attribute non-attendance was not a serious problem in this choice experiment. A fairly significant number of respondents attended to almost all the attributes while making choice decisions. Fuel wood saving was considered less in the choice exercise. This could be attributed to the fact that rural households are not constrained by the availability of fuel wood. Given the rising price per unit of fuel wood perhaps this attribute will be more important for urban residents who have to purchase the wood.

4.4.2 Econometric results and discussion

A starting point for discrete choice models (in this case the multinomial logit model and the mixed logit model) is to run the basic model with only alternative specific attributes as explanatory variables (Hensher and Greene, 2003). Table 4.9 presents the results of the basic multinomial logit (MNL), mixed (random parameter) logit (MLM), scale heterogeneity multinomial logit model (S-MNL) and generalized mixed logit model (G-MNL). Column 2 of Table 4.9 gives the results of the multinomial logit model. The overall fit of the model as measured by McFadden's Pseudo R^2 is good (0.20) but using the log-likely test and information criterion it performs poorly as compared to the other models. The coefficients from this model are significant at the less than 1 per cent significance level except for fuel wood saving. This indicates that all the selected attributes except fuel wood saving significantly affected the choice of the improved cook stove. However, the MNL model is estimated under a stringent assumption of IIA. The study tested this assumption by using the Hausman test by excluding one of the alternatives. The Chi-square value of 17.96 with p-value of 0.006 shows that the IIA assumption was violated under the MNL model. As a result, the study estimated the alternative model which relaxes this assumption. The first model is the random parameter model also known as the mixed logit model. The merits of this model are not only relaxing the assumption of IIA, but it also considers preference heterogeneity and could trace the sources of heterogeneity in preferences. The results of the mixed logit model are presented in Column 4 of Table 4.9. The estimates of standard deviation show that there is preference heterogeneity in choosing the improved cook stove.

Table 4.9: Results from various discrete choice models

Variables	MNL		Mixed Logit model MIXL		Scale heterogeneity S-MNL		Generalized Multinomial logit model G-MNL	
	Coefficient	S.E	Coefficient	S.E	Coefficient	S.E	Coefficient	S.E
ASC	**0.89**	0.30	**3.19**	0.56	**1.89**	0.92	**3.98**	0.69
Emission reduction	**0.24**	0.05	**0.28**	0.12	**0.22**	0.06	**0.44**	0.14
Fuel saving	0.07	0.06	0.07	0.10	0.06	0.07	-0.04	0.12
Risk of fire	**0.84**	0.05	**1.41**	0.12	**0.94**	0.09	**1.50**	0.27
Durability of the stove	**0.08**	0.01	**0.11**	0.01	**0.09**	0.01	**0.13**	0.02
Price of the stove	**-0.002**	0.001	**-0.003**	0.001	**-0.002**	0.001	**-0.002**	0.001
SD emissions			**1.36**	0.17			**1.25**	0.23
SD fuel			**0.85**	0.19			**0.90**	0.17
SD RISK			**0.91**	0.14			**1.40**	0.20
SD durability			**0.10**	0.01			**0.06**	0.01
Tau (τ)					**0.46**	0.15	**0.42**	0.24
Gamma (γ)					0.00	0.00	0.55	0.42
Sigma (σ_i)					**1.00**	0.46	**1.00**	0.42
No of parameters	6		10		9		13	
LL	-1112.2		-999.01		-1110.2		-1002.9	
Pseudo R-squared	0.20		0.51		0.45		0.50	
AIC	2236.5		2018.0		2234.4		2029.8	
BIC	2269.6		2073.2		2273.0		2096.0	

HQIC	2248.7	2038.4	2248.7	2054.2

NB: Significant variables are indicated by bold.

The positive and significant ASC coefficient indicates that respondents had higher utility of the policy alternatives (cook stove improvement alternatives) as compared to the status quo. As expected, the coefficient of price was negative and significant indicating that respondents had higher utility of alternatives with lower price levels. The positive and significant coefficients of emission reduction, reducing risk of use and durability of the stove show that the respondents derived higher utility from the stove with lower levels of emission, lower risk of fire and durability of the stove.

The coefficients from the scale heterogeneity multinomial logit model (S-MNL) confirm the existence of scale heterogeneity (significant tau). Further, the results of the generalized multinomial logit model show the existence of both scale and preference heterogeneity. Thus accounting for these would improve the efficiencies of the estimated coefficients.

The mixed logit model assumes continuous preference heterogeneity in estimating random parameters. However, in the real world people exhibit discrete preference heterogeneity. Thus, this paper estimated the latent class model to allow a discrete change in preferences. Optimum class size was selected using the information criterion. Since the third and fourth classifications bring no improvements to the model fit, the two-class model was estimated. The results of this model are given in Table 4.10.

Table 4.10: Model results from the latent class model

Attributes /Class	Class 1	Class 2
Utility functions		
ASC	-0.076	-3.143
	(0.453)	(2.056)
Emission reduction	0.245***	-0.151
	(0.057)	(0.353)
Fuel wood saving	0.100	-0.983**
	(0.063)	(0.431)
Reducing risk of fire	0.863***	0.643**
	(0.055)	(0.316)
Durability of the cook stove	0.085***	0.044
	(0.006)	(0.043)
Price of the cook stove	-0.001***	-0.016***
	(0.0005)	(0.005)
Class membership function		
Constant	16.669***	
	(5.838)	
Income	0.005***	
	(0.0015)	
Age	-0.325***	
	(0.105)	
Latent class probs.	0.961	0.039
Number of obs.	1842	
Log likelihood	-1074.22	
Pseudo R^2	0.47	

Finally, from the estimated models the study computed marginal willingness to pay for each attribute. This result carries important policy implications as cook stove designers, producers and policymakers can clearly identify the most important features of the cook stove. The part-worth or marginal rate of substitution given in Table 4.11 shows the rate at which a consumer trades-off one attribute for another.

Table 4.11: Marginal willingness to pay (part-worth) of the improved cook stove's attributes from the MNL model

Model/Attributes	Emission reduction	Fuel saving	Risk reduction	Durability
MWT_MNL	117.98***	36.49	472.58***	46.35***
Std. Dev.	(42.98)	(35.61)	(127.18)	(12.39)

As we can see from Table 4.11 the respondents made trades-off when they took decisions about adopting the improved cook stove. They attached more value to the emission reduction attribute of the improved cook stove followed by reduction of risk of fire. Their marginal willingness to pay was lower for fuel saving attributes of the proposed cook stove.

This chapter also examined the determinants of willingness to pay for the improved cook stove using data generated by the contingent valuation survey. Double-bounded contingent valuation data was analyzed using the interval data model. For comparison purposes we estimated the probit model using initial bid and the biprobit model using both responses to initial and follow-up bids and interval data model. The results of the probit model are given in Table 4.12. As expected, as the bid increased the probability of saying yes decreased. The education level of a household's head, income of the household, livestock ownership and non-farm income positively and significantly affected the household's willingness to pay for the improved cook stove.

Table 4.12: Determinants of WTP results from CVM data

Variables	Coef.	Std. Err.
Stove price (Bid)	-0.08***	0.002
Age of respondent (log)	0.04	0.39
Level of education	0.06*	0.03
Family size (AME)	-0.16**	0.06
Income (log)	0.69***	0.20
Livestock (TLU)	0.18***	0.05
Off-farm employment	-0.48*	0.28
Non-farm employment	0.15*	0.09
Land owned	-0.03	0.02
Access to credit	0.26	0.21
Own private tree	0.38	0.28
Cheap talk	-0.64***	0.21
Constant	-2.95	2.11
Pseudo R^2	0.29	
LR Chi^2	85.20 (P-value 0.000)	

Note: ***, **, * represent coefficients significant at the 1 per cent, 5 per cent and 10 per cent levels respectively.

The price of the stove (bid), family size and off-farm employment negatively and significantly affected the adoption of the improved cook stove. As expected, provision of cheap-talk reduced willingness to pay. This implies that households who received the questionnaire with cheap-talk as an option stated lower willingness to pay as compared to those without the cheap-talk option. Thus, cheap-talk can help reduce hypothetical bias in contingent valuation.

After estimating the determinants of willingness to pay for adopting the improved cook stove, this study also estimated mean willingness to pay from the different models estimated. The results of mean willingness to pay are presented in Table 4.13.

Table 4.13: Results of mean willingness to pay from different models

Variable/Model	Probit	Probit with covariates	Doubleb	Doubleb model with covariate
Mean willingness to pay	353.87***	208.56***	276.56***	152.66***
Standard error	47.72	44.75	10.45	27.72

As we can see from Table 4.13, mean willingness to pay for the improved cook stove ranged between 152.66 Birr to 353.87 Birr. The estimated mean willingness to pay shows that respondents in the study area could only afford a lower price as compared to the actual market price of the stove. This suggests that the dissemination intervention for the improved cook stove requires a sort of price support (subsidization policy) for it to be effective.

4.5 Conclusion and recommendations

This study used two stated preference survey techniques to analyze households' willingness to pay and preferences for the improved cook stove in Ethiopia. Different discrete choice models (multinomial logit model, mixed logit model, latent class model, scale heterogeneous multinomial logit model and generalized mixed logit model) were used to estimate the determinants of the use of the improved cook stove for the data generated using the choice experiment survey.

The results of our study show that cook stove related attributes and socioeconomic characteristics of the respondent were vital in determining preferences for adopting the improved cook stove. Emission reduction, lower risks of use and durability of the stove positively and significantly affected the probability of households adopting the improved cook stove. Among the attributes, the estimated marginal rates of substitution (part-worth) showed the trade-off that households make while deciding about purchasing the improved cook stove. Thus, cook stove designers, producers and pricing should take into account this trade-off for effective dissemination of the stove. The estimated results of the scale heterogeneous multinomial logit model clearly show the existence of scale heterogeneity and the generalized multinomial logit model coefficients show that there are both scale and preferences heterogeneities. Thus, failure to account for these factors will underestimate the coefficients of product related and socioeconomic characteristics in estimating willingness to pay for the improved cook stove.

The results of our study also show that sampled respondents were aware of the side effects of traditional energy sources and their health, environmental and economic consequences. They were interested in adopting and using the improved cook stove but were frustrated by low quality products and related inconveniences of use for existing products. Attribute non-attendance was not a serious problem in this survey exercise but cheap-talk played a significant role in reducing the hypothetical bias in the stated preference survey.

Finally, the estimated mean willingness to pay ranged from about 150 Birr to 350 Birr. This indicates that the respondents' willingness to pay was below the supply price of the improved cook stove in the area. This needs a pricing policy intervention (subsidizing) for its effective dissemination.

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Appendix: Survey questionnaire

Elicitation of Households' Preferences and willingness to pay for improved cook stove in Ethiopia

Name of the Enumerator: ________________

Date: ______________________________

Time Started: ________________________

Time Ended: ________________________

Place: ___________________________

Choice Experiment version: B1

Hello, how are you? My name is ____________________, an interviewer for the survey designed by Mekonnen Bersisa. Dear respondent, we are conducting this survey to collect information for a research project to elicit households' preferences to evaluate willingness to pay for various attributes of the improved cook stove in rural Ethiopia. As all of us clearly understand the traditional cook stove (three-stone stove) for daily cooking has health, environmental and economic consequences. Use of the traditional cook stove needs a lot of fuel wood; it takes time for cooking and collecting fuel wood and leads to health problems from burning and smokes during cooking. It also leads to deforestation. To reduce these problems a new cook stove has been designed that will reduce these problems of the traditional cook stove. The success of this new technology depends on your genuine responses and evaluation of the product so that the design meets your demands. You are kindly requested to respond to the following questions correctly. We want to assure you that the responses will be strictly confidential and that there is no right or wrong answers for each question; we simply want your opinion. Thank you in advance for your cooperation.

Do you agree to be interviewed? 1. Yes _____ 2. No____

If no, stop here and go to the next respondent selected. If yes, continue to next question.

Part I: Demographic characteristics of the respondent

1. Respondents identification: ID No ______ Zone______, District _____, Kebele:____
2. Age of the respondent: _______ years
3. Sex of the respondent: 1. Male _______ 2. Female ______
4. Marital status: 1.Single _______ 2. Married ____ 3. Widowed ___ 4. Divorced _____
5. Education level ______ years of schooling, 1. Only read and write______ 2. Religious educ. ________, 3. Does not read and write _____

6. Status in the household:
   1. Household head ___ 2. Head of household's wife ___ 3. Son or daughter ____
   4. Other household member ________

7. Religion of the respondent: 1. Orthodox ___ 2. Muslim ____ 3. Protestant ____ 4. Waqefeta ______ 5. Catholic______ 6. Others ______
8. How many people live in the household? _______ persons.

No	Age category	Male	Female
1	<10 years		
2	10-13 years		
3	14-16 years		
4	17-50ears		
5	>50 years		

Part II. Socioeconomic profile

1. How many people in the household are currently employed? 1. On-farm_____ persons, 2. Off-farm _______ persons 3. Non-farm ______
2. How many timad of land do you have__________?
3. How many timad of land did you cultivate this year_________?
4. How many timad of land did you rent-in_________?
5. How many timad of land did you rent-out_______?
6. How many oxen do you have_________?
7. Household's major sources of income ______?: 1. Farming/crop production only____ 2. Sale of livestock and its products (milk, eggs…) only_____ 3. Both livestock and farming products _____ 4. Trading/business _______ 5. Hand crafts _____ 6. Petty trade ______ 7. Sale of firewood/charcoal _______ 8. Others _____
8. What is the livestock profile of the household?

No	Type of Livestock	Number of livestock	No	Type of Livestock	Number of Livestock
1	Calf		7	Donkey (young)	
2	Heifer		8	Camel	
3	Weaned calf		9	Sheep and goat (Adult)	
4	Cows and oxen		10	Sheep and goat (young)	
5	Horse		11	Chicken	
6	Donkey (adult)				

9. On average how much does your household spend per month: _____Birr

10. What is the average monthly income of the household? ________ Birr

Part III: Cooking habits and perceptions about the cook stove

1. Who usually cooks in the household? _____
2. Where do you cook your meals? 1. Kitchen inside the house _______ 2. Separate kitchen _____ 3. Outside (not in a kitchen) _______ 4. Others ______
3. How many meals do you cook for the household per day? ___ meals/day.
4. How many hours do you spend, on average, making daily meals for the household (baking enjera, cooking wat, boiling coffee and water etc.?) _______
5. Do you use the same type of stove for all meals? Yes _____ No _____
6. If the answer to **question 5** is yes, which stove do you use? __________
7. If the answer to **question 5** is no, which type of stove do you use for which type of meal?

   1. Baking 'enjera'/bread_____
   2. Making 'wat'_______
   3. Boiling coffee ______
   4. Heating __________
   5. Lighting __________

8. Why do you use different types of stoves?

   1. Not flexible for different uses____
   2. The traditional type is appropriate for certain meals ______

   3. Some cook faster ____ (specify which one________)

   4. Some are appropriate for a larger pot (specify which one ______)

   5. Fuel sources are not reliable______

   6. Others ______

9. Have you heard about the Mirt improved cook stove? 1.Yes ____ 2.No ____ (**show picture of the stove**)
10. How/where did you hear about it? 1. Radio_____ 2. Television_____ 3. From a friend/parent_____ 4. From DAs______ 5. Idir______ 6. Other sources ______(specify)……………………..
11. Are you currently using it? 1. Yes_______ 2. No_____
12. If the answer to question 11 is yes, since when ______EC?
13. How did you acquire it? 1. Purchase_____ 2. Gift______ 3. Free distribution________ 4. Others________ (specify)………………...)
14. If the answer to question 11 is no, have you ever used one before?

    1. Yes____ 2. No_____

15. If you have used one before, why did you stop using it (you can choose more than one answer)? 1. Did not match my pans___________

2. I did not like it_____________ (specify why________________________)

3. Is broken________________

4. Required too much fuel____ (specify which type of fuel you use_________)

5. Others (specify) ___________________

16. Will you use it again if it is fixed? 1. Yes_____ 2. No ______
17. If the answer to question 11 is yes, what difference do you see in the improved cook stove as compared to other stoves (you can choose more than one answer)? 1. Cheaper_____ 2. Easy to handle______ 3. Reduces cooking time_______ 4. Less smoke______ 5. Less dirt_______ 6.Safer_______ 7. Keeps fuel heat longer_____ 8. Others (specify)________
18. What improvements did it bring in your household (you can choose more than one answer)? 1. Meals ready earlier_______ 2. Do not have to watch the fire______ 3. Fewer injuries_____ 4. Fewer respiratory diseases______ 5.Reduces the food expenses______ 7. More time to do other activities_____ 8. Others (specify)___________
19. Have you ever experienced any health related issues due to cooking with your current fuel and stove, such as respiratory problems or physical burns? 1.Yes ____ 2. No____
20. If yes, specify ____

____

21. How many times did it happen over the past year?________
22. Use of the improved cook stove (Mirt stove) improves household's health status.

1. Strongly agree 2. Agree 3. Undecided 4. Disagree 5. Strongly disagree

23. What are the inconveniences of the improved stove? 1. None________ 2. Breaks quickly________ 3. Slow to heat__________ 4. Not suitable for large pots_________ 5. Others_______

24. Use of the improved cook stove (Mirt stove) saves you or other household members' time?

1. Strongly agree 2. Agree 3. Undecided 4. Disagree 5. Strongly disagree

25. If the answer to question 24 is (1 or 2), please check that the following apply: 1) Fuel wood collection______ 2) Dung collection______ 3) Cooking ______ 4) Others ________
26. Which type of fuel do you use to cook the main food? 1. Charcoal______ 2. Wood______ 3. Husk______ 4. Animal dung_____ 5. LPG_____ 6. Electricity_____ 7. Biogas___ 9. Others_____
27. Do you use the same type of fuel for all meals? 1. Yes______ 2. No______

28. If no, which type of fuel do you use for which type of meal? (use ***X*** where it applies)

No.	Purpose	Charcoal	Firewood	Dung	Crop residual	LPG	Others
1	Making 'wat'						
2	Baking 'enjera'						
3	Boiling coffee						
4	Heating						
5	Light						

29. Why do you use this (these) fuel(s)? 1. Easily accessible _____ 2. Cheap ____ 3. Give more heat ______ 4. Make the food tasty _____ 5. Less smoke_____ 6. Easy to use_______ 7. Others (specify)___________________
30. Do you have solar power in your home? 1. Yes ______ 2. No _____
31. Do you have access to electricity? 1. Yes _____ 2. No ______
32. Do you have home produced biogas? 1. Yes _____ 2. No ______
33. Is it easy to buy an improved cook stove (like Mirt, Lakechi, Gonze and others) in your area? 1. Strongly agree 2. Agree 3. Undecided 4. Disagree 5. Strongly disagree
34. Fixing the cook stove is easy.

    1. Strongly agree 2. Agree 3. Undecided 4. Disagree 5. Strongly disagree

35. Use of the improved cook stove should be mandatory in Ethiopia.
    1. Strongly agree 2. Agree 3. Undecided 4. Disagree 5. Strongly disagree

36. Have you ever used credit from any source? 1. Yes _____ 2. No ______
37. If the answer to question 36 is yes, from which source? 1. MFI_______ 2. Friends ____ 3. Local money lender ______ 4. Relative _______ 5. Other sources ______
38. How far is the place from where you collect firewood (in hours)? _____ hrs.
39. Do you have private trees (Eucalyptus or others)? 1. Yes __ 2. No ___

Part IV: Improved cook stove adoption Choice experiment Questions

Scenario Description

Here is a short description of the proposed programs to improve the design of the cook stove that will reduce problems surrounding the use of the traditional cook stove. You are kindly requested to attend to the description attentively. This will help you to understand the choice sets that will be provided. Further we would like to remind you that this study is not part of the government's plan and its only objective is to understand individual preferences for the various attributes of the improved cook stove and to better understand and alleviate the problems related to the use of the traditional cook stove. But it supports the government's strategy of green growth and goals of sustainable development through the research output that will help design and distribute improved energy use technologies. One of the policy interventions with regard to this target is to make improved cook stoves accessible to rural households by 2025. Use of improved cook stoves reduces energy consumption, indoor emissions and saves time in cooking. This has economic, health and environmental benefits for households. However, production and distribution of the improved cook stoves depends on the salability of the products. Of course, designers of the improved cook stoves try to meet household preferences by including different attributes in their products.

We ask you to consider the attributes and their levels and the costs for carrying out various measures in the choice questions that follow. Please note that for the questions that follow, no 'right' or 'wrong' answers are expected. What is required is choosing your best preferred option. Please mark the preferred option as if it is the only choice you can make assuming that the levels of these attributes are independent of each other and other attributes and characteristics of the improved cook stove remain the same. If you face any difficulties in understanding the options, do not hesitate to ask for further clarifications. In case you change your mind, feel free to go back and change your previous choice(s).

Four characteristics of an improved stove, which are relatively more important and expected to generate economic value, have been selected. These are: (a) *Indoor smoke/emission reduction* (b) *Risk of use*, (c) *Fuel saving* and (c) *Durability of the stove.* The stove is designed in such a way that it serves multiple purposes. It can be used for baking enjera, cooking wat, boiling coffee etc.

Now suppose that the company designing and producing the improved cook stove wants to produce a new cook stove that will reduce the problems of the traditional stove and assures the sustainable use of the new cook stove while enhancing the benefits that households can get by using it. To help the company make a decision, it wants to see which of the options people prefer. In order to accomplish this, various development options have been planned. The proposed measures for the four attributes are:

A. ***Indoor smoke/ emission reduction*****:** indoor smoke is a serious problem that rural households face by using the traditional cook stove. High emission levels expose households to different health risks such as irritants, burning in the eyes and respiratory problems. Thus, this program is designed to reduce the problem of indoor smoke from using the traditional cook stove. The program will integrate different packages with the improved cook stove that will reduce the level of emissions. Under different packages it will reduce emissions from 40 per cent to 90 per cent.
B. ***Fuel saving*****:** shortage of fuel wood, higher costs of firewood and their environmental effects are some of the crucial problems related to firewood collection and use. This program will improve the efficiency of the stove and reduce firewood usage by 25 to 65 per cent as compared to the three-stone cook stove.
C. ***Risk of use*****:** this plan is designed in response to different hazards of using the traditional cook stove. The program involves designing a cook stove such that it reduces fire, burning and explosion risks. It will make the households safer while cooking and reduce related costs in the prevention and treatment of injuries.

D. ***Durability of the stove***: the stove breaking down frequently exposes a household to unnecessary costs. This program will produce stoves which will last for different durations of time --- from about 5 years to 20 years.

However, it has to be clear that all these plans require money for their implementation. To make such improvements the company will have to incur additional costs which should be transferred to consumers by increasing the price of the cook stove. Households have to pay the full price of the stove after it has been installed and tested. Please keep in mind that in this kind of a survey people often tend to overstate their willingness to pay to contribute to the proposed project. But we would like to remind you that you are going to purchase the stove from your income which may entail not purchasing some other goods for household consumption.

To the interviewer: Show the choice set cards and explain what they represent. Make sure that the interviewees pay attention to your description. Help them in clarifying any doubts

In the following choice situations, you will be presented with a series of options for different combinations of the attributes of the improved cook stove. Each choice situation has three options described by their characteristics and you will be asked to indicate your preferred option. Note that ***Option 1*** *and* ***Option 2*** *will entail additional costs for your household. You will not incur additional costs for* ***Option C****, but the cook stove will not be an improved one and the related problems will persist. When you make your choice*:

- ✓ *Please choose ONLY ONE OPTION in each situation*
- ✓ *Assume that the options in EACH situation are the ONLY ones available*
- ✓ *Do NOT compare the options given in different situations*
- ✓ *Options will be backed by pictures for clarity*

Choice set B1.1

Attributes	**Option 1**	**Option 2**	**Option 3**
Emission reduction	40%	40%	Neither 1 nor 2
Fuel saving	25%	45%	Neither 1 nor 2
Risk of fire	High	High	Neither 1 nor 2
Durability of the stove	15 years	5 years	Neither 1 nor 2
Price of the stove (in Birr)	150	250	Neither 1 nor 2
Which one do you choose?	☐	☐	☐

Choice set B1.2

Attributes	Option 1	Option 2	Option 3
Emission reduction	90%	40%	Neither 1 nor 2
Fuel saving	45%	65%	Neither 1 nor 2
Risk of fire	Low	Moderate	Neither 1 nor 2
Durability of the stove	5 years	15 years	Neither 1 nor 2
Price of the stove (in Birr)	150	250	Neither 1 nor 2
Which one do you choose?	☐	☐	☐

Choice set B1.3

Attributes	Option 1	Option 2	Option 3
Emission reduction	40%	40%	Neither 1 nor 2
Fuel saving	45%	25%	Neither 1 nor 2
Risk of fire	Moderate	Low	Neither 1 nor 2
Durability of the stove	20 years	5 years	Neither 1 nor 2
Price of the stove (in Birr)	75	75	Neither 1 nor 2
Which one do you choose?	☐	☐	☐

Choice set B1.4

Attributes	Option 1	Option 2	Option 3
Emission reduction	65%	90%	Neither 1 nor 2
Fuel saving	25%	25%	Neither 1 nor 2
Risk of fire	Moderate	Moderate	Neither 1 nor 2
Durability of the stove	5 years	20 years	Neither 1 nor 2
Price of the stove (in Birr)	250	150	Neither 1 nor 2
Which one do you choose?	☐	☐	☐

Choice set B1.5

Attributes	Option 1	Option 2	Option 3
Emission reduction	90%	40%	Neither 1 nor 2
Fuel saving	65%	25%	Neither 1 nor 2
Risk of fire	Moderate	High	Neither 1 nor 2
Durability of the stove	5 years	15 years	Neither 1 nor 2
Price of the stove (in Birr)	75	150	Neither 1 nor 2
Which one do you choose?	☐	☐	☐

Choice set B1.6

Attributes	Option 1	Option 2	Option 3
Emission reduction	65%	65%	Neither 1 nor 2
Fuel saving	45%	65%	Neither 1 nor 2
Risk of fire	Low	Low	Neither 1 nor 2
Durability of the stove	20 years	15 years	Neither 1 nor 2
Price of the stove (in Birr)	250	75	Neither 1 nor 2
Which one do you choose?	☐	☐	☐

If you think back on your choice decisions, to what extent did you attend to the individual attributes of the various alternatives in your overall choice? (**Use X where this applies**)

No.	Attributes	Never	Rarely	Sometimes	Often	Always
1	Emission reduction					
2	Fuel saving					
3	Risk of fire					
4	Durability of the stove					

1. When you made your choices, were there any attributes you chose not to take account of? 1. Yes _____ 2. No _____
2. If the answer to question 1 is yes, which attribute(s)? 1. Emission reduction ____ 2. Fuel saving ___ 3. Risk of fire ______ 4. Durability of the stove _____ 5. Price of the stove _____

Debriefing questions

1. On a scale of 1 to 5 how difficult did you find the choices between the cards? (with 1 meaning very easy and 5 meaning highly difficult)

1. Very easy 2. Easy 3.Undetermined 4. Difficult 5. Very difficult

2. On a scale of 1 to 5 how efficient do you think a new cook stove is in improving the household's welfare? (with 1 meaning least efficient and 5 meaning highly efficient)

   1. Least efficient 2. Efficient 3. So how 4. Efficient 5. Highly efficient

3. On a scale of 1 to 5 how realistic do you think the description of the improvements is? (with 1 meaning totally unrealistic and 5 meaning very realistic)

   1. Totally unrealistic 2. Unrealistic 3. So how 4. Realistic 5. Very realistic

4. If you chose neither cook stove improvement alternatives (Option 3) in one of the choice sets above, could you please tell us why you are against any management strategy?

   a) I don't believe that the design of the improved cook stove will be successful _____
   b) I do not have the financial capability to pay for the improved stove ____
   c) I will only pay for it if other locals also do __________
   d) I prefer the existing stove __________
   e) I do not care for the type of stove I use ________
   f) The government should distribute the stove free______
   g) I do not think that the improvements in the cook stove are necessary, there is no risk ______
   h) I don't have enough information about the risk reduction measures of the improved cook stove ________
   i) Others (please specify) ______

Part V: Contingent Valuation

Scenario for the improved cook stove

All households without exception cook in one way or the other to meet their daily food needs. We are all aware that for a long time households' cooking habits have shown that they depend on the conventional three-stone stove for cooking. However, reliance on the traditional three-stone cook stove for daily cooking has health, environmental and economic consequences. Use of the traditional cook stove requires considerable firewood/charcoal for preparing the food every day. Moreover, it requires significant time to collect firewood which the children would have used for studying or helping in other work. The three-stone cook stove emits a lot of smoke when meals are prepared. This smoke affects your health and the health of household members, especially children who stay with you when you prepare the meals. Its common health effects are respiratory problems and itching in the eyes. As a result, currently a new cook stove technology has been designed that will reduce these problems of the traditional cook stove. Compared to the traditional stove, it needs lesser fuel, needs less time for cooking, emits less smoke and is less risky. The success of this new technology will depend on your genuine responses and evaluation of the product so that the design meets your demands. We would like to remind you that you are going to purchase the stove from your income which may entail not purchasing other goods for your household consumption. The improved cook stove will be given to you at your home and it will be installed by development assistants trained by the organization producing and distributing the cook stove. Further, you will pay the money after the cook stove has been installed and tested for cooking.

Did you understand this scenario? 1. Yes ________ 2. No _______

Cheap-talk script (*this version was presented to only 50% of the respondents***)**

Many similar surveys find that when respondents are asked how much they are willing to pay to realize a suggested program, in most of the cases they overstate their willingness to pay. Overstating willingness to pay is seen as a serious problem in such surveys and this is undesirable. If I were you I would consider the effect of the payment on my household economy. For example, if I pay some amount of money for this program, I will have to give up the money I was supposed to spend on leisure or for other purposes. So please assume that you are in a real situation where you are expected to make the payment in cash and answer the following questions without any exaggeration:

1. Suppose that the company producing the improved cook stove has calculated the cost of producing the stove as **75/150/250** Birr and this is how much the stove will cost. Will you buy it (in your current financial situation)? 1. Yes____ 2. No___
2. If the answer to question 1 is no (reduce 50%**),** if the cooking stove is sold at ____Birr, will you buy it (in your current financial situation)? 1. Yes __ 2. No ___
3. If the answer to question 1 is yes (increase by 50%**)**, if the cooking stove is sold at _____ Birr, will you buy it (in your current financial situation)? 1. Yes__ 2. No___
4. What is the maximum amount that you would be willing to pay to acquire the stove? ______

Certainty question

How certain are you of your decision about how much you would pay? Please circle ONE number from 1 to 10, with 1 indicating very uncertain and 10 indicating very certain.

Very uncertain **Very certain**

1 2 3 4 5 6 7 8 10

Interviewer's observations

1. Respondent's cooperation
   1. Excellent ____ 2. Fair ______ 3. Average ______ 4. Bad ____
2. Respondent's understanding of the choice task
   1. Excellent ____ 2. Fair ______ 3. Average ______ 4. Bad ____
3. Respondent being in a rush
   1. Very rushed ____ 2. Somewhat ______ 3. No rush______

Declaration

I, **Mekonnen Bersisa**, do hereby declare to the School of Graduate Studies of Addis Ababa University, College of Business and Economics, Department of Economics that, this dissertation entitled "*Multidimensional Poverty, Energy Poverty and Cook Stove Technology Adoption in Ethiopia*" is a product of my original research work. It was not submitted, in full or part, for the attainment of any academic degree elsewhere. This work has also accredited the views of the research participants. To the best of my knowledge, I have fully acknowledged the materials and pieces of information used in the study. The reporting procedures do comply with the expected standards and regulation of the University.

Name: Mekonnen Bersisa Gadisa

Signature: _______________

Date of Submission: October 2017

Department of Economics

Addis Ababa University

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