ESSAYS IN RURAL ENERGY, FOREST DEPENDENCY AND COVARIATES OF FUEL SAVING TECHNOLOGIES IN ETHIOPIA

By

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Declaration

I declare that this thesis I hereby submit for the degree of Ph.D. in Economics at the University of Pretoria is entirely my own work and has not been submitted anywhere else for the award of a degree or otherwise.

Signed Abebe Damte Beyene

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This thesis contains empirical findings on rural energy, forest resource use and fuel saving technologies in Ethiopia. Using a household survey data conducted in different parts of the country, efforts were made to contribute to the limited empirical evidences in Africa in general and Ethiopia in particular. The thesis has four empirical chapters and the first and the last chapters of the thesis are the introduction and summary, respectively. The main findings and policy implications are highlighted below.

The second chapter examines the coping mechanisms of rural households to fuel wood scarcity. Using randomly selected households, the results of the empirical analysis show that rural households residing in forest degraded areas respond to fuel wood shortages by increasing their labor input to fuel wood collection. The study also finds that there is no evidence for the substitution between fuel wood and dung or fuel wood and crop residues. Supply side strategies alone may not be effective in addressing the problem of forest degradation and biodiversity losses.Any policy on natural resource management in general and rural energy problems in particular should make a distinction between regions of different forest degradation level.

The third chapter examines the relationship between property rights and household demand for fuel wood, as measured by the source from which fuel wood is collected. Results from the discrete choice model indicate that active local-level institutions reduce the dependency on community forests, but, otherwise, increase household dependency on open access forests. However, land tenure security and local level institutions do not increase demand for fuel wood collected from private forests. The results suggest that there is a need to bring more open access forests under the management of the community and increase the quality of community forestry management in order to realize improvements in forest conservation.

The fourth chapter of this thesis deals with finding empirical evidence on the role of local level institutions and property right regimes on forest dependency using data from a random sample of rural households in Ethiopia. We find that forest dependency is negatively correlated to the wealth status of the household. Our estimation results suggest that local level institutions are not significant factors in determining use of non wood forest products unlike major forest products such as timber or woody materials in general. We also find that there is a need to expand the current practice of participatory forest management to other open access forest areas. We conclude that generalization on the forest-poverty link depends on the type of forest management and the specific characteristics that prevail in the area.

The last chapter of the thesis deals with finding empirical evidence on the determinants of adoption of different types of fuel saving technologies in urban Ethiopia. The duration analysis suggests that adoption rates have been increasing over time, that income and wealth are important contributors to adoption, and that substitute technologies tend to hinder adoption of Lakech charcoal stove. However, it was not possible to consider prices or perceptions related to either the technologies or biomass availability in the duration models, and, therefore, further research is needed in order to further inform policy with respect to household technology adoption decisions.

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CHAPTER I

INTRODUCTION

Forests are the main source of livelihood for many poor households in developing countries in general and Africa in particular (WRI, 2005; Narain et al., 2008a). The Ethiopian forests provide a wide variety of wood and non-wood products such as honey, incense, medicinal plants, bamboo, foodstuffs, etc. They are socially and commercially significant to the livelihoods of rural households. Some studies show that forests provide up to 40 percent of the total household income (Cavendish, 1999b; Mamo et al., 2006). Like other many developing countries, forests are also a very important source of energy for both rural and urban households in Ethiopia. In Ethiopia, households consume about 92% of all biomass energy, with the remaining being consumed by small-scale industry and food enterprises (Nune et al., 2010). The urban population is also highly dependent on fuel wood and other biomass energy sources such as charcoal, dung and residues for their cooking activities.[1] In the rural areas of the country, where more than 85 per cent of the total population lives, the traditional fuel sources contribute 99.9 per cent of the total energy consumption, which is constituted 81.9% fuel wood, 9.3% cattle dung, 8.3% crop residues and 0.4% charcoal (Bewket, 2003). Moreover, biomass energy use in both rural and urban Ethiopia is characterized by a very low efficiency of 5 to 10% (ADC, 2003), which can readily be improved with appropriate intervention measures such as introducing and disseminating improved biomass cook stoves.

Despite the contribution of the forestry sector to the livelihoods of the people and the country as a whole, the country loses about 141,000 hectares of forest each year (FAO, 2009)[2]. For a country with a total of 80 million people and around 70 million of livestock population, forest degradation, deforestation, overgrazing, and land degradation are serious environmental problems that negatively affect the welfare of the people and the overall economy of the country (MoFED, 2002)[3]. The literature also associates the use and extent of natural

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[1] The proportion of urban households who are dependent on biomass energy sources ranges 89-95%. Recent estimates on this figure cannot be found.

[2] Different documents report different deforestation rate for Ethiopia. It ranges between 140,000-200,000 ha per year. For example, according to the world rain forest movement (2002) the deforestation rate for Ethiopia is around 200,000 hectares/year.

[3] The terms forest degradation and deforestation are sometimes used interchangeably in the literature. But in this case deforestation is the removal of a forest or stand of trees where the land is thereafter converted to a non forest use. But forest degradation is the deterioration of forest quality

resources degradation or forest product extractions in developing countries to rapid population growth, rural poverty and open access (Dayal, 2006; Bluffstone, 1998). In Ethiopia, many factors contribute to the forest degradation and deforestation problem. Harvesting fuel wood and logging, clearing for agricultural land and grazing, expansion of rural areas and villages into forest regions and lack of clear forest and land tenure policies are believed to be the major factors of forest degradation and deforestation in Ethiopia (Mulugeta and Melaku, 2008). High population growth which results in increase demand for agricultural land, fuel, and other forest products, and poverty also contribute to the current problem of the forestry sector in Ethiopia. In addition, policy failure due to implementation problem may lead to more deforestation and forest degradation problem as this may, among other things, create a property right regime closer to open access (Mekonnen and Bluffstone, 2008).

As described above, land clearing for agriculture is one of the main causes of forest degradation and deforestation in Ethiopia. Ethiopia is highly populated with the rank of second in Africa and around 85% of its population are living in rural areas. The majority of these households have an average land size of less than 1 hectare and characterized by low production and productivity (Birhanu, 2009). As a result of high population and fragmented land size, farmers in Ethiopia are clearing land for agriculture purpose. This is considered as one of the available options for smallholder farmers in Ethiopia who produce over 90% of agricultural products and manages 95% of the cultivated land (Birhanu, 2009). As a result of this practice, the country is experiencing severe land degradation due to loss of soil fertility status.

High and growing demand for fuel wood is one of the main causes of forest degradation and deforestation in Africa in general and Ethiopia in particular (World Growth, 2009). Some authors have questioned the link between fuel wood collection and deforestation. They argue that woodfuel supplies are often a by-product of forest clearance for agriculture and other purposes, but it cannot be considered as the primary cause of forest clearance (see a review by Arnold et al., 2003). These people further argued that the bulk of woodfuel consumption in developing regions comes from trees and shrubs growing outside of forest areas-in fallow lands, brushland, private woodlots, and scattered throughout the agricultural landscape. On the other hand, there are empirical evidences that show the link between fuel wood consumption and forest degradation/deforestation especially in Africa where people are highly dependent on traditional sources of energy for their cooking, heating and lighting activities.[4] It is also believed by the government of Ethiopia that this is one of the main causes of deforestation in the country. High dependence of urban households on woody materials such as charcoal and fuel wood also contributes to the current environmental problems of the country. Various factors such as poverty, unavailability of modern fuels, culture and norms have hindered the transition to modern fuels. As a result, fuel stacking is the main feature of the country (Mekonnen and Kohlin, 2008). Due to the above mentioned factors the current fuel wood demand in the country far exceeds the supply.

In most of the developing countries the critical forestry problems all boil down to lack of clear property rights (Mekonnen and Bluffstone, 2008). Mekonnen and Bluffstone (2008) also explained the main underlying causes of forest degradation and deforestation in Ethiopia. These are market failure, policies and institutions failure. Policy failure occurred due to problems related to design and implementation problems in the policies. Problems with policy and implementation may lead to further degradation and deforestation of forests as it creates a property right regime closer to open access.

As frequently mentioned in other studies poverty also contribute to the current problem of the forestry sector in the country. In Ethiopia, declining standard of livelihood of the farming communities and their close dependence on forests have led to clearing for subsistence farming, cutting of trees for fuel wood and charcoal production, construction material and over-grazing (Bekele, 2001). Alleviating rural poverty and conserving forest resources pose a major economic and moral challenge for governmental and nongovernmental organizations interested in forest conservation initiatives (Reddy and Chakravarty, 1999).

Other factors such as political instability and forest fires, though cited less frequently, are important contributors to the deforestation problem in Ethiopia. Ethiopian farmers have been using fire as a means of production or as a farming tool for a long time. It is believed that fires in different parts of Ethiopia damage every year large areas of forests.

[4] This means fuel wood is one of the main causes of deforestation in many sub-Saharan African. For example, a study by Bandyopadhyay et al. (2006) indicates that fuel wood collection is one of the main causes of deforestation in Malawi. In Vietnam fuel wood collection is the prime cause of deforestation, which accounts for more than 60% of the total Vietnamese deforestation (World Bank 1995, cited in Lind-har, 2003).

Lack or shortage of fuel for cooking and depletion of forest resources used for rural people as a source of food and cash, scarcity of feed for livestock, reduced capacity for carbon sequestration, and biodiversity loss are some of the consequences of forest degradation and deforestation. This will in turn lead to declining agricultural output and decreased household welfare. For example, as a result of deforestation, among other factors, over 1.5 billion tons of soil are washed away annually from the highlands of the country (Girma, 2001). According to Girma, the country also loses about 1-1.5 million tons of grain as a result of soil nutrient loss.

Although there is a growing literature on rural households and forest resource use (particularly on some Asian countries), the available evidences on developing countries in general and Africa in particular are still scanty. Data on environmental resources in general and forest resources in particular do not exist in many developing countries particularly in Africa (Cavendish, 2000). As a result, we have little understanding of the relationship between rural households and forest resource use in the region as a whole.

Understanding these gaps, this thesis tries to investigate the relationship between rural household energy use and forest degradation and empirically examine and understand the link between forest dependency and property rights regimes. Moreover, by recognizing the role of urban households in the current environmental problems of the country this thesis also tries to address one of the demand side strategies, adoption of biomass saving technologies, by using survey data collected from urban households in Ethiopia. Given the paucity of empirical works in this area, the thesis also adds to the limited empirical evidence on the various aspects of the forest people interactions. The implications of the findings of the study for conservation and sustainable use of forests are also highlighted in each chapter of the thesis. The thesis consists of four individual essays presented in chapter two to five.

The second chapter of this thesis deals with rural household's energy use and resource allocation. It is widely recognized that, in addition to other factors, the high dependence on biomass for energy leads to depletion of forests and forest resources in Ethiopia. Currently the country's forest stock is estimated to be between 4-5% of the total land area[5]. Empirical

[5]Various documents indicate different figures on the current forest coverage of the country.

evidences show that a decrease in environmental goods such as fuel wood availability negatively affects the welfare of rural households. This is mainly due to additional burden on women and children, decrease in agriculture productivity as a result of reallocating labour away from agriculture and use of dung and residues as fuel, and declines in nutrition and health (Kumar and Hotchkiss, 1988; Cooke et al., 2008; IEA, 2004). Moreover, increasing scarcity further increases forest degradation and deforestation as households are required to go further into open access forests. Therefore, this chapter tries to understand the coping mechanisms of rural households when forests are scarce. We use a farm household model as a conceptual framework since forest goods are produced and consumed by the household in the study areas.

The analysis was undertaken separately for different forest degradation level (classified based on forest cover) using GIS information to see whether there is any difference in the response of households to fuel wood scarcity. In addition to the standard socioeconomic variables, we have also included other variables obtained from the GIS information such as biomass availability and forest stock and community level variables such as population density. The chapter also examines the possible relationship that exists between fuel wood consumption and other biomass energy sources (dung and residues). The detail estimation for each type of biomass energy sources are presented in the chapter. Important variables that affect household labour allocation to biomass fuel collection are identified and policy implications are highlighted.

Among other factors, lack of clear property rights and tenure insecurity are considered as the main causes of forest degradation and deforestation in Ethiopia. Rural households collect fuel wood from different sources: private, community, and state or natural forests-which are considered as de facto open access forests. As part of the supply side strategies the Ethiopian government has distributed seedlings to farm households with the goal of reducing pressure on open access forests. However, we do not have evidence whether this policy has shifted households away from other open access sources. An example from Vietnam shows that households respond to changes in shadow prices and affect their fuel wood consumption choices among the various sources (Linde-Rhar, 2003). In general, there is a lack of empirical evidences on the choice of fuel wood sources by rural households in Ethiopia. The impacts of different households and community level variables on the determinants of fuel wood collection from each regime should be examined empirically. Specifically, we examine and highlight the implications of tenure insecurity and local level institutions on use of resources from open access forests. In chapter three of this thesis, we have attempted to address this issue by using a random utility framework. We use data collected from two regions and employ a discrete choice model for our empirical analysis. Based on the findings, the implications of tenure insecurity, local institutions and different forest property rights regime on the sustainable use of forests are discussed in the chapter. The findings will help policy makers identify area of intervention for forest conservation and management.

Chapter four deals with forest resource use, property rights and local institutions in Ethiopia. As discussed earlier, in addition to fuel wood, rural households in Ethiopia collect a variety of non-wood forest products from community, private, and other open access forests. In the analysis of forest poverty link, many people argued that poverty forces rural households to depend on the surrounding natural resources for survival. The implication of this is that increase in the income of households will reduce dependence on forest resources and hence decrease in forests degradation and deforestation. However, in addition to poverty, local level institutions and clear property right regimes may help limit the amount of forest resources extracted and the way the resources are utilized. The nature of the link between property right, local institutions and resource use may also depend on the type of natural resources in general and forest resource in particular. It is, therefore, necessary to identify the determinants of forest dependency under different property right regimes. There is no consistency in the literature regarding measure of forest dependency. As opposed to most other related studies, we consider different measures for forest dependency, which will enable us to check the robustness of our results. The determinants of forest resource use for each type of property right regimes are estimated using appropriate econometric strategies. We have also tried to assess the contribution and significance of forest products to the livelihood of the rural people in the study area.

We have also tried to understand the impact of local level institutions on forest dependency in community forests. It is widely argued that devolution of natural resource management is the most viable option for ecological and economic sustainability of the natural resources. It improves the forest cover and biophysical conditions thereby providing economic benefits to the local people. Ethiopia has practiced the transfer of the management of forest to the local community over a decade. The development of participatory forest management program (PFM) is considered as a viable option for forest conservation and is being practiced in different parts of the country. However, the evidence on the determinants of forest products collection in a community forest and equity implications of the transfer of ownership of forest management to the locals is not clear. Therefore, chapter four discusses the role of local level institutions in the use of forest products in a community forest and the implications of transfer of the rights to the local community on forest dependency.

The apparent link between woodfuel use and forest degradation and deforestation formed the basis for policy and programme interventions in many developing countries over the past 30 years (World Bank/ESMAP, 2001; cited by Bensel, 2008). Demand side and supply side interventions were designed in many developing countries. The supply side strategies focus on increasing the supply of fuel wood through more plantations, tree planting, supply restriction and enforcement of property rights. The demand side programmes focus on the promotion and dissemination of improved biomass stoves or on efforts to facilitate inter-fuel substitution away from wood fuels.

By recognizing the role of urban households in the current environmental problems of the country, chapter five focuses on analysing one of the demand side management adopted by the current government of Ethiopia, i.e. dissemination of energy efficient technologies which is considered as technological substitutes for fuel wood (Amacher et al. 1992). The role of urban households in forest degradation and deforestation in developing countries should not be overlooked. The urban demand for energy contributes to the problem of forest degradation and deforestation in some areas (Barnes et al., 2004). As in many sub-Saharan countries of Africa, urban households in Ethiopia are highly dependent on biomass energy sources such as fuel wood, charcoal, and dung for cooking. Adoption of improved biomass stoves reduces fuel wood consumption. According to EPA (2004), sufficient distribution of these improved biomass stoves will have significant contribution in reducing environmental degradation in general and forest resource degradation in particular. Moreover, stoves may provide other benefits such as reduced indoor smoke, reduces time for cooking, etc. Given all these benefits, not all households own and enjoy the benefits of these technologies. Many studies such as Barnes et al. (1994) mentioned that there are a variety of factors including fuel wood scarcity and stove characteristics that affect the adoption and use of improved stoves. However, most of these studies are qualitative in nature and there are still very few household studies that formally estimate the degree of influence of different factors on the adoption and efficient use of improved biomass stoves. The chapter tries to find some empirical evidences on why some households do not adopt the technology while others are benefiting from it using a dynamic framework. Because of data limitations, we concentrate on the socioeconomic characteristics that affect the speed of adoption of fuel saving technologies in urban Ethiopia. Some of the main determinants of adoption of the technology were identified and policy implications are indicated.

In conclusion, the study will add to the current state of knowledge on the link between people's livelihood and forests in Africa in general and Ethiopia in particular. The results will help the government or policy makers and other stakeholders understand the role of forests to improve rural livelihoods and the factors that contribute to the misuse of forests and forest resources. It will help policy-makers and development planners in the design of policies and programs aimed at poverty reduction and improving the degradation of forest resources in rural Ethiopia.

In order to achieve the above objectives the data collection method and the study area are briefly explained below. We used different data sets collected in different parts of the country. We used the survey data collected for the project 'Households forest values under varying management regimes in Ethiopia' to address the second and fourth chapters of the thesis. This project was designed by the Environmental Economics Policy Forum for Ethiopia (EEPFE) based on the outcome of a meeting on forestry research and policy which was held in March 2008. The discussions with government officials focused on new developments and issues for research in forestry. A key issue that came out from the workshop was the need to inform policy makers about the importance of forests/trees in general and their role in the lives of households in particular. In the meeting, the government officials strongly felt that the research on forestry would be very useful if it focuses on sites within watersheds that are identified by the government for an integrated program called Country Partnership Program for Sustainable Land Management (CPPSLM). This program is run by the Ministry of Agriculture and Rural Development and funded by the World Bank and Deutsche Gesellshaft für Technische Zusammenarbeit (GTZ).

Research sample sites were selected using purposive sampling based on certain criteria such as forest cover, institutional differences, agro-ecology, accessibility, etc. Sample sites were selected with in and outside the watershed. Households were selected based on a simple random sampling technique in order to make the sample representative. The total number of sample households was 600. Survey questionnaire includes questions on household characteristics, health and social capital, agricultural production, energy consumption and production, forestry programs, institutions and forest products, shocks and expenditure, off-farm income and remittances, credit, experimentally generated information on households risk preferences.

In addition to the household survey, focus group discussions were held in each Kebele (peasant associations). The purpose of the focus group discussions were to get villagers' attitude and perception regarding the natural resource/forest management, on the current problems related to forests, grazing land, shocks, use and availability of technology, etc. The contents of the survey are clearly explained in each chapter of the thesis. There are 40 communities in the survey. In each village or community, 8-10 individuals were chosen for the focus group discussions. Experienced field supervisors and enumerators were chosen for the survey and three days training were given before they went to the actual survey work in the field. This project is unique in that it has a spatial data obtained by hiring foresters. The spatial data has detail information on biomass availability for each Kebele (peasant associations) and for each type of forests, forest area, GPS points for each Kebele, and number of trees per ha per Kebele.

In addition to the above data, we used two additional surveys collected in the year 2009 and 2007. Data from the rural households' survey collected in the East Gojam and South Wollo zones of the Amhara regional state was used for addressing the issue of property rights and choice of fuel wood sources in rural Ethiopia. The total number of households interviewed was 1760. Community level surveys were also conducted in 14 sites. The second one is different_from the other surveys in that it was conducted in urban areas and focus on only improved biomass cook stoves. Hence, for the analysis of adoption of fuel saving technologies we used survey data collected by Megan Power limited company in different towns of the country in 2009.

In sum, the use of different data sets obtained from different parts of the country allows us to explore and understand different issues on the forest-people interaction from both rural and urban side. As environmental problems are geographic specific, policies designed to address issues related to forest depletion will be most successful if they take into account local, social, economic, and natural resource conditions of the area.

CHAPTER II

RURAL HOUSEHOLDS COPING MECHANISMS TO FUEL WOOD SCARCITY IN ETHIOPIA

Abstract

This study examines the coping mechanisms of rural households to fuel wood scarcity by using survey data from randomly selected rural households in Ethiopia. The determinants of collection of other biomass energy sources were also examined. The results of the empirical analysis show that rural households residing in forest-degraded areas respond to fuel wood shortages by increasing their labour input to fuel wood collection. However, for households in high forest cover regions, forest stock and forest access may be more important factors than scarcity of fuel wood in determining household's labour input to fuel wood collection. The study also finds that there is no evidence for substitution between fuel wood and dung or fuel wood and crop residues. Supply side strategies alone may not be effective in addressing the problem of forest degradation and biodiversity losses. Any policy on natural resource management in general and rural energy problems in particular should make a distinction between regions of different forest degradation level.

1. INTRODUCTION

Many people in developing countries rely on biomass energy sources, primarily fuel wood, dung and crop residues, for their energy needs.[6] Widespread poverty in many rural areas of developing countries, especially in sub-Saharan Africa, is considered to be the main factor for continued dependency on biomass energy sources, as is the continued use of biomass energy in traditional and inefficient ways. The continued dependence can be observed across developing countries in the form of forest degradation and deforestation. The continuing degradation and deforestation, particularly in Asia and sub-Saharan Africa, has, in turn, resulted in firewood scarcity.

Ethiopia is a typical example; nearly all of the rural population depends on biomass energy sources for cooking and other energy requirements. Of the different biomass energy sources, fuel wood accounts for around 78% of the total energy demand, while animal dung and crop residues account for 12% and 9%, respectively (Woody Biomass Inventory and Strategic Planning Project - WBISPP, 2004). As these resources must be collected from the available resource pool, such high dependence is likely to have a fundamentally negative impact on the availability of forest resources. A recent government forest policy document approved in 2007 also noted that fuel wood collection, together with land clearing for agriculture, illegal settlement within forests, logging and illegal trade have resulted in deterioration of forests and forest resources. According to FAO (2009), the country loses about 141,000 hectares of forest each year. Cognizant of these problems, the Forest Development, Conservation and Utilization Policy and Strategy was approved by the Council of Ministers in April 2007, the first time that the Ethiopian government has developed a forestry policy. Though there is considerable policy interest within the government, the link between the socioeconomic, environmental and institutional factors and biomass use is not well documented in Ethiopia. A better understanding of the interaction between rural people and biomass use, under different environmental conditions, may help policy-makers design better strategies in order to conserve forests and forest resources more effectively in rural Ethiopia.

Fuel wood scarcity, especially in rural areas, has attracted the attention of many researchers and policymakers since the mid 1970's, because it is believed that the problem could have

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[6] According to the International Energy Agency (IEA, 2002), 2.4 billion people in developing countries use biomass as a source of energy for cooking, heating and lighting needs.

serious, negative socio-economic consequences for rural livelihoods (Arnold et al., 2003; Mekonnen, 1999). For example, Dewees (1989) and Arnold et al. (2003) argue that scarcity increases the burden on women and children, on whom the task of biomass collection usually falls, influencing the amount of time women and children have for other tasks and activities. Furthermore, in the absence of sufficient fuel wood, increasing quantities of crop residues and animal dung get used for fuel, reducing the availability of livestock feed, soil conditioner and fertilizer. Dewees (1989) argues that fuel wood scarcity could result in increased deforestation, changes in cooking and eating habits, and the emergence of fuel wood markets.[7] However, each of the preceding changes can also occur for a variety of other reasons, not necessarily related to either the physical or the economic scarcity of fuel wood (Dewees, 1989).

Given the potential negative impacts of fuel wood scarcity, understanding the effects of and household level responses to (increasing) fuel wood scarcity represents an important research agenda, with the potential either to impact behaviour or to develop better forestry policy. Early studies examined these responses within the context of fuel wood production and consumption, and, although there are a number of studies of fuel wood production and consumption in Asian and African countries, the empirical evidence is still limited. Kumar and Hotchkiss (1988) find that households in Nepal cope with fuel wood scarcity by increasing time spent on collection. Similarly, Cooke (1998a, 1998b) concludes that when households in Nepal are faced with shortages of environmental goods, as measured by shadow prices, they spend increasing amounts of time collecting these environmental goods, without affecting agricultural productivity, such that the reallocated time must come from other activities, e.g., leisure. Brouwer et al. (1997) find that Malawian households switch to lower quality wood, economize on wood use and increase the number of collectors. Heltberg et al. (2000) find that households increase their collection time, in forest-degraded areas. Similarly, Palmer and Macgregor (2009) find that fuel wood scarcity has a positive effect on labour inputs to fuel wood collection. Both Heltberg et al. (2000) and Palmer and Macgregor (2009) examine the relationship between fuel wood scarcity and forest degradation using collection time per unit of fuel wood as an indicator for fuel wood scarcity. In contrast, van `t Veld et al. (2006) find that households in India do not spend more time searching for fuel wood, when biomass availability from common areas decreases. Instead, households are less

[7] See Cooke-St. Claire et al.(2008) for further implications of fuel wood scarcity on rural household welfare.

likely to collect from common areas at all, and are more likely to use privately produced fuel. Cooke et al. (2008), in their review, argue that there is a need for more evidence from African countries.

In addition to examining the direct household response to fuel wood scarcity, in terms of fuel wood collection efforts, the literature has also examined indirect responses, such as substitution towards other biomass energy sources. Both Heltberg et al.(2000) and Palmer and Macgregor (2009) find that there is limited evidence for substitution between fuel wood from commons and private fuels and fuel wood and dung in India and Namibia, respectively. Mekonnen (1999), using the virtual price of fuel wood, finds that dung and fuel wood are complements. Amacher et al. (1993) find that crop residues and fuel wood are complements in one region of Nepal, but are substitutes in another district of the study area. A review by Cooke et al. (2008) summarizes the cross-price evidence (substitution or complementation) between fuel wood and dung, and fuel wood and crop residues as mixed.

As the previous research suggests, fuel wood scarcity results in increased fuel wood collection efforts. However, it is also clear that the literature has not settled upon the appropriate indicator of fuel wood scarcity. In particular, Brouwer et al. (1997) argue that the distance to collection place and the collection time are not reliable indicators of firewood shortages, as so often postulated in the literature, because households from the same village often show considerable differences in collection strategies. In addition to not settling on a single indicator for scarcity, the literature does not generally relate household responses to forest status, a more appropriate indicator of scarcity, with the exception of Bandyopadhyay et al. (2006) and van `t Veld et al. (2006). As discussed by Dewees (1989) and Arnold et al. (2003) early analyses failed to distinguish between physical and economic measures of scarcity and abundance.

In this research, although we follow the literature in making use of collection time as an economic measure of scarcity, we are also able to control for physical measures of scarcity based on spatial data. As there are few studies combining spatial information with household level data (Dasgupta, 2005), one contribution of this research is to account for differences in household responses to fuel wood scarcity under different environmental conditions. Moreover, the spatial data enable us to separately analyse household's fuel use behaviour by status of forest cover. Our study includes spatial data, incorporates biomass availability related to the level of forest degradation and includes household specific measures of fuel wood scarcity. Using mixed data, this study is able to consider: (i) whether or not households increase their fuel wood collection time, when faced with fuel wood scarcity; (ii) whether or not households respond differently to fuel wood scarcity in different forest conditions; and (iii) the relationship between fuel wood scarcity and the consumption of other traditional fuel sources, such as dung and crop residues. We consider these issues by empirically analysing the link between the socioeconomic, environmental and institutional factors that affect household coping mechanisms in the face of fuel wood scarcity, with special attention to the level of forest degradation.

The remainder of the paper is organised as follows. In the succeeding section, the theoretical and empirical framework is outlined. Given the nature of rural households in this study area, in particular, and other developing countries in general, the theoretical framework is based on the neo-classical household production model. Section 3 describes the study area, the nature and sources of the data, and provides summary statistics of that data. Section 4 presents empirical results and discusses those results within the context of the literature, while Section 5 concludes and discusses policy implications.

2. ANALYTICAL FRAMEWORK

2.1. The Farm Household Model

Rural households in Ethiopia are both producers and consumers of fuel wood and other biomass energy sources, suggesting that markets for biomass energy sources are missing or incomplete. Moreover, collection activities in rural Ethiopia do not involve hired labour, which is further evidence of missing markets. Given that many markets are missing, the appropriate analytical framework is a non-separable household model incorporating the consumption and production decisions of the farm household.[8] The main implication of the household model is the need for household specific shadow prices, in order to examine rural household behaviour towards consumption and production of, as well as labour allocation to, fuel wood and other biomass collection. Because the market price has a limited role for households that produce and consume all their fuel wood, Mekonnen (1999) and Cooke (1998a, 1998b) derive the household opportunity cost for collecting fuel wood and use it to

[8] For further details on agricultural household models, refer to Singh et al. (1986).

estimate the shadow price of fuel wood. The model developed for this study follows a similar strategy, although abstracts from a number of interesting details.

Consider a unitary peasant household with concave utility over net income, energy and leisure. In other words, $U = U(\pi, E, \ell;\ \Omega_U)$, where the first argument denotes net income, the second denotes energy and the third, leisure; these are conditioned on household preferences. Energy is assumed to be the sum of energy from all sources, firewood, dung and crop residues, respectively, such that $E = F_E + D_E + R_E$. Leisure is total time net of all labour supplied in all activities, such as labour supplied to the market and in the collection of fuel wood, dung and residues; therefore, $\ell = T - L - F_L - D_L - R_L$. Income arises from the sale of agricultural goods and fuel wood, although fuel wood could also be purchased, as well as wage earnings. Furthermore, agricultural production is assumed to depend on non-energy dung and crop residues, which are determined by their respective labour inputs, as well as technology, while fuel wood production is also determined by its labour input and the technology affecting production. Allowing a, f and w to represent the prices of agricultural goods, fuel wood and labour, net income is written as in (1), while the conditioning technology information, Ω_j, in each production function is product specific.

$$\pi = a[A(D(D_L; \Omega_D) - D_E, R(R_L; \Omega_R) - R_E; \Omega_A)] + wL + f(F(F_L; \Omega_F) - F_E) \qquad (1)$$

The preceding specification assumes: (i) all energy sources are perfectly substitutable, (ii) the trade-off for using dung or crop residues for energy is a reduction in agricultural output, (iii) the use of labour for any activity reduces leisure, and (iv) $A(0,0; \Omega_A) > 0$, i.e., if no fuel wood is available, households can still produce agricultural goods, while using all dung and crop residues for energy.

Maximizing household utility subject to the energy, leisure and profit constraints, as well as non-negativity constraints for each of the energy and labour choice variables yields a series of conditions specifying optimal household behaviour. The conditions yield a set of household level "market" equilibriums for each labour and energy type. Generally, households will equate the marginal utility of leisure with the marginal utility of profits times the value of the marginal product of labour in each of the three energy collection activities. Similarly, households will equate the marginal utility of energy with the marginal utility of profits times the marginal profit associated with that energy source. Importantly, the equilibriums are only a function of the exogenous information, Ω_j, and prices, a, f and w.[9] Once these equilibriums have been determined, it is possible to place the model within the context of this research. In terms of energy substitution, although it was subsumed in the model specification, energy substitution does not necessarily arise in the model, since substitution away from fuel wood toward either dung or crop residues reduces agricultural productivity. For example, if the value of agricultural goods is high enough, relative to fuel wood, households could prefer to focus on agricultural production, while purchasing their fuel wood from the market. Regarding household level responses to fuel wood scarcity, which would imply an increase in the market and shadow prices of fuel wood, households could choose to either work harder to reduce their expenditure on fuel wood (raise the market value of their sales) or cut their energy use to maintain their leisure and/or focus their efforts on agricultural production. Given the many possible household level responses, even within this simple theoretical construct, the impact of fuel wood scarcity on household behaviour is an empirical question, the methodology for which is considered, below.

2.2. Empirical Methodology

In the preceding subsection, we briefly described a simple model of household behaviour, in the face of fuel wood scarcity. That model yielded separate equations for each type of labour and energy included. However, the focus of the empirical research is only on a subset of these equations: labour devoted to fuel wood collection, participation in dung collected and participation in crop residue collection; the initial equations are intuitively subsumed in the three that are estimated.[10]

2.2.1 The Empirical Model

Guided by theory, but constrained by data limitations, the goal of the empirical analysis is to describe: the household level equilibrium allocation of labour to fuel wood collection activities, participation in and collection of dung and participation in collection of crop residue. In the sample, only 42.5% and 35% collect dung and crop residues, respectively.

[9] A more complex model would include a number of other factors and markets, such as home-produced goods, market-purchased goods, which would expand the set of exogenous information, but not change the general conclusions derived in the model.

[10] Unfortunately, the data do not allow us to separate dung used for agriculture (fertilizer) from dung used for energy or crop residues used for agriculture (livestock feed) from crop residues used for energy. Although the available data detracts from our ability to correctly quantify substitution across energy use, it is still possible to consider substitution across energy sources, although dung and crop residue collection in this data are not only collected for energy use.

Theory suggests that each of these equilibriums is determined by preferences, technology, prices, and other exogenous information, and that these equilibriums are interrelated. Therefore, the empirical strategy is based on the estimation of the following equations related to energy production and consumption by the household.

$$y = G_y(X_y, P) \tag{2}$$

In (2), $y = \{F_L, Q_D, Q_R\}$, where F_L, labour allocation to fuel wood collection, was described earlier, Q_D represents the quantity of dung collected, Q_R denotes the quantity of residues collected, X_y represents a vector of observable controls related to preferences and technology, for the outcome considered, while P represents prices, which might be shadow prices or market prices, depending upon the type of energy considered. In principle, equation (2) could be estimated as a system of equations; however, missing data problems, specifically data that is not missing at random, require a circuitous route.

In the sample used, described more fully below, price information is scant. For example, agricultural prices are not available and therefore those prices are ignored in the analysis. Similarly, labour is provided outside of the household for only a subset of households, and, therefore, wage data is missing for some households. Furthermore, a number of households do not collect fuel wood from the commons, such that fuel wood collection time, our measure of fuel wood scarcity, is not available for all households;[11] therefore we follow methodology similar to that proposed by Heckman (1979). Given that these prices are missing in the data, they are estimated and predicted via selection methods, based on (3) and (4).

$$\text{prob}(P > 0) = \Phi(X_P, Z_P) \tag{3}$$

$$P_{P>0} = P(X_P, \lambda_P) \tag{4}$$

In equation (3), Φ represents the cumulative normal distribution, and, thus, is estimated via a probit specification, X_P is a vector of control variables, while Z_P is a variable that affects participation, but is assumed to not affect the actual price, except through participation. From (3), it is possible to calculate the inverse Mills ratio, λ_P, which is included in (4) to correct for selection bias. Predicted values for the entire sample, based on (4), are incorporated into (2) for estimation using all of the available observations.

$$y = G_y(X_y, \hat{P}) \tag{5}$$

Equation (5) includes two generated regressors, and, therefore, the complete estimation process – the estimation of (3) and prediction of (4) for both wages and fuel wood collection

[11] By assumption, based on observation of the study areas, there are no markets for either dung or crop residues.

time, as well as the estimation of (5) – is bootstrapped to generate appropriate standard errors. The non-separability property of the household model implies that the functional form of the reduced form equations (5) cannot be derived analytically (Singh et al., 1986). Therefore all functions are assumed to be linear in their arguments.

2.2.2. Prices and Exclusion Restrictions

In empirical work on fuel wood scarcity, there are two types of scarcity measures: physical measures and economic measures. Physical measures, such as the distance from the forest or village level biomass availability, as applied by van `t Veld et al. (2006), control for the household's ability to directly access forests. Dewees (1989) and Cooke et al. (2008), however, argue that physical measures may not be a reliable indicator, since labour shortages are often more important for household fuel use decisions than physical scarcity of fuel wood. Therefore, the opportunity cost of the time spent collecting may be a better measure, although it is often unobservable. Two common proxies for the opportunity cost are exemplified by Cooke (1998a, 1998b), who uses the wage rate multiplied by the time spent per unit of environmental good collection, as her measure of scarcity, and Mekonnen (1999), who uses the marginal product of labour in energy collection multiplied by the shadow wage. In the absence of markets, household response to fuel wood scarcity can be assessed through the impact of non price variables on fuel consumption (Heltberg et al., 2000). Therefore, in line with Heltberg et al' argument, we use the time spent per unit of fuel wood collected (measure as hours/kg of fuel wood collected), as our measure of fuel wood scarcity. This better reflects the time cost of gathering fuel wood from the forest.

For households collecting from the commons, it is possible to observe our measure of the fuel wood shadow price. For those not collecting from the commons, on the other hand, it is necessary to predict those values, since they depend on either their own sources or market sources. However, it is not possible to calculate the shadow price of dung and residue collection, as households in the sample collect these energy sources from their own fields; a market for these goods does not exist. Fuel substitution possibilities between fuel wood, dung and residues, are examined via the magnitude and sign of the shadow price of fuel wood (as measured by hours per kg of fuel wood collected from the commons) on the production and consumption of both dung and residues, as measured by participation in collection activities. However, estimation of the economic scarcity, due to missing data problems, requires an exclusion restriction. We use a physical indicator of scarcity, in the form of biomass availability from a GIS survey, as our exclusion restriction.[12]

Also, in the data, only a limited number of households earn income from off-farm activities, such that market wages are not observed for the entire sample. Therefore, we also estimate and predict the opportunity cost of labour, following selection methods (Heckman, 1979).[13]The primary exclusion restrictions for participation in off-farm labour activities include measures of farming activities, such as livestock and land holdings, as well as non-labour income, such as remittances. Larger farms are expected to require greater labour inputs, and, thus, reduce the likelihood that any member of the household works off the farm.[14] Furthermore, actual farm-size should not affect wages in the labour market. Finally, less than half of the sample collects either crop residues or dung; therefore, the quantities collected are also estimated via sample selection methods. The primary exclusion restriction for these quantities is household knowledge of the rules governing forest use.

2.2.3 Analysis Variables and Expected Effects

Although the main interest in the analysis is the effect of fuel wood scarcity on household behaviour, other household and community level variables are expected to affect behaviour, and are, therefore, included. As already discussed, the off-farm wage rate, measures the opportunity cost of household time, although the marginal product of agricultural labour is also common in the literature (Skoufias, 1994; Jacoby, 1993). It is expected that higher opportunity costs reduce household fuel wood and other energy collection activities. The other price, collection time per unit of fuel wood, which is an additional measure of the opportunity cost of time (in fuel wood collection activities) is also expected to affect behaviour. Higher opportunity costs should reduce fuel wood collection efforts; however,

[12]Households located farther from town are more likely to collect fuel wood from communal forests, while households with more educated heads, greater forest access and are located farther from markets are less likely to collect from communal forests. Time spent collecting, on the other hand, is higher for households located farther from markets, but is lower for households with knowledge related to the rules governing forest use, and for households, whose head, has ever been a member of an organization. Although there is a negative selection effect, the effect is insignificant. The results are presented in Appendixes B and C.

[13] For more information on the estimation of Heckman sample selection model and the marginal effects, see Greene (2003, pp 780-787).

[14]Off-farm labour participation is negatively associated with land size and livestock ownership. Participation is positively with the Amhara and Tigray regions. Education also increases the probability of participating in off-farm labour activities. The number of children below 5 reduces participation, although not significantly so. Furthermore, average schooling (positively), distance to town (negatively) and the number of male members of the family (negatively) are all significantly related to the off-farm wage rate. The participation and wage regression results are presented in Appendix B

higher costs of fuel wood collection could either increase or decrease efforts related to collecting other energy sources, depending on the degree of substitutability. Van `t Veld et al. (2006) find that higher opportunity costs lead to substitution towards lower quality energy sources, while Mekonnen (1999) finds that fuel wood and dung are complements.

In an effort to control for preferences and technology, a number of household characteristics are also included, such as: the age, sex and education of the household head. Each is expected to reduce household collection activities. Households with younger heads are more inclined to participate in other activities and, hence, have less time available for fuel collection. Increased education is expected to increase the opportunity cost of time, thus reduce collection efforts. Educated households have greater access to either private sources, and are observed to purchase from the market. Similarly, educated households are more likely to understand the importance of dung and residues, as a fertilizer, in the production of agricultural activities. Children in the household, measured by the number of children below the age of five, is expected to reduce all labour inputs, since it is more difficult to leave young children unattended. However, a greater number of older household members increases labour supply, and, thus, is likely to increase all labour inputs. Similarly, older children would be able to attend to younger children, allowing other household members to work. However, it is also true that larger households are expected to require more energy for household activities, such as cooking and heating. Additional variables include a measure of forest access – greater access lowers the cost of collection activities – and forest management institutions – tighter control over forests is expected to increase the cost of collection activities.

As an indicator for household wealth livestock ownership, land holdings and non-labour income are also included. Relatively wealthy households are expected to consume smaller quantities of traditional biomass fuels. According to the energy ladder hypothesis, as income increases households will shift to better energy sources, such as: kerosene, LPG and electricity. However, given the limited availability of these alternative sources, the energy ladder hypothesis does not hold much traction in the rural Ethiopian context; instead fuel-stacking behaviour could be more relevant.[15]However, it should also be noted that livestock holdings should increase the availability of dung. Similarly, land holdings are likely to

[15] The discussion of the fuel-stacking behaviour of rural households is not the interest of this study. Masera et al. (2000) critiques and provides an alternative to the energy ladder hypothesis.

increase the availability of crop residues, although households with large land holdings have more agricultural production and require more dung and residues for fertilizer.

The impact of variables related to forest stock, level of biomass, forest access and local institutions are also assessed in the analysis. The forest stock, measures the number of people per hectare of forest, and is included to account for forest quality. Population density measures the number of people per hectare of the village, to account for local area demand. Biomass availability is a more accurate combination of forest stock and population density. It is measured as the amount of biomass per hectare of forest per capita; it is more accurate because the numerator is taken from a GIS survey. Reduced forest stocks and increased densities are expected to decrease the marginal product of fuel wood collection labour inputs, which could increase or decrease collection efforts depending upon whether or not the household needs to satisfy a minimum energy requirement and the ability of households to substitute across energy sources. Finally, local level institutions are included to account for the level of protection accorded to the commons within the community. Although the data is not complete, we create a dummy variable indicating household awareness of government rules related to forest use. Greater awareness is expected to reduce fuel wood collection labour inputs, and, assuming substitutability across energy sources, increase the collection of dung and crop residues.

3. STUDY AREA AND DATA

The data arises from a survey conducted under the auspices of the "Household Forest Values under Varying Management Regimes in Rural Ethiopia" project.[16] Data was collected from four regions in the country, namely: Amhara, Oromiya, Tigray and Southern Nations, Nationalities and People's (SNNP) regions. Within those regions, a total of ten Woredas were chosen purposively: three from Amhara, three from Oromiya, three from SNNP, and one from Tigray.[17] The current sustainable land management program (SLM) in the country

[16] Individuals with extensive fieldwork experience were chosen to supervise the data collection efforts, while the enumerators were selected, based on their experience in a similar survey; enumerators received three days of training before entering the field; the entire process was monitored.
[17] Woreda is an administrative division of Ethiopia managed by a local government, which is equivalent to a district. Kebele, or peasant association, is the lowest administrative unit. A woreda is composed of a number of kebeles.

informed site selection.[18] One of the goals of site selection was variation in forest cover, agro-ecology, and local level institutions, and, therefore, four kebeles were selected from each Woreda, two from within and two from outside the SLM programme. Therefore, the total number of sample sites is 40. The households to be surveyed were obtained from household lists available from the Kebele administration offices; 15 households were selected from each kebele, yielding a total of 600 households to be interviewed.[19]

The survey data includes information on household characteristics, health and social capital, consumption and production of various agricultural products and market purchased goods, labour allocation towards various agricultural products and market purchased goods, labour allocation related to various agricultural and non-agricultural activities, information on credit markets, the household's perception of forest values, rules and regulations, forestry programs and questions related to valuations and household time preferences. In addition to the household level survey, focus group discussions were held at each sample site for purposes of gathering villagers' attitudes and perceptions regarding forest management rules and regulations, use of technology, and other relevant information. In addition to the primary (survey) sources, field visits were undertaken to gather information about the study sites at the grassroots level, including information on local forest types, watershed area, area of Woredas and kebeles, the woreda and kebele populations, the location and type of farming system and related information.

3.1. GIS Data

One of the major advantages of this study is the availability of GIS information. Specialist foresters, GIS experts who can integrate aerial photographs with ground-level forest and vegetation information to create a measure of forest cover, collected the GIS data. Information from the GIS survey, such as forest cover, total area of each sample site, and total biomass availability in each site are incorporated in the analysis.[20] From the forest cover data, we were able to identify and classify study sites into two groups: relatively high forest

[18] The Ministry of Agriculture and Rural Development of Ethiopia runs the program, which is funded by external donors such as the World Bank and the Global Environment Facility Trust Fund.

[19] The first household in the kebele was selected randomly from the list, while the remaining households were chosen systematically; For example, if there are 150 households in the kebele, then the first households is chosen randomly. In other words, if the 4th household on the list was randomly selected, the 14th, 24th, and so on, households were chosen until 15 households were included.

[20] One of the project team members undertook the Biomass estimation. The Biomass regression equations he used for estimating the biomass of tropical trees is based on Brown et al. (1989) and Brown and Iverson (1992)

cover (HFC) and relatively low forest cover (LFC), the latter of which is often referred to as a degraded area in what follows. Households living in areas where the forest cover is less than 30% of the total area are classified under LFC, while households living in areas where forest cover exceeds 30% are classified as HFC. Accordingly, 62.1% of the sample households belong to the LFC and 37.9% reside in HFC regions.[21] Figure 1 outlines forest cover (in %, obtained by dividing total forest area by the total area of the kebele) and total biomass (in tons) for each of the kebeles. Unfortunately, forest cover data was not available in Mustembuay, Yelen, Gosh Beret and DebreTsehay, due to the lack of satellite imagery. However, that information gap was filled from community survey estimates.

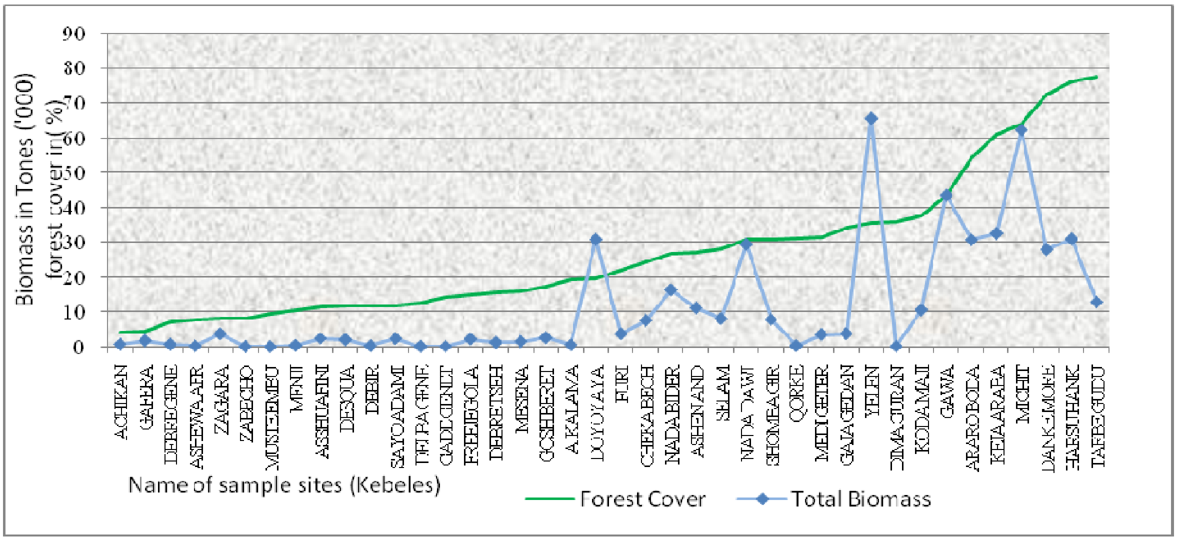

Figure 2.1. Forest Cover (%) and Total Biomass (in tons) for each Kebele

3.2. Energy Use

Modern fuels including electricity are not common sources of household energy in these study regions. Instead, most energy sources (dung, crop residues and fuel wood) are obtained from own fields, natural forests and state or government forests. Very few households, only 4.5% in the sample, purchase fuel wood. However, nearly all households collect either dung or crop residues for own consumption, while all households collect and consume some fuel wood, as part of their energy requirement. Approximately 48% of the sample households

[21] Sample site forestry cover ranges from 65 to 4613.74 hectares, while the forest coverage proportion ranges from 3.9% to 77.4%. On average, sample sites are 26.9% forest. Though there are many ways of classifying forests (for example, low, medium and high forest cover), we prefer to divide the sample in to two. As the sample size decreases, it will reduce the statistical power of a test. As a result, we chose 30% arbitrarily since our objective is to see whether households behave differently in different forest conditions.

collect their fuel wood from commons, while 42.6% and 35% of the sample households are collecting/using dung and crop residues for energy, respectively.

Energy in Ethiopia is primarily used for cooking, heating and lighting. *Injera*, traditional pancake-like bread, requires baking, which is the most energy consuming activity in Ethiopia in both urban and rural areas, and that baking is primarily undertaken through the burning of fuel; other biomass energy sources, such as dung and crop residues, are less preferred sources of energy for household cooking (Zenebe, 2007). However, the nature of the relationship between fuel wood and dung and crop residues is still an empirical issue. These biomass energy sources have other alternative uses. Households use biomass, primarily dung, as a fertilizer and, primarily crop residues, as livestock feed. Biomass is also used for construction purposes; crop residues are common roofing materials, while dung is commonly used for floors and walls.

We expect that increased availability of fuel wood would release dung and residues for these other non-energy purposes. However, about 48% of the sample households responded that they would not reduce their dung consumption, even if more fuel wood became available, while others reported that they would increase their usage of dung, if more fuel wood became available. Survey responses of this nature provide some indication of the difficulty faced by policymakers, as the responses suggest that supply-side strategies, alone, are not likely to effectively address rural energy shortages or reverse the decline in agricultural productivity resulting from the diversion of dung and crop residues for energy needs (IFPRI, 2010). Until there is an increase in alternative energy sources or improvements in the efficiency of, especially, cooking technology, the dominance of biomass energy resources will continue into the foreseeable future in Ethiopia. Therefore, it is necessary to understand the manner in which households use the available energy sources, and design ways to sustainably manage the available resources.

3.3. Descriptive Statistics

Table 2.1 presents a summary of the descriptive statistics of the explanatory variables used in the empirical analysis. The summary is presented for two categories (based on forest cover status), separately. A simple comparison of these statistics suggests large differences between the two groups across a number of variables. For example, average land size and livestock holdings are higher in the relatively high forest cover (HFC) areas, while non-labour income in the form of gifts, remittances and aid is higher in the relatively low forest cover (LFC) areas of this sample. The forest stock, measured as the total number of people per hectare of forest, is 24.82 and 2.78 persons per hectare of forest for the LFC and HFC areas, respectively. By definition, our measure of forest access, the number of people in the community per hectare of the kebele area, is higher in the LFC. Similarly, there is a significant difference between LFC and HFC areas in terms of biomass availability. The mean values of forest stock, forest access, and the level of biomass for the LFC clearly indicates that it is highly degraded compared to HFC. Other individual and household characteristics such as the gender of the household head, the education level of the household head, family size, the number of male and female members 10 years old or older, and the number of children whose age is below 5, are more or less the same in the two groups, suggesting that the sampling strategy was reasonable, and that the analysis should be able to detect differences in household behaviour that can be attributed to biomass availability.

Table 2.1. Summary of Descriptive Statistics by Forest Status

DESCRIPTION	LFC (N=368)	HFC (N=224)	TOTAL (N=592)	Difference in means

Variable	Mean (μ_0)	S.D.	Mean (μ_1)	S.D	Mean	S.D.	$(\mu_0 - \mu_1)$
HOUSEHOLD LEVEL VARIABLES							
Age(Age of the HH head)	45.43	11.98	46.08	13.87	45.68	12.72	-0.650
Sex(Sex of the HH head; 1 if male, 0 if female)	0.91	0.29	0.91	0.29	0.91	0.29	0.004
Educhead(Education of HH head; 1head can read and write, 0 otherwise)	0.48	0.50	0.53	0.50	0.50	0.50	-0.047
livestock (Livestock ownership in tropical livestock unit, TLU)	4.45	2.80	6.24	4.83	5.13	3.80	-1.786***
landha(land size in ha)	1.37	0.97	2.62	2.11	1.84	1.62	-1.249***
Family_adeq(Family size in adult equivalent)	5.70	1.97	5.80	2.29	5.74	2.10	-0.107
Male10(Number of male members age ≥ 10 years)	2.31	1.29	2.31	1.40	2.31	1.33	0.000
Female10(Number of Female members of HH age ≥ 10 years)	2.15	1.08	2.20	1.28	2.17	1.16	-0.050
Child5 (Number of children ≤ 5 years)	1.08	0.93	1.24	1.12	1.14	1.01	-0.155**
Nonlabor(Amount of non labour income in Birr)	311.05	1044.8	168.85	726.9	257.2	939.2	142.20**
Avschooling(Av. schooling level of the family; years of schooling divided by No. of family members above 6 years old)	3.88	2.28	3.57	2.01	3.77	2.19	0.309**
VILLAGE LEVEL VARIABLES							
Forest_acess(Number of people/ HA in the kebele)*	2.81	2.79	1.35	1.16	2.26	2.42	1.46***
Forest_stock(Number of people/ HA of forest)	24.82	24.67	2.78	1.72	16.48	22.22	22.04***
Bio-hh (Biomass availability per household (Kg/ha/hh)	12.18	13.65	49.56	70.87	26.32	48.37	-37.37***
govt_rules(Dummy =1,if a HH is aware of government rules, 0 otheriwse)	0.48	0.50	0.53	0.50	0.50	0.50	-0.05

*Information for 4 sample sites (Mustembuay, Yelen, GoshBeret and Debretsehay) was obtained from villagers estimation (no information from spatial data).

The primary outcome variables of interest in this analysis – labour inputs and the total collection of three types of biomass energy – are summarized in Table 2.2. In order to calculate the values in the table, data on conversion factors were collected from each district for each type of fuel, for each type of forest product and for each type of agricultural product. The quantity of fuel wood, dung and residues were recorded using local units, and later converted into standard weight measures, kilograms. The data is based on annual figures, since all biomass energy sources are collected throughout the year. In particular, the data on number of trips per week (by each member of the family) to collect each type of biomass fuel were asked of the household. A follow-up question related to the amount of biomass fuel collected per trip was also asked. Since the amount of biomass collected may vary between seasons for some households, the same questions were asked for both the summer season and the winter season. The total quantity (per season) was calculated as the product of the number of trips per week and the amount of biomass collected per trip, while the sum across the seasons yields the total quantity. Given that no labour is hired for collection, such that family members collect all of the biomass, a household based summation is an appropriate measure of total collection.

Table 2.2: Descriptive statistics of labour supply and production of biomass energy sources

	N	Mean	S.D.	Min	Max
Annual time(hrs/year)					
Total time fuel wood	577	302.58	342.59	6.07	3796
Total time dung	252	107.31	170.47	2.60	1534
Total time residues	206	152.37	196.23	1.73	1560
Annual Quantity (kg/year)					
Quantity of fuel wood collected	577	2303.39	1542.01	273.00	10920
Quantity of dung collected	252	1919.61	1967.68	145.60	15600
Quantity of crop residues collected	206	1315.07	1320.08	22.75	10400

*The number of observations (N) refers to those households who participated in collection of the fuel.

4. REGRESSION RESULTS

The main objective of the study is to analyse rural household responses to fuel wood scarcity, as measured by collection time per unit of fuel wood collected (in hours/kg). The study emphasizes the time allocation decision of rural households, testing whether or not households shift towards other traditional biomass energy sources and/or increase their time allocation towards fuel wood collection, when faced with firewood shortages. The analysis is based on the estimation of labour allocated to fuel wood collection, the quantity of dung produced and the quantity of crop-based biomass residues produced. Each of these equations are estimated as functions of the quality of the local forest cover available to the households, as well as a number of household level controls, including the off-farm wage; however, since many households do not have members working outside the household, the wage must be estimated for these households. Furthermore, as many households also do not make use of the commons to collect firewood, the shadow cost of fuel wood collection was also estimated for these households.

4.1 Labour Allocated to Fuel Wood Collection

Unlike other studies related to rural energy, we were able to classify study areas based on forest cover using GIS information, allowing us to consider the possibility that forest cover affects the quantity of labour allocated to fuel wood collection. The household labour allocation towards fuel wood collection was estimated separately for degraded forest areas (LFC), and less degraded forest areas (HFC). A Chow test for pooling across this measure of forest cover was also applied, and the results rejected the hypothesis that the estimates could be pooled, at a one per cent confidence level ($F_{(16, 545)} = 2.04$, p-value = 0.0001).

Table 2.3 presents the regression results of fuel wood collection labour inputs for the LFC, HFC and pooled samples, where the labour input is measured as the natural log of total household time, in hours, allocated to fuel wood collection. In line with many similar studies, the shadow price (collection time per kg of fuel wood collected) in the pooled regression is positive and statistically significant at the 5% level.[22] For households in close proximity to degraded forests, the shadow price is positive and significant at the 10% level; however, for households living near higher quality forests, the shadow price is not a significant determinant of total collection time. Therefore, as forest resources become increasingly scarce in an already degraded area, rural households respond by increasing total fuel wood collection time. Any attempt to generalize the responsiveness of demand or production of fuel wood to increasing forest scarcity, without taking into account the forest status of the study area, therefore, would be misleading.

The impact of community level variables related to forest stock, forest access and local institutions are also included in order to examine their influence on fuel wood collection. In the analysis, forest access, as measured by population density, is positively and significantly correlated with fuel wood collection time in LFC areas, but the correlation is insignificant for HFC areas. This result is similar to Heltberg et al. (2000), in that households respond by increasing their collection time in areas where population density is relatively high. Similar to

[22] The results for the participation regression equations for predicting the time spent collecting fuel wood are presented in Appendixes B and C, respectively.

both Heltberg et al. (2000) and Palmer and MacGregor (2009), we find that forest stock, measured by the number of people per hectare of forest, is negatively correlated with the time spent collecting fuel wood in the pooled regression. We find a similar result in the HFC regression, but there is no significant influence on LFC households. In terms of the community level knowledge dummy variable, we find that households that are aware of forestry rules and regulations undertake significantly more hours to collect fuel wood in the pooled regression, although it is not significant in either the HFC or LFC regions.

Household characteristics, such as age, sex and the education level (except for the HFC) of the household head have no impact on fuel wood collection labour inputs, irrespective of the status of forest cover. In contrast to Heltberg et al. (2000), the number of female household members aged 10 years old and older was found to be an insignificant determinant of fuel wood collection time. The number of children is also insignificant in both the HFC and LFC regions, although it is positive and significant for the pooled regression. In contrast, the number of male household members negatively impacts collection time in LFC regions, although the relationship is insignificant within HFC regions and for the pooled sample.

Table 2.3: Regression – Labour Input to Fuel Wood Collection (from all sources)

	POOLED	HFC	LFC
Variable	Coef	Coef	Coef
Collection time	3.963**	3.817	5.704*
	(2.25)	(5.97)	(3.57)
Wage rate (predicted)	-0.652**	-0.005	-0.422
	(0.35)	(0.76)	(0.36)
Age of HH head	-0.152	-0.384	0.114
	(0.24)	(0.34)	(0.31)
Sex of HH head	-0.050	0.045	-0.093
	(0.17)	(0.26)	(0.21)
Education of head	-0.081	-0.272*	0.029
	(0.11)	(0.21)	(0.18)
Land size in hectare	0.429***	-0.107	0.702***
	(0.15)	(0.26)	(0.25)
Livestock ownership in TLU	-0.144	-0.104	-0.093
	(0.12)	(0.16)	(0.15)
Government rules	0.261***	-0.008	0.257
	(0.11)	(0.72)	(0.24)
Amount of Non-labor income	0.000**	0.000*	0.000
	(0.00)	(0.00)	(0.00)
Number of children under 5	0.104**	0.067	0.079
	(0.05)	(0.08)	(0.07)
Number of male members above 10 years	-0.056	0.034	-0.104*
	(0.06)	(0.07)	(0.07)
Number of female members above 10 years	0.013	0.029	-0.021
	(0.05)	(0.07)	(0.06)
Forest access	0.112***	0.056	0.103***
	(0.03)	(0.26)	(0.04)
Forest stock	-0.009***	-0.173*	-0.004
	(0.00)	(0.11)	(0.00)
Biomass availability	0.002**	0.003**	0.015**
	(0.00)	(0.00)	(0.01)
Constant	6.266***	6.516***	4.001***
	(1.18)	(2.64)	(1.54)

*The numbers in brackets are bootstrapped standard errors. *, **, and *** represents significance level at 10, 5 and 1%, respectively. The dependent variable is the log of the total household annual labour time (in Hours) allocated to fuel wood collection. Livestock (in TLU), land (in ha) and Age are in log form. Variance inflation factors were considered for multicollinearity; all were under 5, and deemed acceptable. HFC and LFC represent the relatively high forest cover and low forest cover regions, respectively.

The impact of wealth indicators, such as land and livestock on time use and the impact of non-labour income on time use, were also considered. Contrary to Heltberg et al. (2000), but similar to Chen et al. (2006), land holdings are positively related to labour inputs in both LFC and pooled regressions (but not in HFC regions). Since the dependent variable (total annual time spent for fuel wood collection) and land size are in log-log form, the estimated coefficient can be interpreted as an elasticity. As such, a 10% increase in land size is associated with a 7% increase in total collection time for LFC households. Similar to Heltberg et al. (2000), livestock ownership has no significant impact on fuel wood collection time. The effect of non-labour income is positive and significant for HFC households. The effect of the opportunity cost of time is also examined by considering the effect of the predicted wage rate on the fuel wood collection time. As expected, higher wages, or higher opportunity costs of time, result in reduced fuel wood collection time in the pooled regression. However, the results are statistically insignificant when we consider the level of forest degradation.

The elasticity estimates show that an hour increase in collection time per kg of fuel wood results in a 5.7 % increase in total household fuel wood collection time in LFC areas, while the pooled result implies an increases of about 4%. Heltberg et al. (2000) find that a 10% increase in collection time per unit of fuel wood results in an 8.9% increase in labour time for fuel wood collection in rural India. The pooled results are also in line with those of Kumar and Hotchkiss (1988), Amacher et al. (1993), and Palmer and MacGregor (2009).[23] However, none of the previous studies are able to describe the difference between households living in close proximity to either highly degraded or less degraded forests. Intuitively, labour input is expected to be less elastic when considering the production of basic commodities; however, in the face of increased degradation, some substitutes become more plausible, raising the observed elasticity.[24]

This study is also different from other studies, with the exception of studies by van `t Veld et al. (2006) and Bandyopadhyay et al. (2006), in that it incorporates information on biomass availability obtained from GIS data. According to van `t Veld et al. (2006), per capita biomass availability is an exogenous physical measure of firewood availability. This, however, may not truly reflect the physical scarcity of firewood, as a few large trees may yield significant biomass. In contrast to van `t Veld et al. (2006), our estimation results show

[23] We cannot calculate elasticity directly. However, the value of the elasticity based on Heckman estimates without bootstrapping yields an elasticity estimate that is smaller than that of Heltberg et al. (2000).

[24] A simple descriptive analysis of the responses of surveyed households with regard to their coping mechanisms to fuel wood scarcity supports this finding. More than 44% of the sample households responded that they increase their collection time, when there is a shortage of fuel wood. Others (21%) reduce consumption. The literature also confirms the negative and small own-price elasticities, implying that households respond to increases in shadow prices by reducing their consumption (see for example, Cooke, 1998a and 1998b; Mekonnen, 1999; Helberg et al., 2000 and Palmer and MacGregor, 2009).

that biomass availability is positively correlated to total fuel wood collection time. Van `t Veld et al. (2006) find that higher biomass availability in a village increases the use of commons resources, but does not affect the time spent collecting.

4.2 Other Biomass Production and Consumption Activities

As previously uncovered, the fuel wood labour input elasticity is affected by the quality of the forest cover accessible by these households, and the results suggest that households in highly degraded forests must either increase their labour input further or cut their fuel wood consumption or turn to other sources of energy. In Table 2.4, we report the total production function of dung and residues, because the Chow test fails to reject the null hypothesis that the coefficients are the same in both equations (LFC vs HFC areas) for dung, though it is different for crop residues. Note also that only 27 households participated in the fuel wood market. Of these, 12 households collect fuel wood from private or common sources, while the rest depend on purchased fuel wood only. Because of the small numbers of market participants, we do not distinguish between collecting and purchasing households, as was the case in Palmer and MacGregor's (2009) Namibian study.[25]

In order to examine the effect of fuel wood scarcity on the consumption of other biomass energy sources (dung and crop residues), selection regressions of dung collection and crop residue collection activities was also undertaken.[26] The sign and significance of the fuel wood shadow price in the dung and residue functions suggest the nature of the relationship (substitutability or complementarity) between these two types of biomass energy sources and fuel wood. Here the results are not statistically significant.

Table 2.4: Heckman Estimates of Dung and Crop Residues Collection

[25] Substitution from private trees, dung and residue consumption, and market purchase account for only a small proportion of coping mechanisms for fuel wood shortages in our surveyed households, and, thus, these are ignored in the analysis.

[26] Results for the participation component of the selection regressions are presented in Appendixes D and E for dung and crop residues, respectively. Higher wages and larger family sizes increase the probability of dung collection, while greater land holdings, greater forest access, greater biomass availability and higher average schooling levels in the household reduce the dung collection participation probability. The crop residue participation probability is higher for male-headed households with greater land holdings and greater forest access, but it is lower for larger livestock holdings, greater forest stock, and better knowledge of the rules governing forest access.

	DUNG	RESIDUE
Variable	Coef	Coef
Collection Time	1.359	-2.808
	(3.37)	(4.43)
Wage rate(predicted)	0.236	0.126
	(0.43)	(0.41)
Education of head	0.253**	-0.029
	(0.13)	(0.20)
Sex of HH head	-0.333**	-0.173
	(0.20)	(0.33)
Amount of Nonlabor income	0.000**	0.000**
	(0.00)	(0.00)
Livestock ownership in TLU	0.081	0.137
	(0.13)	(0.17)
Land size in hectare	0.201	-0.007
	(0.19)	(0.24)
Family Size in Adult equivalent	0.069**	-0.006
	(0.04)	(0.05)
Forest Stock	-0.002	0.013*
	(0.00)	(0.01)
Forest Access	-0.009	-0.189***
	(0.04)	(0.07)
Average schooling level of the family	-0.066**	-0.051*
	(0.03)	(0.04)
Inverse mills ratio	0.023	-1.027***
	(0.19)	(0.37)
Constant	6.163***	8.426***
	(1.32)	(1.53)

The numbers in brackets are the bootstrapped standard errors. The dependent variables of the regression equation are collection of dung and crop residues in kg per annum (in log form), land size and livestock are also in log form. The numbers in brackets are the bootstrap standard errors. *, **, and *** represents significance level at 10, 5 and 1%, respectively.

Based on intuition, we expect that biomass availability affects participation, but has no independent effect on the total quantity. Furthermore, a variable indicating awareness of government rules related to forest use should determine participation, but not the total quantity of collected biomass, and, therefore, this variable represents another exclusion restriction. Based on simple Heckman estimates, the Wald test of independent equations rejects the null hypothesis of no correlation between the two disturbance terms (in the outcome equation and selection equation) at a 1% level of significance. Hence, the selection model is appropriate and should be used to avoid inconsistency in the parameter estimation.

As suggested earlier, degradation could affect substitutability, and, hence, influence either the participation elasticity or the production elasticity, given participation. We consider these possibilities by including various measures of forest accessibility in the regressions. Our results suggest that increased forest stocks (people per hectare of forest) are associated with reduced participation in residue collection activities, but positively and significantly affect the amount of residues collected, given participation; however, there is no influence on either dung collection participation or collection, given participation.[27]We further find that an increase in forest access (people per hectare of kebele area) increases the probability of participating in residue collection, but is negatively correlated with the amount of residue collected, given participation. Finally, participation in dung collection is reduced when forest access (people per kebele hectare) rises, while the total dung collection quantity, given participation, is not affected by population density in the area. Given that approximately 50% of households use dung and fuel wood at the same time, it is not all that surprising that forest degradation is not strongly correlated with dung participation or total collection. Furthermore, the small and highly fragmented nature of per capita land size in highly populated regions explains the relationship between forest access and residue collection activities. Intuitively, agricultural production, which provides residues as a by-product, in these areas is also small; thus, although more households participate, there is less opportunity to collect.

Since larger family size implies greater demand for energy sources, we find that it does increase the likelihood of participating in dung collection activities as well as the quantity of dung collected. However, it does not have a significant effect on either the participation decision or the quantity of crop residues collected. Unexpectedly, the education level of the household head is significantly and positively related the amount of dung collected for fuel. However, the average education level of the whole family is negatively related to the probability of collecting dung and the amount of dung collected. Land holdings are negatively related to the decision to collect dung, but positively related to the decision to collect crop residues. The quantities of dung and crop residues collected are not affected by the size of land holdings. Amacher et al (1999), using land holding as a proxy for income, finds that larger (and wealthier) households consume less residues, leading them to conclude that residues are inferior goods for the rich. On the contrary, we find an insignificant relationship between livestock ownership and the quantity of both dung and residues

[27] Heltberg et al. (2000) finds a negative relationship between forest stock and private fuel consumption, while Palmer and MacGreger (2009) find a negative relationship between forest stock and dung collection.

collected, given participation. In other words, as opposed to the energy ladder hypothesis, dung and residues are not perceived as inferior goods in this sample of Ethiopian households.[28] We also included the predicted wage rate in the dung and residue collection regression and found no significant influence on the amount of either dung or residues collected.

4.3 Discussion

The literature on the relationship between fuel wood use and dung use, as well as fuel wood use and crop residue use, is mixed. Cook et al. (2008) survey a number of papers in the literature finding evidence of substitution, as well as complementation. For example, Amacher et al. (1993) find evidence of substitution between fuel wood and agricultural residues in one of their survey districts in Nepal. On the other hand, Mekonnen (1999) finds that dung and fuel wood are complements in the Northern highlands of Ethiopia. According to our results, the effect of collection time on the production and consumption of dung and crop residues is insignificant. In other words, when fuel wood is scarce, households in this area of rural Ethiopia do not readily switch to other biomass energy sources. Our results are consistent with analyses from Nepal (Kumar and Hotchkiss, 1988, and Amacher et al., 1993), India (Heltberg et al., 2000) and Namibia (Palmer and MacGregor, 2009).

In this analysis no direct substitution between fuel wood and other biomass energy sources was uncovered, although forest cover and forest access effects do suggest indirect substitution patterns. Furthermore, the availability of more fuel wood (in the form of increased biomass per household) does not necessarily reduce consumption of other biomass energy sources, though it decreases the likelihood of participating in dung, supplementing Mekonnen's (1999) findings that rural households in northern Ethiopia do not use less dung, when more forest biomass is available, due to the complementarity between dung and forest biomass, when it comes to cooking. For policymakers, the implication of this result is that the development of plantations and other measures to increase the supply of fuel wood may not have a significant impact on reducing the demand for alternative energy sources, which, at least from a policy perspective, have higher values in maintaining soil fertility. However, it should be noted that we are not able to separate dung and crop residue use for energy from dung and crop residue use for fertilizer.

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[28] The energy ladder hypothesis states that high-income households reduce consumption of lower quality energy sources (Leach, 1992).

5. CONCLUSION AND POLICY IMPLICATIONS

This paper reports results from an analysis of household survey data collected in rural Ethiopia. The survey was conducted in order to examine rural household coping mechanisms, when faced with fuel wood shortages. The study aimed to address whether households in rural Ethiopia respond to fuel wood shortages by increasing their labour input to fuel wood collection or switch to other biomass sources, which are considered as inferior goods by some scholars. By using information from a GIS survey we have classified our study area into two regions: low and high forest cover areas. Rural household behaviour towards fuel wood was examined separately for LFC and HFC areas, while pooled regressions were considered for the collection or production of other biomass sources, i.e., dung and crop residues.

The results of the analysis suggest that household responses to fuel wood scarcity depend on the status of forest degradation. Households living in a degraded environment respond to fuel wood scarcity, as measured by collection time per kg, by increasing their labour input to fuel wood collection. However, this is not the case for those living in high forest cover areas (HFC). Households in HFC areas respond neither to the physical measure nor economic measure of fuel wood scarcity. For households in HFC regions forest stock (negatively) and biomass availability (positively) may be more important factors than scarcity of fuel wood in determining household labour input allocation.

The analysis also uncovers no evidence of substitution between fuel wood and dung and crop residues. Households do not switch to dung and crop residues when faced with fuel wood shortages. Similar to what has been found in Nepal and Namibia, consumption of other biomass energy sources may not necessarily decrease, when more biomass is available. The implication of our finding is that supply-side strategies, alone, may not be effective if the aim is to reduce forest degradation and biodiversity losses, and simultaneously increase the supply of dung and residues for soil management.

Population pressure in all regions, in general, and in LFC regions, in particular, contribute to forest degradation and a loss of biodiversity, as is easily observed in rural Ethiopia, where encroachments for agriculture and grazing are common. As explained by Heltberg et al. (2000), the underlying factors responsible for forest degradation or deforestation in the area need to be addressed if specific forest policies, such as afforestation and area enclosure establishments, are to be effective at the local level.

Finally, there is a need to make a distinction between forest degraded regions and relatively good forest cover regions, when planning for natural resource management and use by the surrounding people. Further investigation could consider whether the increase in labour input to fuel wood collection, when fuel wood becomes more scarce, comes at the expense of other productive activities, such as agricultural production in forest-degraded regions (Cooke, 1998a and 1998b; Bandyopadhyay et al., 2006). Moreover, it is necessary to identify which members of the household are most affected by fuel wood scarcity in environmentally degraded regions.

CHAPTER III

PROPERTY RIGHTS, INSTITUTIONS AND CHOICE OF FUEL WOOD SOURCES IN RURAL ETHIOPIA

Abstract

This study examines the relationship between property rights, defined by land tenure security, the strength of local-level institutions, and household demand for fuel wood, as measured by the source from which fuel wood is collected. A multinomial regression model is applied to survey data collected in rural Ethiopia. Results from the discrete choice model indicate that active local-level institutions reduce the dependency on community forests, but, otherwise, increase household dependency on open access forests. However, land tenure security and local level institutions do not increase demand for fuel wood collected from private forests. The results suggest that there is a need to bring more open access forests under the management of the community and increase the quality of community forestry management in order to realize improvements in forest conservation.

1. INTRODUCTION

Like many other developing countries, biomass resources such as fuel wood, dung and agricultural crop residues are the most important energy sources in both rural and urban Ethiopia. According to the Woody Biomass Inventory and Strategic Planning Project (2004), over 90% of the country's total energy for household cooking is derived from biomass fuels – 78% from firewood – while 99.9% of the total rural population make use of woody and other traditional biomass resources, such as animal dung and agricultural residues (Zenebe, 2007). Such heavy reliance on biomass energy sources has resulted in serious forest degradation; between 1990 and 2010, Ethiopia lost an average of 140,900 ha - 0.93% of its initial forest coverage area – each year.[29] Given that all major forests in Ethiopia are state-owned, while the government, like those in many other low-income countries, has neither the capacity nor the incentive to properly regulate these forests, such rates of forest degradation may not be that surprising.[30] There is *de facto* open access to all forests, which is expected to aggravate the degradation and deforestation problems in the country.[31] Fortunately, the problem has been recognized and there is keen interest within government to alleviate or reverse the situation, and increase forest cover in Ethiopia.

In April 2007, the Ministry of Agriculture and Rural Development's (MoARD) Forest Development, Conservation and Utilization Policy and Strategy was approved. According to MoARD (2007), one component of the policy is the provision of seedlings and the granting of certificates of ownership to lands designated for forest development. Another policy instrument contained in MoARD (2007) is the continued extension of land tenure security, since tenure security reduces investment risk and should promote increased forest sustainability.[32] The provision of seedlings is one of the supply-side strategies adopted by the current government to reduce the pressure on forests and minimize problem of land degradation, while the granting of certificates harnesses both demand-side and supply-side

[29] See http://rainforests.mongabay.com/deforestation/2000/Ethiopia.htm. Fuel wood collection, together with land clearing for agriculture, overgrazing and other shocks (such as fires) also contribute to the unsustainable use and misuse of forests in Ethiopia.

[30] Mekonnen and Bluffstone (2008) note that the regulation incentive is particularly low in Ethiopia, because forests produce goods used mainly by local villagers.

[31] Forest resource degradation and the misuse of forest resources in Ethiopia, due to the fact that those resources have been primarily state-owned, is one more example of Hardin's (1968) tragedy of the commons.

[32] Modelled on an effort in Tigray during the late 1990s, an initial program on land certification was undertaken in the country's main regions in 2003, with the objective of reducing tenure insecurity and its negative impact on investment (Deininger et al., 2008).

strategies. However, the success of these policies hinges, in part, on whether or not households reduce their demand for fuel wood from, especially, open access forests, when private sources are available, as well as whether or not private ownership and seedlings incentivize better forest stewardship.

Recent Ethiopian studies have focused on the impact of land certification on investment and productivity in agriculture (Deininger et al., 2008; Deininger et al., 2009; Holden et al., 2009, Mekonnen, 2009). Deininger et al. (2009), for example, assess the effects of the low-cost land registration program in Ethiopia on soil and water investment, finding that, despite policy constraints, the program has resulted in increased soil and water related investment. Holden et al. (2009) provide further evidence on the effectiveness of land certification on investment. They use a unique balanced household and plot-level panel dataset covering the five main zones of the Tigray region in northern Ethiopia to assess the investment and productivity impacts of the recent low-cost land certification. Their findings indicate that land certification has significant positive impacts, including improved maintenance of soil conservation structures, increased investment in trees, and increased land productivity. Mekonnen (2009) analyses the roles of tenure insecurity and household endowments in explaining tree growing behaviour in Ethiopia, where farmers cannot sell or mortgage land and factor markets are imperfect. However, Mekonnen used perceived expropriation of land in the five-year period after the survey as an indicator of land tenure insecurity. The results of Mekonnen's (2009) analysis suggest that land tenure insecurity influences the decision to grow trees, but not the number of trees households grow.

Although the initial program has received some attention in the literature, that focus has been on the investment effects of the land certification policy. To date, no study has considered the possible impacts of the program on forestry use, which is the purpose of this research. Specifically, this research seeks to provide empirical evidence related to the determinants of household fuel wood source choices, with a focus on tenure insecurity and local-level institutions.

A number of different fuel wood sources are available in the rural parts of the country. Private trees or farm forests, state or open access forests, community forests, and markets are the major sources of fuel wood and other forest products. In terms of use, the wood supplied from open source forests is mainly used for fuel wood, fencing and construction. However, as previously described, government policy has attempted to provide incentives for better forestry use and to involve local people in the management and use of forests and forest products, leading to the development of community forests. Thus, for the government to achieve its objectives – increasing the contribution of forests to the economic development of the country, maintaining the ecological balance, as well as conserving and enhancing biodiversity through the sustainable utilization and development of forest resources – it is necessary to examine and understand the factors that drive rural households to collect fuel wood from a given source, and, especially, determine patterns of substitution across sources.

Though there are some studies on the relationship between biomass production and property rights regimes in developing countries, the available empirical evidence on household fuel wood source choices is rather limited. Some of these studies, for example, Jumbe and Angelsen (2006), who consider Malawi, show a high correlation between the specific attributes of fuel wood collection sources (such as area, species, distance to the forest, etc.) and the household's choice of fuel wood collection source. Among the three types of fuel wood sources: customary, plantation and forest reserves, in their study, customary forests and forest reserves are substitutes, while substitution is more limited between plantation forests and forest reserves. However, Jumbe and Angelsen (2006) do not examine the role of private sources; markets sources were also not incorporated into the analysis.[33]

Unfortunately, only a few researchers have examined the role of private trees. Heltberg et al. (2000) find evidence of substitution between forest fuel wood and private energy sources (like dung, residues and homestead trees) in India. Based on the findings from India, Nepal, and Ethiopia, Cooke et al. (2008) indicate that private trees and trees in common forests are substitutes in the production of fuel wood for rural households, at least for households owning land. Mekonnen (1999) studies biomass consumption and production in the East Gojam and South Wollo zones of the Amhara region of Ethiopia and concluded that consumption of other biomass energy sources, such as dung and crop residues, will not decrease, when more fuel wood is available.

The available empirical literature focuses on rural energy consumption and production and is geographically limited, with more emphasis on Asia, particularly India and Nepal. Moreover,

[33]Linde-Rahr's (2003) Vietnamese study, which is similar to Jumbe and Angelsen (2006), finds strong substitution between open access and plantation forests.

the available empirical evidence does not emphasize the impact of local-level institutions and tenure security on farmer forestry resource use in Africa. Similarly, Ethiopian studies focus on the role of tenure security on the farmer's long-term investment, with a focus on land related investments, and not on forestry use. Therefore, the purpose of this study is to add to the empirical literature by considering the determinants of household demand, measured by the choice of fuel wood source, focusing on tenure insecurity and local level institutions, providing policy implications related to the management and conservation of forests.

In this study we examine the importance of local-level institutions and land certification on source of fuel wood choices, in order to provide information to policymakers. Our estimation results indicate that active local-level institutions reduce dependency on community forests, but increase the probability of collection from open access areas. However, tenure security does not have impact on household decision to collect fuel wood from private sources. The results from this study provide valuable insight for Ethiopia's current demand-side and supply-side strategies for addressing rural energy problems and halting the unsustainable use and exploitation of those resources. The policy implications, gleaned from the results, are that there is a need to bring additional open access forests under the management of the community and increase local awareness related to the rules associated with forestry management, as well as benefits of improved conservation.

The remainder of the paper is organized in the usual fashion. Section 2 outlines the empirical approach, which is based on the random utility model and its estimation, via the multinomial logit regression. The data and study areas are described in Section 3. Empirical results and a discussion of these results are provided in Section 4, while Section 5 presents concluding remarks.

2. METHODOLOGY

Consider a household choosing between five different possible sources of fuel wood for their energy needs: private (or own sources), community forests, the market, open access forests, or a variety of sources. Households are assumed to select the fuel source option that maximizes their expected utility, and, therefore, the household chooses a fuel source based on their preferences and other factors associated with their options. For the i^{th} household faced with J choices, utility of choice j can be written as:

$$U_{ij} = X_{ij}\beta_j + \varepsilon_{ij} \qquad (1)$$

The preceding structure of household i's utility for choice j is the standard random utility model, where U_{ij} is the utility derived from $j's$ choice of fuel wood source, X_{ij} is a vector of explanatory variables that affect the choice of fuel wood source, ε_{ij} is a disturbance term and β_j is the vector of parameters, coinciding with the variables that are deemed to influence utility for choice j. Assuming that choice j is the preferred fuel wood source, it is assumed that the random utility associated with choice j exceeds the random utility associated with any other choice h that is not j.

$$U_{ij} > U_{ih}, j \neq h \qquad (2)$$

Depending on the distribution of the disturbance terms, various empirical structures can be applied. The analytical model followed here is the multinomial logit regression framework.[34] Therefore, the probability that j is chosen is the probability that the random utility of choice j exceeds that of all other choices.

$$Pr(U_{ij} > U_{ih}) \forall j \neq h \qquad (3)$$

Equation (3) can be further re-arranged, as shown by McFadden (1974).

$$Pr(X_{ij}\beta_j + \varepsilon_{ij} \geq X_{ih}\beta_h + \varepsilon_{ih})$$
$$Pr(\varepsilon_{ih} - \varepsilon_{ij} \leq X_{ij}\beta_j - X_{ih}\beta_h)$$

Let Y_i be the unordered categorical dependent variable that takes on a value of zero or one, for each of the J choices. Assuming that $\varepsilon_{ih} - \varepsilon_{ij}$ has a logistic distribution, the probability for choice of fuel wood source can be specified as:

[34] Because of the need to evaluate multiple integrals of the normal distribution, the probit model has found rather limited use in this setting (Greene, 2003). The logit model, in contrast, has been widely used in empirical research, due to its relative ease of estimation. However, the one drawback of the model is the assumption used to derive its formulation, that all choices are independent of irrelevant alternatives. However, since the dependent variables do not vary across alternatives, IIA is not a significant problem. It is a much bigger problem in the case of conditional logit models, in which there are choice-specific dependent variables.

$$P_{ij} = \frac{\exp(X_{ij}\beta_j)}{\sum_{h=1}^{J}\exp(X_{ih}\beta_h)} \quad (4)$$

Where $X_{ij}$and X_{ih} are case-specific regressors and $\beta_j$and β_h are vectors of coefficients for each fuel wood source. In this model, the regressors do not vary over choices, such that the model is consistent with a multinomial logit regression. Since, $\sum P_{ij} = 1,$ a restriction is needed to ensure model identification. Hence, we set $\beta_J = 0$, so the remaining coefficients can be interpreted with respect to category *J*, the base category. Due to the complex nonlinearity of the multinomial regression model, the estimated coefficients are difficult to interpret. Therefore, interpretation is based upon the marginal effects of the explanatory variables on the probabilities. Marginal effects for the k^{th} variable in *X* are derived as:[35]

$$\delta_{jk} = \frac{\partial P_j}{\partial x_k} = P_j\left[\beta_{jk} - \sum_{h\neq j\in J} P_h\beta_{hk}\right] \quad (5)$$

The marginal effects measure the expected change in the choice probability with respect to a unit change in the requisite explanatory variable. In the case of a binary independent variable, marginal effects are determined by the probability with the binary indicator turned on net of the probability with the binary indicator turned off.[36]

3. DATA SOURCE AND DESCRIPTIVE STATISTICS

3.1. Nature and source of the data

The data for the analysis was collected in 2007 from a sample of rural households in the East Gojam and South Wollo zones of the Amhara region of Ethiopia. This data is part of a longitudinal survey conducted through a collaborative research project between Addis Ababa University and the University of Gothenburg, and financed by the Swedish International Development Cooperation Agency/Swedish Agency for Research Cooperation (Sida/SAREC). The selection of the sites was deliberate, and ensured variation in the characteristics of the sites, including agro-ecology and vegetative cover (Mekonnen, 2009).

[35]For a detailed derivation, see Greene (2003, pp 721-722).
[36] It is possible that the signs of the coefficients and the marginal effects differ, as the latter depends on the signs and the magnitudes of the other coefficients.

Households from each site were then selected randomly.[37] A total of 1760 households from 14 sites were interviewed, as part of the survey.

The data includes information on household characteristics, household perceptions regarding land certification and registration, energy collection and consumption, assets, credit, off-farm activities, the nature and type of forests and other relevant information. More specifically, in this study we have included household characteristics such as the age, the sex and the education level of the household head. We also include family size, household access to credit, land holdings and livestock ownership. Land holdings was originally reported in local units and converted into a standard measure (ha). Similarly, we measure ownership of livestock in terms of tropical livestock units (TLUs). The effect of gender of the household head enables us to examine whether male- or female-headed households are more dependent on private, community, open access or other sources of fuel wood. Access to credit is a dummy variable that refers to whether the household can immediately borrow money from any source (for example, from banks, micro credit institutions, friends, private lenders, etc). It is also clear that efficient use of biomass through improved cook stoves affects the time spent in collection of fuel wood, and, hence, household preferences for different sources of fuel wood. Therefore, a dummy variable denoting ownership of an improved stove is included.

Community surveys were also conducted, which enabled us to use additional information in the empirical analysis. Villagers' perceptions about the use and management of natural resources such as forests, grazing land and water, as well as the use and availability of technologies in local agriculture and land management, the situation regarding infrastructure and services, etc., were gathered during the field survey. This data was then restructured into three community-level variables: a dummy variable for region, allowing us to capture agro-ecological differences; the average distance, in hours, of the kebele (village) from the nearest forest; and a variable indicating the strength of local institutions.

As an indicator of tenure insecurity, a dummy variable, accounting for whether the household has been awarded a land certificate, is included. In addition to the examination of tenure insecurity, we also consider the effect of local level institutions, especially community-level forestry institutions, on fuel wood source choices, using an index constructed from a series of

[37]The sample sites were selected purposively and households from each site were then selected based on simple random sampling technique.

questions related to the household's understanding of the institutions and perceptions of enforcement related to those institutions. Households were asked to rate their perceptions regarding forestry rules and regulations on a five-point scale, which was then averaged to create a household-level index, which is further aggregated across questions and rescaled to remain within the five-point range. Finally, the rescaled index is then categorized as either relatively strong, if the rescaled index is greater than or equal to three, or relatively weak, if the rescaled index is below three.[38] Our expectation is that households, operating within a strong forestry management setting, are constrained in their ability to collect fuel wood from community forests, and, therefore, are forced to make use of other sources. Deininger et al. (2009) used the same data to assess the effects of a low-cost land registration program in Ethiopia, finding that these institutions increased land-related investments. In our analysis, we use the data to determine whether or not the institutions affect the source of fuel wood collection source.

3.2. Descriptive Statistics

The primary interest in this analysis is the location from which households are accessing their fuel wood, which is assumed to be affected by household, community and institutional variables. In the areas in which data were collected, there are a number of different places fuel wood can be gathered or collected. Although the majority of households accessed only one location, there were households that accessed more than one. Therefore, in addition to open access forests, community forests, private forests or market sources, we included multiple sources as a collection option.[39] The source choices, as a proportion of households, are noted in Table 3.1.

Table 3.1: The proportion of households by fuel wood collection source

Source	**Mean**	**SD**
Private Forest	0.723	0.45
Community Forest	0.077	0.27
Open Access Forest	0.086	0.26
Market Source	0.073	0.28
Multiple Sources	0.041	0.20

[38]The lists of the questions used for the purposes of creating this index are indicated in Appendix B. The mean values of each index are indicated at both the household and community level.
[39]Primarily, these are households that used two sources, although a small number of households access more than two sources (only 0.2 % of the sampled households).

As can be seen in Table 3.1, the majority of the sampled households (72.3%) collect their fuel wood from private sources, while 7.7% collect from community forests and 7.3% of the collect from open access (OA) areas. Furthermore, some households satisfy their fuel wood demand from the market (8.6%). As should be expected, most of the households buying fuel wood from the market are those without land or with land holdings too small to both plant trees and grow crops for their livelihood (see Table 3.2, below).

Table 3.2: Summary of Descriptive Statistics of Variables by sources of fuel wood

	PRIVATE (N=1117)		COMM (N=119)		MARKET (N=113)		OA (N=133)		MULTIPLE SOURCE (N=63)	
Variable	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Age of HH Head	52.43	14.46	50.36	15.84	43.35	12.44	50.57	16.17	50.06	14.16
Sex of HH Head (1 if male, 0 if female)	0.84	0.37	0.79	0.41	0.71	0.46	0.73	0.45	0.87	0.34
Education of HH Head(1 if the head has attended any kind of education, 0 otherwise)	0.50	0.50	0.41	0.49	0.56	0.50	0.35	0.48	0.44	0.50
Family Size	6.75	2.37	6.45	2.67	5.49	2.46	6.29	2.40	7.13	2.29
Access to Credit	0.86	0.35	0.91	0.29	0.88	0.32	0.88	0.33	0.87	0.34
Landholdings (HA)	1.35	0.91	1.64	1.19	0.82	0.59	1.04	0.63	1.60	1.20
Distance from town (in hours)	1.21	0.88	1.18	0.70	0.93	1.08	1.64	0.95	1.31	0.83
Uses Improved Biomass Cookstove	0.80	0.40	0.82	0.39	0.81	0.39	0.68	0.47	0.67	0.48
Livestock owned in TLU	4.12	3.04	3.77	2.90	1.86	2.31	3.03	2.69	3.98	3.07
Dummy variable if a HH posses land certificate for his holding, 0 otherwise	0.82	0.39	0.80	0.40	0.67	0.47	0.67	0.47	0.87	0.34
Dummy variable for region (1 if East Gojam, 0 if south Wollo)	0.44	0.50	0.78	0.41	0.48	0.50	0.53	0.50	0.60	0.49
Average distance of forest in hours	2.44	2.18	2.10	1.94	2.67	2.23	2.84	1.94	2.07	1.74
Dummy variable for institutions(1 if it is relatively strong, and 0 if it is weak	0.54	0.50	0.25	0.44	0.61	0.49	0.56	0.50	0.49	0.50

The remaining summary statistics, as well as definitions of independent variables, for the participating households are presented in Table 3.2, by source of fuel wood. Summary statistics that are not separated by source are available in Table 3.3. From table 3.2, it can be inferred that the characteristics of the independent variables vary by collection source. However, given the relative closeness of the means and the size of the standard deviations, across collection source, the calculated means lie reasonably comfortably within two standard deviations of each other.[40] Descriptively, the largest means for the analysis variables are observed within the private source collection group for the age of the household head. For community forest source, the largest analysis variable means are observed for households with access to credit, landholdings and households using improved biomass cook stoves, while the lowest mean is observed for the community forest institutional index. For market purchases of fuel wood, the largest means for the analysis variables are observed for the education of the household head, while the lowest means are observed for the sex of the household head, the size of the family, landholdings, distance to town, livestock ownership, and land certification. The largest analysis variable means are observed for households accessing open forests, for distance to town and for distance from the nearest forest, while the smallest means are observed for the education of the household head and land certification. Finally, within the multiple sources group, the largest means are observed for the gender of the household head, the size of the family and land certification, while the lowest means are observed for the use of an improved biomass cookstove and for the distance from the community forest.

[40]For that reason, it was not deemed necessary to separately test differences in means across the groups. It is, however, possible to test for differences in means, either group by group, or through the application of analysis of variance methods. One-way analysis of variance (ANOVA) is usedto determine whether there are any significant differences between the means of three or more independent (unrelated) groups.Overall there is sufficient evidence that the mean values of most of the explanatory variables are statistically different across the sources of fuel wood (see Appendix C).

Table 3.3. Summary of Descriptive Statistics (N=1545)

Variable Description	Mean	S.D.	Min	Max
Household characteristics				
AGEHH Head	51.35	14.75	15.00	97.00
SEXHH Head	0.82	0.38	0.00	1.00
Education of HH Head	0.48	0.50	0.00	1.00
Family Size	6.61	2.42	1.00	20.00
Acess to Credit	0.87	0.34	0.00	1.00
Landholdings(ha)	1.32	0.93	0.04	6.72
Distance from town (in hours)	1.23	0.90	0.00	4.67
Uses Improved Biomass Cookstove	0.78	0.41	0.00	1.00
Livestock owned in TLU	3.83	3.02	0.00	31.59
Dummy variable if a HH posses land certificate for his holding, 0 otherwise *	0.80	0.40	0.00	1.00
Community characteristics				
Dummy variable for region (1 if East Gojam, 0 if south Wollo)*	0.48	0.50	0.00	1.00
Average distance of forest in hours	2.45	2.13	0.74	9.85
Dummy variable for institutions	0.52	0.50	0.00	1.00

4. RESULTS OF ECONOMETRIC ANALYSIS

The main purpose of the analysis is to provide insights into demand-side effects, as measured by the choice of fuel wood source, of land tenure security and community forestry management institutions, and this was undertaken via multinomial logit regression. The empirical estimation enables us to understand the effects of these variables on household's substitution patterns amongst the various fuel wood sources. The results of the regression are presented in Tables 3.4 and 3.5. Since the estimated coefficients are difficult to interpret, marginal effects are discussed, rather than the parameter estimates.[41]

As noted earlier, Mekonnen (2009) and Deininger et al. (2009) examine the relationship between tenure insecurity and long-term investments in private trees and land, respectively. However, no studies have, yet, considered the impact of insecurity on forest use. Although we expect that greater security will improve land management, as has been previously shown in the literature, it is not obvious that improved management has, yet, led to reduced demand for open access forest products, or increased use of privately owned forests. Our measure of security is based on household answers to a survey question regarding whether or not they

[41]The base category in the regression is private sources of fuel wood, and the results are not sensitive to the choice of base category.

had a certificate for their land. Contrary to our expectation, tenure security is not a significant determinant, in terms of marginal effects, on the use of private sources (although the sign is positive), community sources or the market (although the signs for the latter two are both negative). However, there is evidence that land certification does reduce demand pressures on open access forests – the marginal effect estimate is -3.7% and significant at the 10% level – and does raise the probability that households make use of multiple sources – the marginal effect estimate is 2.3% and is significant at the 5% level.[42] One possible explanation for the limited effect observed in this analysis is that private sources require an initial and sustained investment in forests that has not, yet, led to significantly increased stocks that can be used by households. A less positive explanation, though, is also plausible: security has not impacted investments in private forests enough to alleviate the demand for open forest products for reasons that cannot be observed in this analysis. For example, high levels of poverty could be associated with high discount rates (not available in the study), and high discount rates would lead to low levels of investment. However, given Mekonnen's and Deininger et al.'s findings, the latter explanation is less likely. Regardless, additional empirical research on the role of land certification, farmers' long-term investment decisions and household demand for forest products, by source, may be required to supplement these findings.

Our results also support the hypothesis that stronger community forestry institutions reduce demand-pressures on community forests (-5.7%), while increasing pressure on, especially, open access forests (4.7%) and multiple sources (1.9%). However strong institutions are not significant determinants, in terms of marginal effects, of either private forest use or market purchases of fuel wood. In terms of policy, the unintended consequences of expansion of community forests, in tandem with strong local-level institutional control, will not help reduce the depletion and degradation of forests and forest products, because it diverts households away from community forests, which can be properly managed, towards open access forests. A caveat, however, is necessary. If all open access forests are turned into community forests, and those community forests are properly managed, our results imply that it is possible that forest degradation can be alleviated.

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[42]The land certification coefficient estimate for open access sources is negative and significant at the 5% level, and for multiple fuel wood sources is positive and significant at the 10.5% level.

Table 3.4: Parameter Estimates from Multinomial Logit of choice of fuel wood source

Variables	Community	Market	O.A.	Multiple Source
AGE of HH head	-0.007	-0.034***	-0.012*	-0.018*
	(0.01)	(0.01)	(0.01)	(0.01)
SEX of HH head	-0.235	-0.211	-0.285	0.330
	(0.28)	(0.28)	(0.24)	(0.42)
Education of HH head	-0.342	0.233	-0.674***	-0.445
	(0.22)	(0.24)	(0.21)	(0.28)
Family size	-0.050	-0.039	0.057	0.088
	(0.05)	(0.05)	(0.05)	(0.06)
Access to Credit	0.769**	0.167	0.291	0.016
	(0.34)	(0.34)	(0.30)	(0.41)
Landholdings (ha)	0.029	-0.856***	-0.381**	0.165
	(0.12)	(0.24)	(0.17)	(0.16)
Distance to town (in hours)	-0.274**	-0.509***	0.514***	0.151
	(0.13)	(0.15)	(0.12)	(0.17)
Uses Improved Biomass Cook Stove	-0.111	-0.092	-0.754***	-0.836***
	(0.26)	(0.27)	(0.21)	(0.29)
Livestock owned in TLU	-0.059	-0.333***	-0.126***	-0.105*
	(0.04)	(0.06)	(0.05)	(0.05)
Dummy variable if a HH possess Land certificate for his holdings, o otherwise	-0.101	-0.082	-0.499**	0.740
	(0.33)	(0.29)	(0.25)	(0.46)
Dummy variable for region (1 if East Gojam, 0 if South Wollo)	1.249***	1.117***	0.478*	1.058***
	(0.32)	(0.32)	(0.27)	(0.38)
Average distance of forest in hours	-0.084	0.097*	0.040	-0.064
	(0.07)	(0.06)	(0.06)	(0.09)
Dummy variable for local institutions	-0.853***	0.286	0.716***	0.550
	(0.30)	(0.31)	(0.27)	(0.35)
_cons	-1.411*	1.027	-1.252*	-3.355***
	(0.84)	(0.81)	(0.70)	(1.05)

Table 3.5: The Marginal Effects from Multinomial Logit of choice of fuel wood source

Variable	Private	Community	Market	Open Access	Multiple
AGE of HH head	0.003***	-0.000	-0.001***	-0.001	-0.001
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
SEX of HH head*	0.027	-0.013	-0.007	-0.019	0.012
	(0.03)	(0.02)	(0.01)	(0.02)	(0.01)
Education of HH head*	0.060***	-0.016	0.011	-0.041***	-0.014
	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)
Family Size	-0.002	-0.003	-0.001	0.004	0.003
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Access to Credit*	-0.051*	0.034***	0.004	0.014	-0.002
	(0.03)	(0.01)	(0.01)	(0.02)	(0.01)
Land Holdings (ha)	0.039***	0.005	-0.029***	-0.023**	0.008
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Distance to town (in hours)	-0.005	-0.017**	-0.018***	0.035***	0.005
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Uses Improved Biomass Cook Stove*	0.086***	0.000	0.001	-0.053***	-0.034**
	(0.03)	(0.01)	(0.01)	(0.02)	(0.02)
Livestock owned in TLU	0.022***	-0.002	-0.011***	-0.007**	-0.003
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Dummy variable if a HH possess Land certificate for his holdings, o otherwise *	0.021	-0.005	-0.002	-0.037*	0.023**
	(0.03)	(0.02)	(0.01)	(0.02)	(0.01)
Dummy variable for region (1 if East Gojam, 0 if South Wollo)*	-0.154***	0.068***	0.034***	0.019	0.033**
	(0.03)	(0.02)	(0.01)	(0.02)	(0.01)
Average distance of forest in hours	0.001	-0.005	0.003*	0.003	-0.002
	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)
Dummy variable for local institutions *	-0.019	-0.057***	0.009	0.047***	0.019
	(0.03)	(0.02)	(0.01)	(0.02)	(0.01)

(*) dy/dx is for discrete change of dummy variable from 0 to 1.
Using the correlation matrix and the VIF (found to be less than 5), we found no severe multicollinearity problem.

The remainder of the estimation results examine other potential determinants of fuel source choices, such as those related to various demographic, socioeconomic and environmental factors. Household demographic and socioeconomic characteristics, such as the age, the gender, and the education of the household head, affect the choice of fuel wood source differently. The age and education of the household head significantly raise the probability of fuel wood collection from private sources, but education significantly reduces the probability of collecting fuel wood from open access forests – reducing the probability of collecting from OA areas by 4.1%. Possibly, educated household heads are more aware of the importance of forest conservation and its use in maintaining soil fertility and mitigating against climate change. Household head age and gender reduces the probability of fuel wood purchases from the market, though the latter is not significant, while gender does not significantly determine the choice of fuel wood source. Contrary to Jumbe and Angelsen (2006), household size, in our analysis, has no significant influence on the choice of fuel wood source.

Household economic indicators were also included in the analysis. Household assets affect production capabilities and preferences, and most studies of this nature include some measure of household wealth, such as landholdings (Edmunds, 2002) and livestock ownership. We chose to include two additional measures: credit opportunities (whether the household can immediately borrow money from any source) and the use of improved biomass cook stoves. Regardless of the measure of wealth used in the various studies, each finds that most poor households cannot afford to buy fuel wood from market. Poverty, especially related to total land under control, implies that poor households do not have enough land to enable them to plant trees. Therefore, we expect poor households to depend more on forests owned by government (*de facto* open access) or community forests in order to satisfy their energy demands. Our results show that a one-unit (hectare) increase in land holdings reduces the probability of fuel wood collection from open access forests and the market by 3.4% and 2.9%, respectively. On the other hand, also as expected, a one-unit increase in land holdings significantly raises the probability of fuel wood collection from private sources by 3.9%. Heltberg et al. (2000) draw similar conclusions in their analysis conducted in India – larger landowners collect less fuel wood from the commons and produce more fuel wood privately. Similarly, Cooke et al. (2008) argued that households with little or no land are less able to produce fuel wood themselves. With respect to livestock ownership, the direction of the wealth effect was generally the same as that for land, although the magnitudes were generally lower.[43]Specifically, a one-unit (TLU) increase in livestock ownership was associated with a significant increase in the probability of collecting fuel wood from private sources (2.2%), but was associated with a significant reduction in the probability of collecting fuel wood from open access forests (-0.7%) and a reduction in the probability of market purchases (-1.1%). Improved cook stoves provide qualitatively similar results to both land holdings and livestock ownership. Ownership of these stoves is associated with an increased probability of privately sourced fuel (8.6%), and is associated with a reduced probability of openly sourced fuel (5.3%). Credit opportunities, on the other hand, do not have the same effect as other sources of wealth, possibly because they signal a current wealth shortage, although they might also signal borrowing for investment purposes. We find that credit access reduces the probability of using private sources by 5.1%, but raises the probability of accessing community forests for fuel wood by 3.4%.

In addition to the preceding set of variables, a number of location-specific variables, such as the household's distance to the nearest town and distance to the nearest forest, as well as a region-specific dummy variable were also included in the analysis. As most markets are located in or near towns, it is not surprising that the distance to town reduces the probability of fuel wood purchase from the market by 1.8% per unit.[44] Similarly, households located farther from town have a lower probability of collecting fuel wood from community forests (1.7% per unit). We also find that the distance from town raises the probability of fuel collection from open access forests by 3.5% per unit. On the other hand, the household's distance from the nearest forest significantly increases the probability of purchases from the market, although by an economically miniscule 0.3% per unit; however the distance from the forest does not have any significant effect on other sources of fuel wood collection. Overall, these results provide little evidence in support of other studies (e.g, Heltberg et al., 2000) that people tend to substitute fuel wood from forests with private fuels as distance to forest increases. In terms of the regional coefficient, it was significantly related to all sources, other than open access forests. We find that households in East Gojam are less dependent on private sources (15.4%), but more dependent on community forests (6.8%), market purchases (3.4%) and multiple sources (3.3%), compared to households in the South Wollo regions.

[43]Magnitudes are, unfortunately, relative, as hectares and tropical livestock units are not directly comparable.
[44]Note that distance to town is measured in terms of walking distance (in hours) from the household's residence to the nearest town.

5. CONCLUSION

In this paper we have examined the determinants of rural households' preferences for source of fuel wood using a discrete choice model, multinomial logit regression, developed within the context of random utility. The model has been employed to examine whether socioeconomic and environmental factors affect rural Ethiopian household choices, with a specific emphasis on institutional factors related to the community forestry program that is available in the region. The analysis was undertaken using data collected from the East Gojam and South Wollo zones of the Amhara region of Ethiopia.

The primary purpose of the analysis was to consider the importance of local-level institutions and land certification on these choices, in order to provide some information to policymakers, since the current government of Ethiopia and other organizations working on natural resource conservation are promoting the transfer of forests to the local people. In terms of the analysis, institutions do play a role in household choices. Better institutions are associated with a reduced probability of collecting fuel wood from community forests, primarily for those households that are not part of the community forestry management programme, while raising the probability of collecting fuel wood from open access forests and collecting from multiple sources. With respect to policy, the results are positive, in the sense that the demand for community forest resources appears to be lowered by community forestry institutions, the results are also negative, in the sense that the demand for open access forest resources rises, in the face of better community forestry institutions. In other words, there is a need to bring additional open access forests under the management of the community and increase local awareness regarding the use and rules associated with forestry management.

Land certification, on the other hand, is associated with reduced collection probabilities in open access forests and increased collection probabilities for multiple sources for fuel wood collection. However, although the literature (Deininger et al., 2009; Holden et al., 2009) suggests that land certification is responsible for increased investment in the land's productivity, through better soil conservation and planting of trees, our results suggest that these investments have, as yet, not resulted in significantly increased use of private forests for fuel wood. The lack of significance is likely due to a long investment lag – it is unlikely that trees planted within the last few years have grown big enough for harvest – however, in terms of policy, the reduced probability of collecting from open access forests is a positive result, suggesting that land certification should be furthered. Additional empirical research on the role of land certification, as well as farmers' investment and use decisions may be required to supplement these findings.

A number of additional implications can be developed from the analysis. Firstly, the results suggest that household characteristics, such as: age, gender, and the education of the household head affect the choice of fuel wood source differently. For example, education is negatively correlated with the probability of fuel wood collection from open access forests, suggesting that improving education could lead to improved forest conservation by reducing the demand for fuel and other forest products from open access areas. This also implies education makes collection of fuel wood from open access areas unprofitable and hence households substitute fuel wood from open access areas by private sources. The current extension system in Ethiopia may have a role to play in this regard, if the extension system can undertake useful education interventions related to forest management and conservation.

Secondly, the choice of fuel wood source also varies between regions, depending on agro-ecological factors, suggesting that there is a need to consider regional variation when examining household choices. Thirdly, households with large landholdings and greater livestock ownership are more likely to collect fuel wood from their own private sources and are less likely to collect from either open access forests or purchase from the market. Regarding policy, interventions related to forest conservation, especially in open access areas, would be more likely to succeed, if the interventions are capable of targeting the poorer households in the region.

Finally, distance matters, particularly with respect to market purchase of fuel wood. The probability of market purchase is increased when the forest is farther away, and when households are closer to town, suggesting that people will depend more on the market as forests become more inaccessible. We have little evidence to argue that households tend to substitute fuel wood from forests with private fuels, as forest becomes inaccessible. Similarly, the probability of collection from open access areas is increased for households located farther away from town. Therefore, policies designed to increase the supply of fuel wood, or at least increase access to fuel wood – e.g. through improved transportation networks – will help reduce fuel wood expenditures and environmental pressures on open access forests.

The results from this study can provide valuable insight for Ethiopia's current demand-side and supply-side strategies for addressing rural energy problems, especially policies related to forests and forest resource conservation, as well as halting, and hopefully reversing, the unsustainable use and exploitation of those resources. Future studies in this area are necessary, and can provide further information related to the long-term effect of land tenure security (land certification) on farmers' investment decisions, and the implication of these decisions on rural energy demand and forest degradation in the region. Although this study provides a number of meaningful insights with respect to forestry conservation and management, focusing on an application to rural Ethiopian households, it is likely that the results and policy implications can be generalized to other developing regions. Importantly, many developing regions have similar forestry structures, in that forests are owned by the government, and suffer from many of the same problems, such as forest degradation that is continuing (or even accelerating) on a pace that is likely to be unsustainable. Therefore, even though the analysis focuses on a very specific region of one country, the similarity of structures and problems suggests that there is scope for developing or extending these policies in other similar countries.

CHAPTER IV

NON-TIMBER FOREST PRODUCTS DEPENDENCE, PROPERTY RIGHTS AND LOCAL LEVEL INSTITUTIONS: EMPIRICAL EVIDENCE FROM ETHIOPIA

Abstract

This study examines the role of local level institutions and property right regimes on the forest-poverty link, with respect to non-wood forest products, using data from a random sample of rural households in Ethiopia. Households in the sample derive approximately 8.7% of their income from these products. The determinants of forest dependency were examined separately for different types of forest property right regimes. The findings suggest that forestry management devolution enhances resource use by the poor, while reducing dependency among the rich. Our estimation results, which are consistent across the different measures of forest dependency, also suggest that local level institutions are not significant factors in determining the use of non-wood forest products, a result that differs from the analysis of timber and other woody materials. From the study results, we conclude that generalizations of the forest-poverty link are not possible, as the link depends on the type of forest management and the specific characteristics that prevail in the area.

1. INTRODUCTION

Empirical evidence from developing countries indicates that forest products play a significant role in rural livelihoods, particularly for the rural poor. Almost a quarter of a billion people live in or around the dry forests of Sub-Saharan Africa (CIFOR, 2008), and most of them depend on the forests for building materials, food, cropland, fuel wood, non-wood products and many other things. Forest product extraction and the extent of natural resource degradation in developing countries is often attributed to rapid population growth, rural poverty and the open access nature of those resources, especially forests (Dayal, 2006; Bluffstone, 1998).

Rural households in Ethiopia are able to access forest products from a variety of sources, including: participatory forestry management (PFM) forests, or community forests; state forests, which are *de facto* open access forests; and private sources, such as on-farm forests and trees around the homestead. Experiences in many settings are consistent with Hardin (1968):open access resources tend to be overexploited and depleted. Recognizing this fact, Ethiopia, a decade ago, began to transfer the management of state forests to the local communities living near the forests. As part of its efforts, PFM, initiated by non-governmental organizations, such as FARM Africa and GTZ, has devolved to Oromiya and the Southern Nations, Nationalities and Peoples' (SNNP) regions of the country. It is believed that the new management style has improved environmental outcomes and contributed economic benefits to the local people. There is, however, little quantitative empirical evidence related to the effect of these institutional changes on the forest-poverty link. As argued by Shyamsundar et al. (2005), understanding the impacts of these institutional changes is important both for governments and for other stakeholders.

It is widely argued that devolution – the transfer of rights and responsibilities to local level user groups – of natural resource management is the most viable option for ecological and economic sustainability of natural resources. According to Dayal (2006), the transfer of the rights of state managed forests to local people is the primary forestry policy goal in many developing countries, including Ethiopia. As a result, donors, practitioners and governments are advocating a change in the management of forest at the local level. However, the success of common property resource management depends, to a great extent, on the rules and regulations applied and practiced in the management of natural resources (Ostrom, 1990, cited in Mekonnen, 2000). Besides household and village characteristics, institutional factors at the local level – such asthe clarity of rules for accessing the forests, the degree of village level forest monitoring and village level participation in forest management –are found to be important in the analysis of the poverty-environment nexus, in general, (Wunder, 2001; Reddy and Chakravarty, 1999) and the forest-poverty link, in particular (Adhikari et al., 2004).

Many researchers have documented the role of environmental resources and non-timber forest products (NTFP) in the economic development of local communities and sustainable forest management.[45]Available evidence from developing countries (Arnold and Bird, 1999; Cavendish, 1999a and 1999b; Adhikari, 2005; Reddy and Chakravarty, 1999; Narain et al., 2008b) focuses on quantifying the contribution of natural resources or forest products to rural income and analysing the socioeconomic factors that affect forest dependence. Recent studies tracking household income conclude that NTFPs contribute between 10% and 60% of income (Cavendish, 2000; Reddy and Chakravarty, 1999; Fisher, 2004; Mamo et al., 2006), and that this contribution varies substantially across households. Similarly, Neumann and Hirsch (2000) argue that, while NTFPs contribute to household income in many places, the contribution is geographically uneven, varies across social groups and is highly differentiated by gender, class and ethnicity. Though many studies find a strong positive link between poverty and NTFP dependence, Pattanayak and Sills (2001) find that relatively wealthier households depend on NTFP to reduce risk and smooth both consumption and income. In other words, many complex factors affect the forest product use and dependence in rural areas of developing countries.

As explained in the preceding paragraph, the contribution of forest resources to rural livelihoods varies across studies, depending on the nature of forest products included in the study, the methods employed in the valuation of products, and the type and management of forests prevailing in the study area. However, despite the importance of understanding the role of local level institutions and property right regimes on rural household forest product use and dependence, the empirical evidence is still limited (Edmonds, 2002). Therefore, there

[45]Different definitions are used in the NTFP literature. Various authors interchange minor forest products, non-wood forest products, and secondary forest products. In this paper, the term NTFPs and NWFPs are used, interchangeably, to refer to all forest products except for fuel wood and other woody materials, which can be derived from forests, wooded land and trees outside of forests.

is a need to evaluate and analyse the forest-poverty link at the local level, in order to more appropriately design policies and programs aimed at improving rural livelihoods, reducing forest degradation and increasing forest resources (Gutman, 2001).

The main objective of this research is to examine the factors that affect NTFP dependence, with a particular emphasis on the role of property right regimes and local level institutions. Moreover, the study assesses the contribution that forest products, especially NTFPs, make to rural livelihoods, by examining time allocation – to the collection of NTFPs – and the share of income derived from the forest. The study contributes to the existing literature by including institutional variables and property right regimes with in the forest-poverty nexus. This study also complements the limited literature related to the forest-poverty link in Africa, in general, and Ethiopia, in particular.

In this study, we find that forestry management devolution enhances forest resource use by the poor, while reducing dependency among rich households. There is no evidence that richer households influence either the formal or informal access restrictions on access in their favour, when the forest belongs to the community. However, our findings also suggest that the relatively richer households exploit forest resources from OA more than the poor suggesting that there is a need to expand the current practice of PFM to other OA areas. We also find that local institutions do not have any significant effects on forest dependency in a community forest. This might be because institutional conditions are well understood by the PFM participants, meaning that households are fully aware of the forest use rules, regulations and management policies of the community forest. The policy implications is that improving property rights, either through community forestry or private ownership, is likely to reduce the exploitation of forest resources, and may provide equity benefits for the rural population.

The structure of this paper is as follows: Section 2 discusses the methodology, including the conceptual framework and empirical strategies employed in the analysis. Section 3 presents the study area, describes the nature of the data and presents descriptive statistics for the survey data. The results of the empirical analysis are presented and discussed in Section 4. The final section, Section 5, concludes and discusses policy implications.

2. METHODOLOGY

2.1. Analytical framework

Generally, farm households in developing countries are both producers and consumers of agricultural and forest products; the study area examined here is no different. Furthermore, in our study areas, factor markets and agricultural output markets are either weak or absent, due to high transaction costs and limited information, as well as poor infrastructural networks (transportation and communication). Thus, insight into the highly heterogeneous role of forest products in rural household economies can be obtained through microeconometric modelling within the non-separable agricultural household production framework (Sills et al., 2003).[46]

The basic theory assumes a household that maximizes its utility, typically a unitary measure of utility, subject to a set of production, budget, and time constraints. The major implication derived from this model is that household-specific implicit prices are needed whenever key markets are either missing or incomplete. Moreover, the optimal decisions are such that households allocate their labour between various activities (such as agriculture, NTFP collection, and off-farm activities) by equating the marginal utility of leisure to the value of the marginal product of labour in each activity. Households allocate their time such that the shadow value of NTFP collection time is equal to the marginal utility of NTFPs obtained by allocating more time to collecting, which is the familiar proposition that marginal cost equals marginal benefit, applied, in this case to NTFP collection. The optimal conditions yield a set of production, consumption and labour allocation equations, which are functions of prices and wages, household preferences and technologies, which can be empirically examined.

2.2. Empirical Strategies

As previously stated, the main objective of the analysis is to understand NTFP dependence, with a particular emphasis on property rights and local level institutions. In order to examine the NTFP dependence across the different property right regimes and institutional settings, separate regression models were specified for PFM (or community) forests, private sources and open access forests. From the theoretical framework the dependent variable could be NTFP production, NTFP consumption or labour allocation to NTFP collection. As the model

[46]Amacher et al. (1996), Cooke (1998), Mekonnen (1999), Köhlin and Parks (2001), and Heltberg et al. (2000) develop and apply such models in the examination of fuels, especially fuel wood.

is non-separable, the functional form of the reduced-form equations cannot be derived analytically (Singh et al., 1986). Therefore, researchers have relied on numerous methodologies, including: descriptive and multiple regression methods, such as OLS (Adhikari, 2005); discrete choice models, such as Tobit (Fischer, 2004; Dayal, 2006); instrumental variable models, and panel data analysis (Cooke, 1998).

2.2.1. Time Allocation

Due to the variety of sources available to the household, it is likely that only a subset of households make use of any one particular source, such that resource use is censored at zero. Censoring could be random or non-random. If censoring is random, an independent hurdle model, such as the standard Tobit model or a more general two-part model could be applied. If censoring is not random, a dependent hurdle model is, instead, required to mitigate the effect of non-random censoring, more commonly referred to as selection bias. In this analysis, only a subset of households participate in the PFM, and, given the name, it is reasonable to assume that households choose to participate, such that censoring is non-random. Note also that only members of the PFM are allowed to collect resources from the community forest. Non-members or non-participants, on the other hand, are required to either use their own sources or use open access forests. Thus, only considering members of the community forest will yield inconsistent estimation results.

On the assumption that rural households decide where to collect the non-timber forest resources, based on their access, as well as the measure of income related to collection, Heckman's (1979) sample selection methodology is followed. The participation, or selection function, follows a probit specification.

$$y_1 = \mathbb{I}(Z\gamma - \varepsilon_1 > 0) = \Phi(Z\gamma) \quad (1)$$

In (1), $\mathbb{I}$ is an indicator function yielding a one when the expression in brackets is true, such that $y_1 = \{0,1\}$, $Z$is a set of observable controls, which are assumed to be uncorrelated with the observed controls, γ is vector of parameters to be estimated, ε_1 represents unobserved determinants, and Φ represents the cumulative normal distribution. The outcome equation follows a standard linear regression format.

$$y_2 = X\beta + \varepsilon_2 \quad (2)$$

In (2), X is a set of exogenous controls assumed to affect time allocated to collection of forest products and the measure of forest resource income (share of income and total income) used in the analysis, ε_2 represents the unobserved determinants of resource collection, which are assumed uncorrelated with observed determinants, and β is a vector of parameters to be estimated. The system (1) and (2) are estimated via full information maximum likelihood, correcting for heteroscedasticity following White (1980), and further assuming a bivariate normal distribution.

$$\begin{bmatrix}\varepsilon_1\\ \varepsilon_2\end{bmatrix} \sim N\left(\begin{bmatrix}0\\ 0\end{bmatrix}, \begin{bmatrix}1 & \rho\\ \rho & \sigma^2\end{bmatrix}\right) \quad (3)$$

The key to identification in the system is finding exogenous variation in participation that does not affect collection time, allowing for identification of the correlation between the unobserved determinants of participation and resource use, as measured by ρ.In this analysis, the household's distance to the forest is used for identification.

In order to check the robustness of the results, the share of income and total income derived from each type of property rights regime were considered as income measures related to NTFP dependence, while time spent collecting was also considered as a different measure of NTFP dependence. The estimation strategy, described by (1) – (3), is used for both the share of income and total annual income derived from NWFPs. However, further estimates of time spent, share of income and total income derived from all sources, were derived from OLS specifications, although it was applied only for households involved in the collection of NWFPs from at least one source.

2.2.2 Local Level Institutions

As the analysis is concerned with broad measures forest dependency, in relation to NTFP, and there is a PFM policy in place, the analysis also considers the effect of local level institutional effects on forest dependency. Recent literature, though, has emphasized the endogeneity of forest management institutions. In the presence of endogenous explanatory variables, the instrumental variable regression is the preferred approach. However, in this analysis, the Durbin–Wu–Hausman test was used to test for endogeneity. Initially, 'enforcement strength' was regressed on other independent variables. Residuals from the initial regression were included in an augmented resource regression. The same test procedure was implemented for institutional characteristics. The hypothesis of no endogeneity was rejected in both cases, and, therefore, OLS corrected for heteroscedasticity was employed, since endogeneity was not statistically relevant in this sample.

The necessary data for measuring institutional strength in the area were collected, as part of the survey, although data is only available for PFM members. The institutional variables focus on forest management, forest monitoring, household participation and household perception related to forest use and status. Forest user group members were asked to indicate their agreement or disagreement, on a Likert-type of scale (i.e., strongly agree=1, agree=2, no opinion=3, disagree=4 and strongly disagree=5), to a wide range of statements. Given the large number of statements, and the limited number of observations in the sample, it is practically very difficult to include all the variables in the analysis. Therefore, an index was constructed combining, and, thus, reducing the number of closely related variables.[47]Two such indexes were constructed, one relating to enforcement strength, "ENFORINDEX", the other related to institutional characteristics, "INSTINDEX".[48] All the questions related to monitoring, penalties and social sanctions are grouped under enforcement strength, while other variables, such as the clarity of rules and regulations, fairness in the distribution of benefits and participation in forest management are grouped under institutional characteristics.

2.2.3. Valuation and Estimation of Share of Income from NWFPs

The values of NWFPs derived from different sources are based on the different approaches found in the literature. First, the value of tradable products was calculated from the quantity collected and the local market price. Second, the value of some non-marketed forest products was calculated from the collection time and the current market wage rate in the area, i.e, through an opportunity cost approach. See for example, Chopra (1993) and Adhikari (2005), who note that if labour time is the major input required in the accrual of a good or service, its opportunity cost can be treated as an approximation of the product's value in use. However, this latter method underestimates the true value of some forest products in the study area.

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[47] Although, principle components regression is one possibility, a simpler index related to the UNDP's human development index was, instead, used. The calculated index is based on the average of the N indices, and rescaled to lie in the unit simplex. That is, $Index_i = N^{-1}\sum_{j=1}^{N}\left(\max(I_j) - I_j\right)/\left(\max(I_j) - \min(I_j)\right)$, when max and min are the lowest and highest values in the sample, *N* is the number of institutional components included under the index. The result is, therefore, unit free and represents a simple average of the institutional variables. Bluffstone et al. (2008) applied a similar formula to calculate their index. Principal components analysis was also applied, but led to results that were difficult to interpret.

[48]The correlation coefficient between the two indices is 0.12, suggesting that the variables are not strongly correlated measures of institutional conditions.

Instead, a unit of time spent (including travel time) in collection of marketed forest products was multiplied by the total time spent to collect other similar non-marketed products. Extreme observations and unclear reported values or quantity units were removed from the analysis. Furthermore, the contributions of forests to major environmental services, such as soil conservation and carbon sequestration, as well as general aesthetic and spiritual values are not considered in this study.[49] In general, the values reflect the gross economic value of NWFPs. Unfortunately NTFPs (NWFPs) have often been undervalued in previous studies, since previous studies have only considered them in terms of their direct-use values (Shackleton et al., 2001).

The share of income derived from NWFPs, as implied by the moniker, is obtained as the ratio of income derived from NWFPs to the total annual expenditure of the household.[50] As opposed to most other studies, expenditure is used, rather than income, since expenditures are less variable and more closely related to expected lifetime income.[51]

3. STUDY AREA, DATA COLLECTION AND DESCRIPTIVE STATITICS

3.1 Study Area and Survey

The survey was conducted in Gimbo Woreda[52] in the SNNP region of Ethiopia. Gimbo Woreda is part of the southwestern Ethiopian highlands and is found in Kaffa Zone, about 450 km of southwest of Addis Ababa, the capital city of Ethiopia. The total population of the Woreda is estimated to be 147,905, 78% of which are located in rural areas. The population density of the Woreda is estimated to be 116.5 people per square kilometer. Most of the population is Kaffa, although there are also small numbers of people from the Menja and Mana tribes. Major crops grown in the area include: cereals, pulses, *enset* (a large, thick, single-stemmed banana plant), sugarcane, coffee and spices. Livestock is also important to the farm economy.

[49]To measure such environmental services of this nature, specialized valuation techniques (contingent valuation, travel costs methods, hedonic pricing, or production function approaches) are preferred (Cavendish, 2000). However, data to perform such valuations was not collected, as part of the survey.

[50]There is little agreement on the appropriate approach to including durable goods expenditure; however, in this analysis, a percentage of expenditure on the good is allocated to the year in question. Although this may minimize the underestimation of annual total household expenditure,it is subject to the assumption used.

[51]Recognizing the problem of current income in measuring forest dependency, Narain et al. (2008) introduce the concept of permanent income in their analysis of resource dependence in rural India.

[52] A *Woreda* is an administrative division of Ethiopia managed by local governments, which is equivalent to a district.

The largest proportion of today's Ethiopian coffee forests is situated in the southwestern part of the country (SNNP and Oromyia Regional States). However, as in other parts of the country, the forest areas in this region are declining rapidly, primarily due to the conversion of forests into agricultural land (Bekele, 2003). In an attempt to mitigate or even reverse the rapid decline, the FARM Africa-SOS Sahel PFM project was established in our study area to foster and promote sustainable forest resource use and management in the study area (Bekele, 2003). The PFM project was first introduced in the area by FARM-Africa in 1996. PFM is a system of management, whereby members of the local community manage the local forest. The traditional role of local government from one of owner and regulator has been altered to include facilitation, capacity building, advising, analysing and generating new technologies (Jirane et al., 2008).The objective of the project is the improvement of forest cover, by slowing down deforestation and forest degradation, and the improvement of the economic livelihoods of the local rural populations. PFM is a partnership between the government's Department Forestry and Community Forest Management Groups. That partnership is contractual, as the community forest managers and government sign an agreement specifying the rights, obligations and duties of both parties, as well as specifying current use rights, future use rights and forest product revenue sharing for the local communities.

Table 4.1: List of sample sites and their respective sample sizes.

List of Kebeles	Number of focus groups	Name of Focus Group	
		PFM	NPFM
Yebito (88)	2	Agama (58)	Mula and Hindata (30)
Bita Chega (49)	1	Dara (49)	--
Mitchiti (80)	3	Beka (32), Matapha (24)	Chira and Botera (24)
Woka Araba (50)	1	---	Woka Araba (50)
Keja Araba (47)	1	---	Keja Araba (47)
Maligawa (63)	2	Sheka (37)	Sheka (26)
TOTAL	10	200	177

*The numbers in brackets refer to sample sizes. NPFM denotes non PFM groups.

Research villages were purposively selected, in order to evaluate the impact of the participatory forestry program (PFM) on rural livelihoods. A total of 10 focus groups, five under the PFM and five operating outside of the PFM, were selected. Household selection into the focus groups was based on the list of community forest users and non-users; a systematic random sampling method across the lists was adopted to ensure the sample was representative of the area. Accordingly, a total of 377 rural households were interviewed. The questionnaire was prepared in both English and Amharic, which is the local language. Data was collected on household and individual characteristics, forest management institutions, the consumption and purchase of various goods and services, the quantity of labour allocated to forest resource collection and the collection, purchase and sale of NTFPs. Additional data on community level variables related to population size, village location and perceptions of forest status were also collected. Table 4.1 lists the kebeles, the focus group names, the number of focus groups and focus group sample sizes, based on PFM participation; 200 households are part of the PFM; the remaining 177 households do not participate in the PFM.

3.2. Descriptive Statistics

The definitions of the explanatory variables used in the analysis, together with descriptive statistics, are presented in Table 4.2. Since there is little variation in wages, the education level of the household head is included to account for unobserved labour market opportunities (Heltberg et al., 2000). Education is expected to be negatively correlated with forest resource use; as the opportunity costs of time rise, less time is devoted to resource collection and use. Similarly, because there is missing markets for NWFPs, forest product prices were not included in the empirical specification, and, therefore it is assumed that the impacts of these prices can be captured indirectly through household and village characteristics.

Table 4.2: Description of variables and descriptive statistics

Variable*	Description of variable names	Mean	S.D	Min	Max
AGE	Age of the household head in years	43.54	14.13	18	90
SEX	Sex of the household head (male=1, female=0)	0.94	0.25	0	1
DEDUCAN	Education of head (read and write=1, none=0)	0.42	0.49	0	1
LANDSIZE	Size of land owned by the household in ha	2.34	1.57	0	10
LIVESTLU	Livestock ownership in TLU	4.32	2.64	0	19.9
DISTTOWN	Distance of household from the nearest town in kms	6.84	3.83	0.01	20
ADUFEM10	Number of female members age greater or equal to 10	1.87	1.07	0	7
ADUMAL10	Number of male members age greater or equal to 10	1.96	1.11	0	6
OFFFARM	Dummy whether any member from the family is participating in off farm activities (yes=1, No=0)	0.11	0.31	0	1
DISMARKET	Distance of the village from the nearest market (walking distance in minutes)	79.68	32.46	35	140
DISFOREST	Distance of the household from the community forest (walking distance in minutes)	45.35	57.78	1	500
FAMSIZEeqv	Family size in adult equivalent	5.07	1.9	1.97	12.4
DENSITY**	Number of households per hectare of forest	0.47	0.28	0.1	0.96

* The variables are in level form, while some of the variables in the regression analysis are logarithmic
** DENSITY refers to the PFM groups only, as data for non-PFM is incomplete.

The theoretical model suggests that technology matters, and, thus, the state of the forest also matters. Unfortunately, the data does not include an objective measure of the state of the forest. Instead, forest-level population density (the number of households per hectare of forest) is used as a proxy for the state of forest. Low density is expected to increase the marginal product of labour, and, hence, reduce the time required to collect a unit of forest product. Unfortunately, it is only available for PFM groups, so is only included in PFM-specific regressions.

In terms of the expected effects of the household characteristics, larger families are expected to demand more forest products, and tend to extract more forest resources. Furthermore, larger families are expected to have more labour that can be made available for extraction activities. As noted previously, expenditure is used, instead of income; however, wealth is also included in the models. Edmonds (2002) and Dayal (2006), for example, include livestock and house type, respectively, in their analyses. In line with these authors, this analysis includes livestock ownership (in tropical livestock units; 1TLU=250kg) and landholdings. Cavendish (1999a, 1999b) and Sills et al. (2003) find a negative correlation between wealth and the collection of NTFPs, which they associate with changing preferences, the opportunity cost of time, or effective risk. On the other hand, Adhikari (2005) finds that the rich are more dependent on natural resources than the relatively poor in Nepalese community forests.

Infrastructural proxies, such as access to markets and the distance to town, are expected to negatively impact forest resource use and, hence, reduce the time devoted to forest resource collection. Infrastructural access is expected to promote off-farm activities, reducing the time available for forestry activities. However, improved transportation networks may increase forest product demand; improved roads increase access to other, potentially, bigger markets.

Table 4.3 presents summary statistics of household and community level variables used in the study; they are presented by forest property right regime type. As can be seen in the table, household characteristics are rather similar across the regimes. However, and as is needed for potential identification of PFM participation, PFM households are closer to community forests than are those households depending on either their own sources or open access forests.

Table 4.3: Descriptive statistics by source of forest products.

	Community (N=198)		Open Access (N=129)		Private (N=182)	
Variable	Mean	S.D.	Mean	S.D.	Mean	S.D.
AGE	43.65	13.56	43.82	13.93	43.41	13.95
SEX	0.92	0.27	0.95	0.21	0.94	0.24
DEDUCAN	0.41	0.49	0.43	0.50	0.42	0.50
LANDSIZE	2.27	1.47	2.60	1.55	2.32	1.47
LIVESTLU	4.21	2.48	4.66	2.87	4.52	2.60
ADUFEM10	1.88	1.11	1.90	1.03	1.90	1.02
ADUMAL10	1.97	1.10	1.89	1.09	2.04	1.07
DISTTOWN	6.34	3.90	7.57	3.58	7.16	3.94
DISFOREST	23.15	27.58	70.83	74.31	52.04	54.27
DISMARKET	75.86	32.62	81.24	29.42	82.14	32.41
FAMSIZEeqv	5.15	1.92	4.99	1.85	5.15	1.90
OFFFARM	0.13	0.34	0.07	0.26	0.10	0.31
DENSITY	0.47	0.28	0.60	0.36	0.49	0.28

Table 4.4 presents a descriptive analysis of time allocation, the share of income and total income derived from NWFPs from the different forest property right regimes. The mean annual NWFP income obtained from community forests is Birr 655, meaning that an average household derives 5.4 % of their total income from NWFPs. Furthermore, 95% of the PFM households earn up to 18% of their total income from NTFPs, while the range for the upper tail is between 19 and 41%. Given the income ranges, and the fact that government lacks the institutional capacity to control access to their own forests, it is not surprising that, on average, households spend more time in open access forests than in either private or community forests.

Table 4.4: Mean values of time allocated, share and total income from NWFPs by sources.

Sources	No.	TIME (Hr/Month)	SHARE (%)	TOTAL INOCME (Birr/Year)[53]
COMMUNTIY	198	2.379	5.4	655.24
OPEN ACESS	129	3.233	6.4	750.92
PRIVATE	182	3.091	7.2	873.29
TOTAL	373	3.975	8.7	1042.54

[53] The exchange rate was 1 USD ≈ Birr 12.615 during the survey period.

Finally, Table 4.5 outlines the descriptive statistics for the two institutional variables for each community forest; recall that there are five PFM forests in the data set. The index, described in footnote 43, was based on the answers to a series of questions related to the PFM program. The information contained in Table 4.5 suggests that enforcement and management is strong within all of the PFM forests. However, the similarity of these indexes suggests that there is not enough independent variation to provide empirical traction, which will result in insignificant estimates.

Table 4.5: The mean values of the institutional indices for each community forest

Name of community Forest(PFM Groups)	ENFORINDEX				INSTINDEX			
	Mean	S.D	Min	Max	Mean	S.D	Min	Max
Agama(58)	0.80	0.15	0.29	1	0.80	0.22	0.08	1
Beka(31)	0.76	0.21	0.17	1	0.87	0.17	0.25	1
Dara(48)	0.82	0.15	0.54	1	0.87	0.14	0.42	1
Matapa(24)	0.81	0.15	0.50	1	0.91	0.15	0.33	1
Sheka(37)	0.80	0.17	0.25	1	0.81	0.18	0.42	1

4. RESULTS AND DISCUSSION

4.1. Results

4.1.1 Time Allocation

Table 4.6 presents the estimates of equations (1) – (3) for the quantity of household time allocated to the collection NTFPs from community, private and OA forests, separately. The probit parameter estimates are presented in the first three columns, while the outcome equation estimates are presented in the last four columns; the non-selection estimates of total time for all households is presented in the last column of the regression section.

Table 4.6: Estimates of Time Allocation to NWFPs collection

	SELECTION			REGRESSION			
Variables	COM	O. A	PR	COM	O.A	PR	TOTAL[a]
AGE	0.089**	-0.000	-0.113***	-0.315**	-0.585**	0.113	-0.284**
	(0.04)	(0.04)	(0.04)	(0.15)	(0.23)	(0.20)	(0.13)
AGESQUARE	-0.001**	0.000	0.001***				
	(0.00)	(0.00)	(0.00)				
SEX	0.156	-0.103	-0.250	0.267*	0.362**	0.237	0.223*
	(0.38)	(0.35)	(0.43)	(0.16)	(0.17)	(0.21)	(0.12)
DEDUCAN	-0.257	0.208	0.468**	0.099	-0.192	0.124	0.074
	(0.21)	(0.20)	(0.23)	(0.11)	(0.16)	(0.12)	(0.09)
LANDSIZE	0.034	0.545**	-0.570**	-0.008	0.414***	0.267*	0.273***
	(0.22)	(0.24)	(0.24)	(0.12)	(0.14)	(0.15)	(0.10)
LIVESTLU	-0.031	-0.051	0.062	-0.165*	0.069	0.018	-0.055
	(0.20)	(0.17)	(0.19)	(0.09)	(0.13)	(0.12)	(0.08)
ADUMAL10	-0.074	-0.190**	0.248**	0.050	0.017	0.056	0.041
	(0.10)	(0.08)	(0.10)	(0.04)	(0.07)	(0.07)	(0.04)
ADUFEM10	-0.030	-0.042	-0.018	-0.013	-0.050	0.066	0.013
	(0.08)	(0.08)	(0.09)	(0.04)	(0.07)	(0.06)	(0.04)
DISTTOWN	-0.731***	0.671***	0.071	0.162*	0.123	-0.035	0.229***
	(0.18)	(0.17)	(0.18)	(0.09)	(0.15)	(0.10)	(0.08)
DISFOREST	-0.875***	0.401***	0.425***				
	(0.10)	(0.09)	(0.09)				
Access to private sources by community users	9.240***			-0.418***			
	(0.37)			(0.12)			
Access to private sources by OA users		2.624***			-0.906***		
		(0.34)			(0.18)		
Access to Openacess			8.621***			0.195	
			(0.94)			(0.28)	
Access to community			9.668***			0.517*	
			(0.71)			(0.28)	
Access from two sources							0.011
							(0.08)
_cons	2.097**	-3.697***	0.090	1.819***	2.75***	-0.437*	1.34
	(0.95)	(1.08)	(1.03)	(0.61)	(0.92)	(0.72)	(0.51)
Rho	0.154	-0.365***	0.508				
	(0.16)	(0.12)	(0.26)				
N	373	373	373	198	129	182	365

[a] Estimation is by using OLS, corrected for heteroskedasticity. *, **and *** represent 10, 5, and 1% level of significance. DCOMM_private, DOACESS_private, DPRIVATE_Openacess, DPRIVATE_community and Dtwo_sources are all dummy variables referring to whether community forest members are collecting resources from private source, OA users are also collecting from private source, private users are collecting from OA forest , private users are also collecting resource from community forest , and whether the household is collecting NWFPs from two or more than two sources, respectively. They can be considered as indicators of availability of substitutes.

With the exception of collection time within community forests, collection activities are selective. According to the selection results, unobserved factors that increase the probability of collection from open access forests, tend to decrease the collected quantity, while unobserved determinants associated with an increased probability of private forest collection, tend to increase the collected quantity.[54] One potentially important unobserved determinant is the price of NTFPs, while another is true forest productivity. Intuitively, increased prices would tend to raise both participation probabilities and collection time. On the other hand, increased forest productivity could increase the probability of participation, while simultaneously reducing collection times, and vice versa. In the context of this research, the unobserved price effect appears to dominate the unobserved productivity effect for privately produced NTFPs, while the opposite appears to be true for open access collectors.

In terms of participating in the collection of NTFPs from community forests, the probability is a concave function of age of the household head, and is also higher for users that are also able to access their own sources; however, the probability is decreasing in both the distance to town and the distance to the community forest. Collecting from open access forests, on the other hand, is more likely for households located farther from town and from the community forest. Furthermore, open access collection is more likely for households with larger landholdings, as well as access to private sources, but is less likely for households with a larger number of males aged 10 years and older. Finally, the probability of collection from private sources is a convex function of the age of the household head, and is decreasing in landholdings; however, the probability is higher for households also able to access both open access forests and community forests, as well as for households located farther from community forests. It is also higher for households with a more educated head, and for households with a greater number of adult males.

In terms of collection time, results of which are presented in the rightmost columns of Table 4.6, total collection time is a convex function of the age of the household head across all sources, except for own sources. Collection time is also larger for male-headed households, again, with the exception of own sources. With the exception of community forests, collection time is also increasing in landholdings. Livestock holdings, on the other hand, are

[54]Although one might argue that collection times are likely to be affected by distance to forest, the exclusion restriction, in an OLS regression of collection times including all the factors in the right-hand columns of Table 6, as well as distance to forest, was found to be statistically independent of collection time.

associated with reduced collection times in community forests, while total collection time in community forests, and in total across all forest sources, is larger for households located farther from town. Access to private sources reduces both community forest and open access collection times, although access to community forests increases private source collection times.

4.1.2. Share of Income and Total Income Derived from NTFPs

Equations (1) – (3) were also examined in the context of the share of income derived from NTFPs, as well as total income derived from NTFPs. The results are presented in Tables 4.7 and 4.8, respectively. As should be expected, the determinants of participation in the collection of NTFPs from various sources are qualitatively, and nearly quantitatively, identical to those presented in Table 4.6. The only real difference is the correlation between the unobserved determinants for the share of income derived from NTFPs collected from own sources, where it is insignificant. If prices are an important unobserved determinant to collection, it is reasonable to expect that prices will have the same effect on both the numerator and the denominator, in the income share, and, therefore, it is reasonable to expect that prices will not strongly influence the correlation between the unobserved determinants.

Regarding the outcomes related to the share of income regressions by collection source, that share tends to be lower for households with older household heads, greater landholdings and access to additional private sources. Total income derived from community forests is larger for households with a greater number of adult males, and is lower for households also accessing their own private sources. The share of income derived from NTFPs collected in open access forests is higher for households with greater landholdings, but lower for households with an older head and with access to additional sources. The results for total income follow a similar pattern, although the parameter estimates are larger, due to the fact that there is greater variability in total income than in the share of income. Finally, the share of income derived from NWFP collection from own sources is higher for households with greater landholdings, as is total income derived from NWFP collection from own sources.

Table 4.7. Determinants of Share of income from NWFPs by source of NWFPs

	SELECTION			REGRESSION			
Variables	COM	O.A	PR	COM	O.A	PR	TOT
AGE	0.091**	0.006	-0.093**	- 0.035**	-0.041*	0.026	-0.023
	(0.04)	(0.04)	(0.04)	(0.01)	(0.02)	(0.02)	(0.02)
AGESQUARE	-0.001**	0.000	0.001**				
	(0.00)	(0.00)	(0.00)				
SEX	0.167	-0.066	0.184	0.018	0.013	0.003	0.015
	(0.38)	(0.35)	(0.57)	(0.02)	(0.03)	(0.02)	(0.02)
DEDUCAN	-0.233	0.179	0.415*	0.012	-0.018	0.015	0.008
	(0.21)	(0.20)	(0.21)	(0.01)	(0.02)	(0.01)	(0.01)
LANDSIZE	0.043	0.551**	-0.488**	-0.009	0.051***	0.044**	0.041***
	(0.23)	(0.23)	(0.24)	(0.01)	(0.02)	(0.02)	(0.01)
LIVESTLU	-0.047	-0.046	0.091	-0.023**	-0.000	0.001	-0.007
	(0.20)	(0.17)	(0.19)	(0.01)	(0.01)	(0.01)	(0.01)
ADUMAL10	-0.077	-0.200**	0.205**	0.001	-0.001	-0.008	-0.005
	(0.10)	(0.08)	(0.09)	(0.00)	(0.01)	(0.01)	(0.00)
ADUFEM10	-0.035	-0.035	-0.024	-0.004	-0.008	-0.001	-0.004
	(0.08)	(0.08)	(0.09)	(0.00)	(0.01)	(0.01)	(0.00)
DISTTOWN	-0.722***	0.665***	0.027	0.005	0.001	-0.003	0.013
	(0.18)	(0.17)	(0.18)	(0.01)	(0.02)	(0.01)	(0.01)
DISFOREST	-0.878***	0.396***	0.363***				
	(0.10)	(0.087)	(0.09)				
Access to private sources by Community users	9.031***			-0.033***			
	(0.46)			(0.01)			
Access to private sources by OA users		2.628***			-0.083***		
		(0.35)			(0.02)		
Aaccess to openacess			8.427***			0.017	
			(0.47)			(0.09)	
Access to community			3.578***			0.012	
			(0.47)			(0.04)	
Access from two sources							-0.005
							(0.01)
_cons	2.071**	-3.818***	-0.499	0.217***	0.23**	- 0.066	0.116*
	(0.97)	(1.10)	(1.14)	(0.06)	(0.10)	(0.08)	(0.06)
Rho	-0.065	-0.332**	0.256				
	(0.13)	(0.13)	(0.37)				
N	373	373	373	198	129	182	365

Table 4.8. Determinants of total income obtained from NWFPs by source of NWFPs /Heckman Sample Selection/

	SELECTION			REGRESSION			
Variables	COM	OA	PR	COM	OA	PR	ALL
AGE	0.083**	0.005	-0.107***	-0.489	-0.785**	0.007	-0.450*
	(0.04)	(0.04)	(0.03)	(0.43)	(0.42)	(0.33)	(0.24)
AGESQUARE	-0.001**	0.000	0.001***				
	(0.00)	(0.00)	(0.00)				
SEX	0.171	-0.062	0.29	1.049	-0.159	0.41	0.419
	(0.37)	(0.34)	(0.54)	(0.69)	(0.46)	(0.55)	(0.36)
DEDUCAN	-0.237	0.203	0.459***	0.014	-0.315	0.269	0.199
	(0.21)	(0.19)	(0.19)	(0.29)	(0.27)	(0.21)	(0.17)
LANDSIZE	0.062	0.526**	-0.514**	0.108	0.781**	0.864***	0.696***
	(0.22)	(0.23)	(0.21)	(0.32)	(0.31)	(0.25)	(0.19)
LIVESTLU	-0.038	-0.044	0.108	-0.046	0.099	0.094	0.054
	(0.20)	(0.17)	(0.19)	(0.25)	(0.23)	(0.20)	(0.14)
ADUMAL10	-0.066	-0.189**	0.208**	0.191*	0.038	0.034	0.024
	(0.10)	(0.08)	(0.09)	(0.11)	(0.15)	(0.09)	(0.09)
ADUFEM10	-0.021	-0.039	-0.026	0.099	-0.082	0.073	0.007
	(0.08)	(0.08)	(0.08)	(0.11)	(0.14)	(0.10)	(0.07)
DISTTOWN	-0.735***	0.664***	0.068	-0.087	0.087	-0.24	0.083
	(0.18)	(0.17)	(0.15)	(0.37)	(0.28)	(0.19)	(0.14)
DISFOREST	-0.858***	0.364***	0.352***				
	(0.12)	(0.08)	(0.09)				
DAccess to Private by comm	9.385***			-1.062**			
	(0.67)			(0.54)			
DAccess to private		2.665***			-1.264***		
		(0.34)			(0.44)		
Access to Openacess			6.663***			1.36***	
			(1.95)			(0.43)	
Acces to community			3.995***			1.25***	
			(0.43)			(0.41)	
Access to two sources							-0.032
							(0.14)
_cons	2.12**	-3.70***	-0.048	6.02***	8.63***	3.25**	6.37***
	(0.94)	(1.08)	(0.85)	(1.98)	(1.67)	(1.41)	(0.92)
Rho	0.303	-0.325	0.908**				
	(0.35)	(0.23)	(0.12)				
N	373	373	373	198	129	182	365

4.1.3. Dependency within Community Forests

The final analysis was based on collection time, share of income and total income collected in PFM forests. The analysis was based on OLS regressions, since all households included in the analysis are members of the PFM, and, therefore, selection issues do not arise. The results are available in Table 4.9. The focus for the analysis was on the institutional effects across the various forest programs. In all regressions, livestock holdings and the age of the household (although both were insignificant in the total income regression), the off-farm wage, forest density, and access to separate private sources were associated with a reduction in the outcome variable of interest. However, although expected given the limited variation in institutional conditions across the programs outlined in Table 4.5, neither enforcement strength nor institutional characteristics are associated with total collection time, the share of income derived from NTFPs or total income derived from NWFPs.

4.2 Discussion

4.2.1 Time Allocation

In contrast to Adhikari (2005), who argues that richer households collect more forest products from community forests in Nepal, this analysis found that wealth is negatively correlated to forest product collection from community forests. According to the results presented for outcomes in Table 4.6, a 10% increase in livestock holdings is associated with a 1.65% reduction in the amount of time spent in community forest collection activities. Clearly, richer households have resources, other than livestock, such as land, enabling them to easily substitute community forest products for products from private sources. However, our results, suggest that landholdings do not influence community forest collection times, although they do influence open access and private source collection times; a 10% increase in landholdings increases the amount of time spent collecting from open access forests by 4.1%, while only increasing time spent collecting from private sources by 2.7%.

On the other hand, in rural India, Heltberg et al. (2000) find that landowners substitute private fuels generated on the farm for forest fuel wood, which is consistent with a subset of our findings. We find that community forest collection time is lower, by 41.8%, for households with access to their own sources, while open access collection time is 90.6% lower for households with access to private sources. Possibly, properly managed community forests are yielding equity gains. Similarly, community forestry management that takes into account access to private sources will help reduce household dependence on the commons, and, hence improve the ecological balance and biodiversity.

Table 4.9:Regression results for forest dependency on community forests

Variables	SHARE NWFPS	COLLECTION TIME	Total income NWFPs
AGE	-0.001***	-0.007**	-0.006
	(0.00)	(0.00)	(0.01)
SEX	0.023	0.378**	1.26*
	(0.02)	(0.17)	(0.69)
DEDUCAN	0.010	0.077	-0.005
	(0.01)	(0.11)	(0.30)
FAMSIZEeqv	0.000	0.038	0.188***
	(0.00)	(0.02)	(0.07)
OFFFARM	-0.033***	-0.327***	-0.968**
	(0.01)	(0.12)	(0.44)
LIVESTLU	-0.025**	-0.173*	-0.138
	(0.01)	(0.09)	(0.25)
DISTTOWN	0.011	0.223**	0.129
	(0.01)	(0.10)	(0.33)
DISMARKET	0.020	0.305	0.676
	(0.02)	(0.19)	(0.60)
DISFOREST	-0.001	0.052	0.008
	(0.00)	(0.05)	(0.15)
DENSITY	-0.061***	-0.673**	-1.454*
	0.02	(0.27)	(0.84)
ENFORINDEX	0.020	-0.153	1.268
	(0.03)	(0.30)	(1.01)
INSTINDEX	0.005	0.204	0.639
	(0.03)	(0.27)	(0.82)
Dummy access to private sources	- 0.033***	-0.514***	-1.503***
	(0.01)	(0.09)	(0.30)
_cons	0.030	-0.404	0.462***
	(0.09)	(0.76)	(2.46)
N	198	198	198

The numbers in the brackets are the White-robust standard errors. The dependent variables (collection time and total income), livestock ownership (LIVESTLU), distance to town (DISTTOWN), distance to market (DISMARKET) and distance to forest (DISFOREST) are also in log form. There was no serious multicollinearity problem as the Variance inflation factor (vif) was less that 5 for all variables. *, **, and *** represent 10%, 5% and 1 % significance level, respectively.

4.2.2. Income Share and Total Income

The results of the analysis further suggest that the relationship between forests and poverty depends on the type of property right regime. Although poverty is not directly analysed, both the share of income and total income derived from NWFPs is lower for households with their own sources, and tend to be larger for households with greater landholdings. The share of income collected in community forests is 3.3% lower for households also collecting from private sources, while total income from community forests is 106% lower. Similarly, the share of income from open access forests is 8.3% lower for households collecting from their own sources, while total income is 126% lower. In terms of land holdings, however, the income share from NWFPs ranges from 4.1% to 5.1% higher, depending upon the collection sources, while total income from NWFPs increases between 69.6% and 86.4%, depending upon the source. As Cavendish (1999a, 1999b) notes, it is difficult to make broad generalizations about the relationship between income and environmental changes, in part, because this relationship is varied, and, in part, because there are many other environmental demand determinants.

4.2.3. Dependence within Community Forests

Previously, little attention has been given to the impact of local level institutions on the poverty-environment hypothesis, particularly in areas where the community participates in the management and use of resources. In many developing countries, on-the-ground management can often correspond poorly with stated policies. Perceptions, therefore, have the potential to better reflect reality (Bluffstone et al., 2008). Unfortunately, as already noted, institutional conditions are not related to any of the resource outcomes. The results, however, should be interpreted with caution. The lack of significance does not necessarily mean that local level institutions are not important in natural resource management. As indicated in the descriptive statistics, members of the PFM groups are well acquainted with the rules, regulations and management of the community forest. Therefore, one explanation for the insignificance of these variables is the limited variation in the perception of households regarding the various local rules and institutions governing the community forest. Another possible explanation is that institutional conditions may not be specified for NTFPs. The various rules and regulations may be applied and practiced in the case of major forest products such as timber or other woody materials like fuel wood.

The important determinants in the regressions reported in Table 4.9 include, forest-level population density, access to own sources and off-farm labour opportunities. The last results, consistent with Bluffstone (1995), suggest that the presence of an off-farm labour market helps stabilize forest stocks, despite open access to resources, while the absence of off-farm opportunities may lead to further degradation and deforestation.

5. CONCLUSIONS AND POLICY IMPLICATIONS

This research examined the role of property rights regimes and local level institutions on forest resource use in southwest Ethiopia, using a household survey conducted in the region. The primary purpose of the analysis was to examine the link between forests and poverty under different property right regimes, although forest dependency was considered through proxies related to time allocation, the share of income derived from NWFPs and total income derived from NTFPs. The findings suggest that forestry management devolution enhances forest resource use by the poor, while reducing dependency among rich households. There is no evidence that richer households influence either the formal or informal access restrictions on access in their favour, when the forest belongs to the community. However, our findings also suggest that richer households, as measured by land holdings, exploit forest resources from OA more than the poor suggesting that there is a need to expand the current practice of PFM to other OA areas.

We have also observed that the contribution of NWFPs to household income cannot be ignored. On average, households derive 8.7% of their total income from NWFPs from all sources; PFM participants derive 5.4% of their total income from NWFPs, while open access and private sources yield 6.4% and 7.2% income shares, respectively. However, there is some substitution present, NTFP collection from private sources is negatively correlated with collection from other sources, suggesting that development agents and government organizations should encourage households to develop, maintain and use their private sources to ease the pressure on open access and community forests.

Although the role of local institutions was also considered in the analysis, no significant results could be identified. However, we cannot conclude that local level institutions are not important for proper natural resource management. Importantly, institutional conditions are well understood by the PFM participants, meaning that households are fully aware of the forest use rules, regulations and management policies of the community forest.

These results are suggestive for policy. Improving property rights, either through community forestry or private ownership, is likely to reduce the exploitation of forest resources, and may provide equity benefits for the rural population. Moreover, with such measures, it is possible to maintain, or even improve, the environmental and ecological services provided by forests. In this regard, the distribution of seedlings and provision of technical assistance to rural households could also be beneficial, although such activities could not be addressed in this study.

CHAPTER V

CLEAN FUEL SAVING TECHNOLOGY ADOPTION IN URBAN ETHIOPIA

Abstract

The heavy dependence and inefficient utilization of biomass resources for energy have resulted in high depletion of the forest resources in Ethiopia, while the use of traditional cooking technology, one source of inefficient biomass resource use, has been linked to indoor air pollution and poor health. In response, the government and other institutions have pushed for the adoption of new cooking technologies. This research examines the speed of adoption of some of these technologies – Mirt and Lakech cook stoves – in urban Ethiopia. The duration analysis suggests that adoption rates have been increasing over time, that income and wealth are important contributors to adoption, and that substitute technologies tend to hinder adoption. However, it was not possible to consider prices or perceptions related to either the technologies or biomass availability in the duration models, and, therefore, further research is needed in order to further inform policy with respect to household technology adoption decisions.

1. INTRODUCTION

Like many other sub-Saharan African countries, Ethiopia is highly dependent on biomass energy sources, such as: fuel wood, charcoal, animal dung and crop residues. These biomass energy sources account for more than 90% of the total domestic energy demand, according to the Ethiopian Environmental Protection Agency (EPA, 2004). The EPA further reports that about 95% of the total population in Ethiopia uses biomass fuels for their main source of energy for cooking, heating and lighting. Even though urban households have better access to commercial energy than the rural population, the difference in biomass use is not large – approximately 99% of rural households and 94% of urban households. Given the high levels of dependence, biomass will continue to dominate energy demand in both rural and urban Ethiopia in the foreseeable future. The heavy dependence and inefficient utilization of biomass resources for energy have resulted in high depletion of the forest resources in Ethiopia. In general, Ethiopians are poor, and, as noted by Geist and Lambin (2003) as well as Vance and Iovanna (2006), poverty, in particular, as well as other socioeconomic factors, result in exploitation of forest resources for domestic energy consumption and commercial gain by the developing world's population.

The developing world's dependence on biomass fuels for energy is associated with 3% of the global burden of disease and 4.9% of the Ethiopian burden of disease, according to the World Health Organization (WHO, 2002).[55] Similarly, particulate matter resulting from fires is associated with a number of other health problems. Surveys by Bruce et al. (2002), Smith et al. (2004), Emmelin and Wall (2007) and Fullerton et al. (2008) summarize the strength of association between indoor air pollution – especially biomass fuel use – and a wide range of illnesses and diseases.[56] Associations are shown to exist for acute lower respiratory tract infection, low birth weight, nutritional deficiency, interstitial lung disease, chronic obstructive lung disease and lung cancer, tuberculosis, lung cancer, cardiovascular disease, and cataracts; WHO (2006) provides similar information. Furthermore, the aforementioned health problems tend to be greater in areas in which traditional cooking technology, based on

[55]The World Health Organization (WHO, 2002) estimates that, with 95% of households using biomass fuels as their primary energy source, 4.9% of the Ethiopian burden of disease can be attributed to solid fuel use for cooking, heating and lighting. The WHO also estimates that nearly 50,000 deaths can be attributed to the same cause.

[56] Etyemezian et al. (2005) note that both PM10 and CO concentrations are highest around 7:00 in Addis Ababa and that this peak is associated with motor vehicle traffic, food preparation and the heating of homes.

biomass fuels, are more common, as reported by Smith and Mehta (2003), Masera et al. (2007) and Tasleem et al. (2007).

In order to reduce pressure on forests and plantations and the adverse impact of indoor air pollution, the government has devised supply augmenting strategies and demand management strategies. The supply-side management strategy deals primarily with increasing the availability of fuel wood, through distribution of free seedlings, developing plantations, imposing and enforcing supply restrictions, and the enforcement of property rights. The demand-side management strategies, on the other hand, deal primarily with reducing the demand for biomass energy sources by promoting alternative modern fuels, promoting income growth and increasing the availability of fuel saving technologies, such as improved biomass cooking stoves (Cooke et al., 2008), including the Lakech and Mirt stoves, discussed below.[57]

In December of 2010, the EPA and the US Peace Corps signed a Memorandum of Understanding (MoU), including support for the Global Alliance for Clean Cookstoves in Ethiopia. For Ethiopia, the MoU will result in increased promotion of clean cooking stoves and education related to air quality issues, partly as a response to the burden of disease associated with the use of solid fuels. It is presumed that the large-scale distribution of more efficient stoves will help reduce pressure on biomass resources, increase land productivity – by reducing crop residue and dung usage for fuel – and improve family health. The intervention is expected to benefit women and children, in particular, by reducing fuel collection workloads and limiting exposure to flame hazards and the emission of harmful pollutants.[58]

In order to achieve the expected benefits, sufficient distribution of these improved stoves is necessary, and the preceding MoU could yield positive benefits in this regard. Further, if these benefits can be realized, biomass cook stoves have the potential to significantly contribute to reductions in the demand for biomass resources, while also combating land degradation, thus mitigating the effects of drought, as well as having the potential to yield

[57]The EPA (2004) estimates that if all rural and urban households (estimated to be about 14.44 million) in Ethiopia shift to the improved Lakech and Mirt stoves, a savings of about 7,778,800 tones of fuel wood (requiring the clear-cutting of 137,192.24 ha of forest) will be achieved on an annual basis.
[58]The World Health Organization (WHO, 2002) estimates that fumes from indoor biomass cook stoves kill 1.6 million women and children in developing countries, each year.

improvements in health. However, Nepal et al. (2010) show that improved cookstoves in Nepal do not yield reductions in the demand for firewood, while Sorrell et al. (2009) provide a summary of literature related to the rebound effect. The realization that improved cook stove technology has the potential to alleviate the pressure on biomass resources led to improved cooking stove programs in a number of developing countries, including Ethiopia; Barnes et al. (1994) provide an excellent survey of the programs put in place before 1994, as well as the lessons that could be learned from those programs, while Bhattacharya and Abdul-Salam (2002) provide a detailed description of programs in India and China. Similarly, by recognizing the benefits of improved stoves, a number of governmental institutions, such as the Ethiopian Rural Energy Development and Promotion Center (EREDPC), and other institutions, such as the Deutsche Gesellshaft für Technische Zusammenarbeit (GTZ), have been involved in the development and dissemination of different types of biomass cook stove technologies since the early 1970s in Ethiopia (EPA, 2004). However, Barnes et al. (1994) and Shanko et al. (2009), suggest that the efforts by these institutions to disseminate various types of fuel saving technologies have faced different problems at different times. Some of the stoves were not successful, due to problems related to the stove itself (technical problems); other programs were not successful, due to a lack of understanding of consumer tastes; still other programs were not successful, due to the lack of an appropriate promotion strategy.

Most available studies related to technology adoption, including those related to improved biomass cook stove technologies, such as Amacher et al. (1992), Zenebe et al. (2005) and Inayat (2011), have generally focused only on the dichotomous decision to adopt new technologies, and not considered the time lag associated with adoption. Although informative, these binary analyses are static and ignore the dynamic nature of the adoption process. Therefore, this research makes two contributions to the literature.

First, the available limited studies focus on rural areas, such that the urban sector is under-represented. However, the high dependence of urban dwellers on biomass resources has also contributed to the current environmental problems in the country. For example, charcoal, which is one of the main causes of deforestation in the country, is almost exclusively used in urban areas, irrespective of the level of living standards. Moreover, since many households cannot afford modern energy sources, such as kerosene, liquefied petroleum gas (LPG) and electricity, a substantial portion of the urban poor will continue to rely on fuel wood and charcoal. Therefore, focusing on urban households is useful, from the viewpoint of protecting forest cover, as well as reducing the ill effects of biomass fuel use on health.

Second, the commonly applied binary dependent variable analysis, which considers only adoption or non-adoption, does not account for adoption over time, since it does not allow for differences in the time to adoption by the households. This analysis, therefore, employs duration analysis, rather than static analysis, and, as far as we are aware, is the first to do so, within the context of improved cook stove technology adoption. The main objective of this research is to examine and understand the determinants of the speed of adoption of fuel saving technologies, especially for Mirt and Lakech cook stoves, in urban Ethiopia.[59] Though many factors, such as the technical design of the stove, are likely to affect the speed of adoption, the data available for this study allows us only to address socioeconomic factors associated with the dissemination of improved biomass cook stoves in urban Ethiopia.

The analysis unfolds in the usual fashion. The next section deals with the method of analysis. Section 3 discusses the stove technologies being examined in the analysis, as well as the data used in the analysis. The results of the empirical analysis are presented in Section 4, while Section 5 concludes.

2. DURATION ANALYSIS

The analysis of duration data, commonly referred to as survival analysis, has been applied in a number of situations in economics, as well as in demography and medicine. In terms of medical research, the focus is mostly on patient survival following disease diagnosis (Brookmeyer et al., 2002), or following the administration of a medical treatment (Locatelli et al., 2001). In demography, survival analysis is often applied in the examination of mortality rates and relates to the length of time a child survives from birth, or the time that a mother survives following childbirth; some examples include Lavy et al. (1996), Abou-Ali (2003) and Handa et al. (2010). Within economics, unemployment duration and the duration of strikes have often been examined via duration models, such as Kennan's (1985) and Jaggia's (1991) analyses of strike duration in the US manufacturing sector. Most relevant to this study, though, is the analysis of technology adoption, such as that by Dadi et al. (2004),

[59]Lakech and Mirt are local words meaning excellent and best, respectively.

Fuglie and Kascak (2001) and Burton et al. (2003), and the adoption of privatization policy analysed by Lee (2003). As argued by Burton et al. (2003) duration anlaysis has strengths compared with the conventional bivariate approaches. Conventional discrete choice models, such as logit or probit, cannot capture the intertemporal nature of the adoption process. Under these circumstances the use of duration models is superior to the analysis of adoption at a point in time.

Survival analysis depends primarily on the distribution of durations, or the length of survival times, in the population. Following the standard formulation, let $T \geq 0$ denote the duration, while t denotes a particular value of T. In our case, duration is the length of time, measured in years, until the household adopts the new technology. The cumulative distribution function (CDF) of T is defined as $F(t) = P(T \leq t)$, assuming $t \geq 0$. Assuming that T is continuous, the survivor function is defined as $S(t) = 1 - F(t) = P(T > t)$, the probability that a duration will last longer than time t, assuming survival up to t.

One of the central concepts in the analysis of duration data is the hazard function. Assuming an individual occupies a given state up to time t, the probability that such an individual exits from the state within an interval Δ, at or after t is $P(t < T \leq t + \Delta | T \geq t)$. Therefore, the average probability of leaving the state, per unit of time period over a short time interval Δ, at or after t, can be used to create the hazard function, the average probability over a vanishing time interval. Assuming a differentiable CDF, that hazard function is defined in (1).

$$h(t) = \lim_{\Delta \to 0} \frac{P(t < T \leq t + \Delta | T \geq t)}{\Delta} = \frac{f(t)}{S(t)} \tag{1}$$

As defined before, *S(t)* is the survival function, while *f(t)* is the probability density function. The hazard function specifies the instantaneous rate of completion of a spell at *T=t*, conditional upon survival up to time *t*. It is the rate at which spells will be completed at duration *t,* given that they last until *t.* In our case, the hazard function, therefore, represents the probability that a household adopts the improved stove at time *t,* given that it has not adopted before *t.* In the case of the adoption of fuel saving technologies, higher hazard rates indicate higher rates of adoption.

A variety of functional forms have been proposed for duration models; Keifer (1988) presents a very detailed summary of the different distributional assumptions behind these models, such as the logistic, Weibull, exponential, lognormal, and gamma probability distributions. The two most widely used parametric distributions are the exponential distributions and the Weibull distributions. The exponential distribution is characterized by a constant hazard function,$h(t) = \lambda$, where the constant parameter, $\lambda > 0$, implies that the passage of time does not influence the hazard rate. That is, subjects fail at the same rate through time and the hazard function constant. These hazards associated are referred to as memoryless. However, as technologies become more widely available, it may be preferable to allow for a hazard with memory. The other commonly applied distribution, the Weibull distribution, is characterised by the hazard function $h(t) = \lambda p t^{p-1}$, with $\lambda > 0$ and $p > 0$. Given this hazard function, the hazard rate for the Weibull distribution is constant, monotonically increasing or monotonically decreasing depending on p. It is monotonically increasing if $p > 1$, and decreasing if $p < 1$. In the case where $p = 1$, the Weibull hazard collapses to the exponential hazard, and is, therefore, constant.

Assuming the duration for each individual, t_i, is independent and not censored, the log-likelihood function for completed spells, assuming $\theta = (\lambda, p)$ is the vector of parameters and X is a matrix of potential time invariant explanatory variables, is given in (2).

$$\ell(\theta|X) = \sum_{i=1}^{N} \ln f(t_i|\theta, X_i) \tag{2}$$

However, in this analysis, as with most analyses of duration data, there are censored observations, especially right-censored observations. Information on the exact durations is not available for right-censored observations, only that they exceed the observable time horizon, such that survival to the end of the observable time horizon is known. Therefore, the density function in (2) cannot be applied; instead, it must be modified to allow for censoring. Thus, the log-likelihood function contains two components, one for non-censored, $d_i = 1$, observations and another for censored observations, $d_i = 0$; K in (3) represents the number of non-censored observations.

$$\ell(\theta|X) = \sum_{i=1}^{K} d_i \ln f(t_i|\theta, X_i) + \sum_{j=K+1}^{N} (1 - d_i) \ln S(t_i|\theta, X_i) \tag{3}$$

The preceding discussion, although conditioning on additional covariates, has ignored the inclusion of these factors within the likelihood function. Both the exponential and Weibull models are members of the proportional hazards family, which allow for the time component to be separated from the contribution of the other covariates within the structure of the hazard function: $h(t, X, \theta, \beta) = h_0(t, \theta)g(X, \beta)$, where β is a vector of parameters to be estimated, h_0 is the baseline hazard, and g is the relative hazard. The most common functional specification for the relative hazard is $g(X, \beta) = \exp(X\beta)$, which ensures non-negativity of the underlying hazard function. Furthermore, this proportional specification allows for easy interpretation of the results, since the marginal effect of a change in any $x \in X$ is simply the coefficient times the original hazard.[60] That specification is applied in the analysis for both the Weibull and exponential models.

Another member of the proportional hazard family is the Cox (1972) proportional hazard model. One of the most attractive features of Cox's model is that the baseline hazard need not be estimated. Further, the model does not impose any shape on the hazard function. It is only assumed that the hazard function is the same for each subject, and that given the covariates, the hazard between one subject and the other differs only by a multiplicative constant, based on the relative hazard. Given that this model does not specify the underlying hazard, it is also used in the analysis to check the robustness of the results.

The specifications described up to now assume that all individuals, households, in this case, are identical. However, it is likely that the data available to us does not explain all of the duration behaviour. Importantly, some of the unexplained behaviour could vary across households. This problem, unobserved heterogeneity, can create biases in the estimates, since each individual with the same values of all covariates may have different hazards out of a given state. Mathematically, the easiest solution is to multiplicatively append a stochastic term to the hazard function, $h(t, X, \theta, \beta) = h_0(t, \theta)g(X, \beta)\varepsilon$, and assume a distribution for that stochastic term. One common assumption applied in the literature is that the stochastic term follows the gamma distribution. Below, we consider the Weibull-gamma mixture

[60] See Cameron and Trivedi (2005:593) for details.

model, as described in Cameron and Trivedi (2005) and applied by Gutierrez (2002), and test for unobserved heterogeneity in our duration models.[61]

3. ANALYSIS DATA

The data for the empirical analysis come from the 'Mirt Biomass Injera Stoves Market Penetration and Sustainability' study conducted by Megen Power Limited in 2009. The survey was conducted in Amahra, Oromiya and Tigray Regions. Three towns from each region were selected for the survey; hence, the total survey was conducted in 9 towns. For the purpose of sampling, towns were classified into three categories: High-Sales Towns, Low-Sales Towns, and Non-Project Towns. The sample size for each region and town was determined proportionately based on the total number of households. Finally, based on sampling frames (lists of households) obtained from the respective Kebeles, households were selected using a simple random sampling technique. The towns selected for the study are presented in Table 5.1.

Table 5.1: Sample Location Information

Region (Total)	Town	Sample size	Percent
Amhara (580)	Bahirdar	424	26.89
36.80%	AmbaGiorgis	60	3.80
	Dagolo	96	6.09
Oromiya(667)	Atnago	66	4.19
42.30%	Goba	409	25.94
	Kofele	192	12.18
Tigray (330)	Hiwane	51	3.23
20.93%	Mehoni	177	11.22
	AdiDaero	102	6.47

Both groups of households with and without Mirt biomass injera stoves were included. Accordingly, the Oromiya region was allocated the largest share of the sample, 667 households (42.3%) followed by Amhara with 580 households (36.8%) and Tigray with 330 (20.9%). Therefore, the total number of sample households was 1577. The questionnaire was further refined prior to fieldwork, through discussion and joint review with enumerators; pre-

[61]Unfortunately, the Weibull-gamma mixture model for the Lakech stove duration did not converge, so we were not able to test for unobserved heterogeneity.

testing of the questionnaire was undertaken with a few households before the main sample interviews.

3.1 Lakech and Mirt Stoves

Various types of improved biomass cook stoves have been disseminated in both urban and rural Ethiopia. In this analysis, we will consider only the two most commonly used types of improved stoves, called 'Mirt improved biomass *injera* stove' and 'Lakech charcoal stove'. The Mirt *injera* stove, which is made from cement and pumice, was designed by the Ethiopian Energy Studies Research Center in the early 1990s; one of their goals was to alleviate environmental degradation (pollution and deforestation or forest degradation). When properly utilized, it serves for approximately 8 years. It is used to cook *injera*, which is the main staple food of Ethiopia. *Injera* baking is the most energy-intensive activity in Ethiopia. It accounts for over 50% of all primary energy consumption in the country, and over 75% of the total energy consumed in households.[62] This stove has been promoted and widely distributed in the country, because it can achieve fuel efficiency of up to 40% over the open fire stove (Yosef, 2007; Shanko et al., 2009). In addition, the reduction of carbon monoxide (CO) concentration during baking is one of the expected benefits of the technology (Yosef, 2007). However, the reduction in particulate matter (PM), another indoor air pollutant, resulting from the use of the Mirt stove is not significant. According to Yosef (2007) the insignificant reduction in PM could have due to the small sample used for the study, and, therefore, improvements in indoor air quality due to use of the Mirt stove, in terms of PM, requires additional investigation.

The Lakech charcoal stove, on the other hand, is made from clay, sand, cement and sheet metal for cladding. Each Lakech stove saves an average of 75 kg of charcoal per household per year,[63] thus, according to EPA (2004), providing a 25% savings over the traditional open fire stove. As discussed in the introduction, thousands of hectares of forests can be saved due to the adoption of improved biomass cook stoves, such as the Lakech stove.

In this analysis, the duration of interest is the length of time it takes a household to adopt either of the two improved biomass cook stove technologies. The date for the start of the

[62] See http://www.tve.org/ho/series1/reports_7-12/Mirte_Stoves_Ethiopia.html.
[63] Retrieved from http://stoves.bioenergylists.org/stovesdoc/Bess/Mirte.htm. According to Bess (1998), the forest savings from the use of the Lakech was equal to the equivalent of over 2,000 hectares of important dryland forest in Ethiopia.

duration for each household is defined as the date at which the improved biomass stove was first introduced in the area. According to a report by Shanko et al. (2009), EREDPC first developed the Mirt biomass injera stove in the early 1990s, while, according to Bess (1998), commercial production of Lakech charcoal stoves began in 1991.[64] Therefore, the dependent variable used in the analysis is the time (in years) households waited before adopting either Mirt or Lakech improved stoves, measured by the number of years elapsed since their introduction, which was taken to be 1991 and 1994 for Lakech and Mirt biomass cook stoves, respectively.[65] For those households who had not yet adopted, the duration was right-censored at the year of data collection. That is, we know the period of introduction of the technology (the beginning of the duration), but we do not know the end for some observations. Note that if the household was formed after the introduction of the technology, duration was calculated from the year the household was formed.[66] The start date is the time when the improved biomass cook stoves were first introduced and the exit date, or the end of the spell, is the time at which the household adopts the fuel saving technology. In other words, reduced time to failure actually means reduced time to adoption of the technology; the results, below, are interpreted with that feature in mind.

Table 5.2 shows the adoption proportions of both stoves by sample region. Adoption of Lakech charcoal stove is relatively higher in Amhara region followed by Oromiya and Tigray. But the proportion of households who adopted Mirt injera cook stove is relatively higher in Oromiya, followed by Amhara and then Tigray region. There is not much difference in the average time of adoption between the two types of stoves. The median time of adoption of Mirt and Lakech predicted, for example, by the Weibull distribution, results discussed below, is 15.66 and 16.94 years, respectively.

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[64]A few households, in the sample, report purchasing the Lakech charcoal stove before 1991, which should not be; therefore, these households were removed from the analysis. Moreover, some households do not provide a clear purchase year; these households were also removed. A similar strategy was adopted for dealing with the Mirt biomass cook stove.

[65]Different documents report different periods for the introduction of both Mirt and Lakech biomass stoves. Lack of consistency in the various reports made it difficult to define the period of introduction of the fuel saving technologies. Moreover, there is no information on the specific year for the introduction of each technology in each region. So we take the same year for all surveyed households.

[66]However, the survey does not have any information on the year of marriage or the time the household was formed. We took year of marriage for those households to be year 18(which is the minimum year for marriage according to the Ethiopian family law).

Table 5.2. Mirt and Lakech biomass cook stove adoption by sample region

	TOTAL		Oromiya		Tigray		Amhara	
Variable	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Lakech	0.346	0.476	0.357	0.479	0.201	0.401	0.418	0.494
Mirt	0.254	0.435	0.340	0.474	0.100	0.301	0.243	0.429
Obs	1557		659		329		569	

3.2. Summary statistics of analysis data

The data also includes information related to each household's socioeconomic characteristics, such as: income; the age, education level, gender and occupation of the household head; type and ownership of improved biomass cook stoves; type and ownership of substitutable cook stoves;[67] children and adults in the household; house ownership and characteristics of the house. Although the initial sample contained 1577 observations, some observations were dropped due to insufficient or missing data. Importantly, households not using biomass for *injera* baking (13 households) are omitted. Moreover, household heads reporting their age to be less than 18 (two in number) are also omitted from the analysis. Thus, the total number of households used in this study is 1557.

Descriptive statistics and the definitions of the explanatory variables included in the analysis are presented in Table 5.3.[68] Education is expected to affect the adoption decision of many technologies. In this case, educated household heads are assumed to be more aware of the environmental and health effects of using biomass fuels, and, therefore, we expect education to increase the speed of adoption. Given that children and women are the ones most likely to be exposed to the indoor air pollution, female-headed households with children are expected to adopt more quickly than male-headed households with children. In this analysis, children are all household members below the age of 15 years.

[67]More than 85% of the household who are using electric Mitad have secondary education or above, possibly suggesting that education is important for households to move up the energy ladder. Note that the preparation of injera requires an appliance known as Mitad, a circular clay pan used for baking *injera*. The electric Mitad is relatively widely used in urban areas.

[68] As expected, the majority of households are dependent on biomass energy sources for baking injera – only 7.8% of the sampled households use electricity for baking injera.

Table 5.3: Descriptive statistics of the covariates of fuel saving technologies

Variable	Mean	S.D.	Min	Max
Sex of HH head (1 if male, and 0 if female)	0.68	0.47	0	1
Age of HH head at the time of the survey	44.88	13.50	18	102
EDUCATION				
Dummy 1 if the household head is illiterate, 0 otherwise	0.21	0.41	0	1
Dummy 1 if the head can read and write or elementary or junior(1-8), 0 otherwise	0.42	0.49	0	1
Dummy 1 if the head is between grade 9 & 12, 0 otherwise	0.20	0.40	0	1
Dummy 1 if the head has a certificate or above), 0 otherwise	0.17	0.37	0	1
Number of children whose age is less than or equal to 15)	1.75	1.54	0	14
Number of adult members of the family	3.38	1.87	1	15
Ownership status of the house (1 if privately owned, and 0 otherwise)	0.72	0.45	0	1
Ownership of separate kitchen (1= Yes , 0 = No)	0.75	0.44	0	1
INCOME				
Monthly income is less than 500 Br(1= Yes , 0 = No)	0.57	0.49	0	1
Monthly income is between 501 & 1499(1= Yes , 0 = No)	0.30	0.46	0	1
Monthly income is between 1500 & 2499 (1=Yes, 0=No)	0.09	0.29	0	1
Monthly income is above 2500 (1= Yes , 0 = No)	0.04	0.20	0	1
A dummy for electric Mitad, a substitute for Mirt (1 if the hh has electric Mitad and 0 otherwise)	0.08	0.27	0	1
A dummy for Metal stove, a substitute for Lakech (if the HH has metal charcoal stove, 0 otherwise)	0.48	0.50	0	1
A dummy for clay stove (if the HH has clay stove, 0 otherwise)	0.31	0.46	0	1
Dummy Tigray region (1 if Tigray, 0 otherwise)	0.21	0.41	0	1
Dummy for Amhara region (1 if Amhara and 0 if not)	0.37	0.48	0	1
Dummy for Oromiya region) (1 if Oromiya, 0 if not)	0.42	0.49	0	1

NOTE: The signs on the second parenthesis show the expected sign.

In the literature on technology adoption, income is one of the consistently significant factors determining household decisions to adopt new technologies (see, for example, Burton et al., 2003; Fuglie and Kascak, 2001). Although the energy ladder hypothesis[69] argues that increases in income will change household demand for source of energy, Barnes et al. (1994) have argued that the introduction of improved cook stove technology, could be a new step in the energy ladder, lying between traditional biomass stoves and the modern fuels and appliances. Therefore, we assume that the Barnes et al. (1994) hypothesis holds, such that wealthier households are able to move up the energy ladder by adopting more efficient technologies, since households with high incomes are more able to afford such purchases. In

[69]The energy ladder is a concept used to describe the way in which households will move to more sophisticated fuels as their income increases; see Mishra (2008). Roughly, households are assumed to move from fuel wood to kerosene, to LPG and then to natural gas and electricity.

addition, we include two additional measures of wealth, based on the ownership of their own home and the availability of a separate cooking facility.[70] Although such a facility could realistically reduce the health effects of biomass fuel use and reduce the demand for improved cook stoves, we hypothesize that the wealth effect dominates the health effect, such that households having the ability to access a separate cooking facility are more likely to adopt improved cook stoves.

A number of other variables are likely to affect the speed of adoption of new technologies. For example, we expect that household perceptions related to biomass fuel availability, information related to trends in the price of biomass fuels, as well as information related to the price of Lakech, Mirt and substitute cooking technologies are important determinants of technology adoption and the speed of adoption. However, although the survey included questions related to household perceptions and trends in biomass fuel prices, few households provided answers, and, therefore, it was not possible to include this data in the analysis. Moreover, the responses related to household perceptions of biomass availability do not show significant variation; thus, even if these perceptions were to be included, the results would be insignificant. Unfortunately, the price of both Lakech and Mirt injera biomass cook stoves and the price of substitutes (other similar stoves serving the same purpose) are not included, because there is no data available. Moreover, the prices may not reflect the actual market price, since the involvement of non-governmental organizations results in market distortions. However, we have included regional dummy variables to control for differences in prices and NGO participation in the local markets.

4. RESULTS OF DURATION ANALYSIS

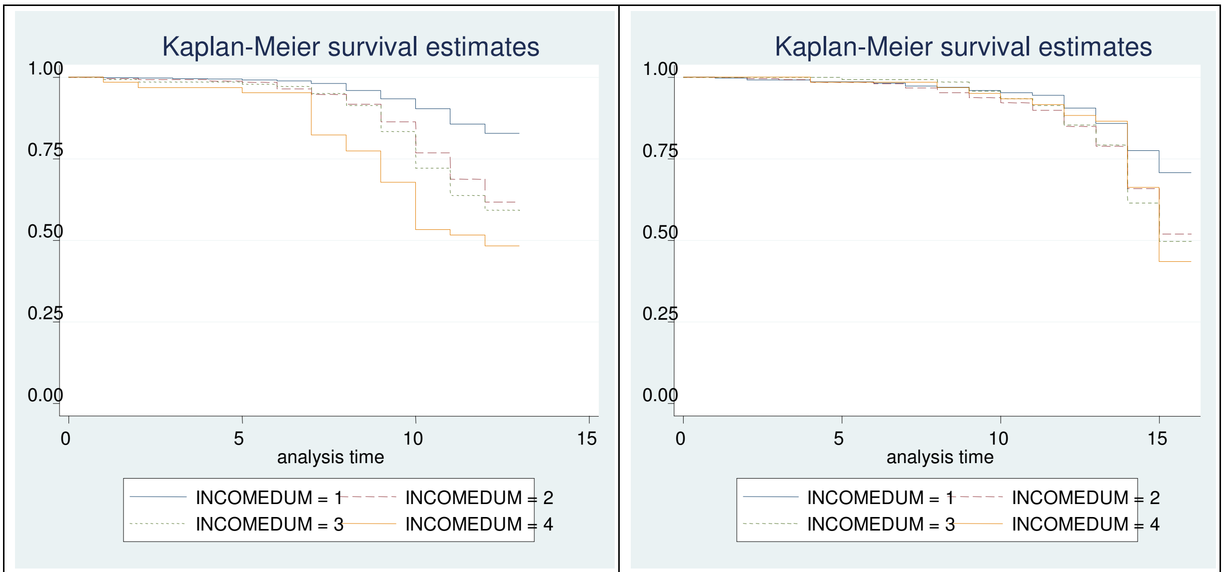
4.1. Nonparametric Results

Before undertaking parametric duration analysis, a simple test of the effect of income on the survival rate is performed, making use of the Kaplan-Meier estimator (Kiefer, 1988). The Kaplan-Meier estimator is non-parametric, meaning that no assumptions regarding the underlying distribution of survival times are made. The primary advantage of the estimator is that it can easily accommodate right censoring in the data. The estimator requires dividing the period of observation into a series of intervals, each containing one or more adoptions at its beginning. The estimator is essentially the ratio of number of survivors to the number of

[70] Around 72% of the households own their own home, while 75% of them have a separate kitchen for cooking.

observations at risk, in each time interval. Figure 1, below, shows the survival functions for the Mirt biomass injera stoves by income level, based on the Kaplan-Meier estimator.

In Figure 5.1, the non-parametric survival function is plotted for each of four different income categories, for both stove types. As can easily be seen, the survival function for income category 1 is higher than the survivor function for category 2, which is higher than that for category 3, which is, in turn, higher than for category 4, where income is highest in category 4 and lowest in category 1. The results suggest that households in the lowest income bracket (less than or equal to 500 Birr) are the least likely and slowest to adopt, while those in the highest income bracket (above 2500 Birr) are the most likely and quickest to adopt. However, a formal test of that relationship is necessary. Both the logrank and Wilcoxon test confirm the ranking; thus the speed of adoption rises with income level.[71]



Panel A: Mirt Stove | Panel B: Laketch stove

Figure 5.1. Survival function for Mirt and Lakech biomass cook stoves

4.2. Results of Parametric Regression

The remainder of the discussion focuses on parametric duration analysis, in which numerous specifications were estimated. Note that in parametric regressions, right censoring must be accounted for, following equation (6).[72] The appropriateness of the model specifications has also been examined through various diagnostic methods for model specification. The primary

[71]The tests reject equality at the 1% significance level. The results of these tests for the Lakech stove are similar, and not reported, but available from the authors upon request.
[72] In STATA, this is accomplished by setting the data to be survival time data and accounting for event failures.

diagnostics are based on the results of the Akaike's Information Criterion (AIC) and the Bayesian Information Criterion (BIC). Each of these criteria prefers the Weibull model to the exponential model for both the Mirt biomass stove and the Lakech charcoal stove. Although the information criteria prefer the Weibull model, we report the results of both the Weibull and exponential models for comparison purposes.[73]

Another problem in duration analysis, as is true for most statistical analyses, is unobserved heterogeneity, which leads to biased estimates, as discussed in Section 2. Following Gutierrez (2002), the Weibull regression model, with gamma-distributed heterogeneity using the frailty (gamma) option to streg in STATA, is fitted to the data. The results of the analysis suggest that frailty, or unobserved heterogeneity, is an important feature of Mirt biomass cook stove adoption decisions.[74]

Tables 5.4 and 5.5 present the results of the Weibull estimation for Mirt and Lakech stoves, respectively. A final robustness comparison is also included in the analysis. Since the Cox proportional hazard model does not parameterize the baseline hazard, it is not necessary to specify or estimate the shape of the hazard function. Therefore, the Cox results are robust to misspecification of the hazard function; however, it should also be noted that both the Weibull and exponential models are special cases of the proportional hazard family. With respect to the Lakech charcoal stove adoption analysis, the duration model parameters are qualitatively similar, suggesting that the choice of specification does not have a significant impact on the results, at least within this subset of the family of proportional hazard models.

As noted in Section 2, the hazard rate is assumed to be constant in the exponential model, while, in the Weibull model, the hazard can be monotonically increasing, monotonically decreasing or constant. The results in both Tables 5.4 and 5.5 suggest that the estimate of the shape parameter, *P*, is significantly greater than one, i.e., the hazard is monotonically increasing. In other words, the rate of adoption is increasing, which is not completely surprising. As technology becomes more widespread, its use should become more and more common.

[73] A Cox proportional hazards model was also estimated, and these results are also presented.
[74] However, the Lakech charcoal stove duration model with frailty did not converge, and, therefore, unobserved heterogeneity was not included in the analysis.

Table 5.4: Determinants of Mirt injera biomass cook stoves adoption

	Weibull*	Weibull	Exponential	Cox
Variables	Coef.	Coef.	Coef.	Coef.
Sex of HH head	-0.321**	-0.278**	-0.251*	-0.264**
	(0.15)	(-0.13)	(0.13)	(0.13)
Age of HH head	0.006	0.006	0.010**	0.007
	(0.01)	(0.00)	(0.00)	(0.00)
The head can read and write, elementary, junior	0.636***	0.580***	0.558***	0.571***
	(0.22)	(0.20)	(0.20)	(0.20)
The head is between grade 9 & 12	1.240***	1.129***	1.020***	1.096***
	(0.25)	(0.22)	(0.22)	(0.22)
The head has a certificate or above	1.085***	0.984***	0.907***	0.976***
	(0.27)	(0.24)	(0.24)	(0.24)
Number of children and youths	-0.042	-0.038	-0.018	-0.035
	(0.04)	(0.03)	(0.03)	(0.03)
Number of adult members of the family	0.088***	0.076***	0.064***	0.074***
	(0.03)	(0.03)	(0.03)	(0.03)
Ownership status of the house	0.296*	0.240*	0.252*	0.242*
	(0.15)	(0.13)	(0.13)	(0.13)
Possession of electric Mitad	0.206	0.118	0.103	0.132
	(0.20)	(0.16)	(0.16)	(0.16)
Ownership of separate kitchen	0.486***	0.455***	0.436***	0.428***
	(0.17)	(0.15)	(0.15)	(0.15)
Monthly income is between 501 & 1499	0.695***	0.619***	0.581***	0.591***
	(0.15)	(0.13)	(0.13)	(0.13)
Monthly income is between 1500 & 2499	0.692***	0.641***	0.595***	0.606***
	(0.22)	(0.19)	(0.19)	(0.19)
Monthly income is above 2500	1.303***	1.123***	0.982***	1.096***
	(0.30)	(0.23)	(0.23)	(0.23)
Dummy Tigray region	-1.184***	-1.096***	-0.970***	-1.050***
	(0.22)	(0.20)	(0.20)	(0.20)
Dummy for Amhara region	-0.447***	-0.432***	-0.365***	-0.402***
	(0.14)	(0.12)	(0.12)	(0.12)
_cons	-11.995***	-11.13***	-5.559***	
	(0.76)	(0.52)	(0.35)	
/ln_p	1.287***	1.191***		
	(0.07)	(0.05)		
/ln_the	-0.343			
	(0.61)			
p	3.620	3.291		
	(0.26)	(0.15)		
1/p	0.276	0.304		
	(0.02)	(0.01)		
theta	0.710			
	(0.43)			

*Weibull regression model, with gamma-distributed heterogeneity using gamma distribution.
Likelihood-ratio test of theta=0: chibar2(01) = 3.05 Prob>= chibar2 = 0.040. The definition of the dummy variables is presented in table 5.3.

Table 5.5: Determinants of Lakech charcoal stove adoption

	Weibull	Exponential	Cox
Variables	Coef.	Coef.	Coef.
Sex of HH head	0.114	0.092	0.100
	(0.11)	(0.11)	(0.11)
Age of HH head	-0.036***	-0.017***	-0.036***
	(0.00)	(0.00)	(0.00)
The head can read and write, elementary, junior	-0.039	-0.012	-0.029
	(0.14)	(0.14)	(0.14)
The head is between grade 9 & 12	-0.015	0.031	0.001
	(0.16)	(0.16)	(0.16)
The head has a certificate or above	0.156	0.197	0.142
	(0.17)	(0.17)	(0.17)
Number of children and youths	-0.043	-0.001	-0.042
	(0.03)	(0.03)	(0.03)
Number of adult members of the family	0.069***	0.061**	0.065***
	(0.02)	(0.02)	(0.02)
Ownership status of the house	0.117	0.124	0.118
	(0.11)	(0.11)	(0.11)
Possession of metal stove	-0.906***	-0.787***	-0.866***
	(0.11)	(0.11)	(0.11)
Ownership of separate kitchen	-0.053	-0.003	-0.056
	(0.11)	(0.11)	(0.11)
Monthly income is between 501 & 1499	0.378***	0.356***	0.355***
	(0.11)	(0.11)	(0.11)
Monthly income is between 1500 & 2499	0.351**	0.335**	0.339**
	(0.17)	(0.16)	(0.17)
Monthly income is above 2500	0.541**	0.507**	0.499**
	(0.22)	(0.21)	(0.22)
Dummy Tigray region	-0.045	-0.031	-0.069
	(0.16)	(0.17)	(0.16)
Dummy for Amhara region	0.044	0.038	-0.003
	(0.10)	(0.10)	(0.10)
_cons	-11.391***	-3.236***	
	(0.52)	(0.26)	
/ln_p	1.481***		
	(0.04)		
p	4.397		
	(0.17)		
1/p	0.227		
	(0.01)		

Note that the frailty model do not converge in all the specifications of Lakech charcoal stoves. The definition of the dummy variables is presented in table 5.3.

In order to interpret the rest of the results, it is important to recall that a negative estimate implies that failure is less likely, meaning that adoption is less likely, while a positive estimate implies that failure is more likely, meaning that adoption is more. For the variables that are measured as categories or levels (income and education), the bottom category was left out, illiterate in the case of education and the lowest income bracket in the case of income, to avoid the dummy variable trap, yielding estimates that are relative to the base category. In terms of our results, both education and income increase adoption rates for the Mirt biomass stove. However, only income increases the speed of Lakech charcoal stove adoption. The results accord with those of Jones (1989), cited in Barnes et al. (1994); middle-income families have adopted improved stoves far more quickly than poor families in most African countries. On the other hand, these income results may also indicate that households will not shift to other, better, sources of energy as their income increases, as postulated by the energy ladder hypothesis, unless we consider the variant of the energy ladder hypothesis proposed by Barnes et al. (1994). Importantly, Masera et al. (2000) note that the original energy ladder hypothesis does not appropriately account for other factors that are likely to affect household switches to modern energy services, such as: affordability, availability, and cultural preferences. Therefore, since the majority of households that depend on biomass are poor, the design and price of new and improved biomass cook stoves should consider poor households capacity to purchase the new technology.

The estimated coefficient for home ownership and separate kitchen facilities suggests that wealth increases the rate of adoption of the Mirt Biomass injera stove, but does not affect the adoption of the Lakech charcoal stove. Mirt is a domestic appliance requiring additional space, due to the fact that it is larger in size than many modern and improved biomass cook stoves. Hence, as Shanko et al. (2009) note, its installation and proper utilization requires access to additional facilities. However, the Lakech charcoal stove is simple and easily mobile, and, therefore, does not require additional space. As a result, it is not surprising that home ownership and access to a separate kitchen are not significant factors in the adoption of Lakech stoves.

We initially hypothesized that female-headed households with many children would favour adoption of these new cook stove technologies, since both women and children are assumed to be most affected by indoor air pollution. However, the results are not consistent across stove types. Female-headed households are more likely to adopt the Mirt biomass cook stove, while the gender of the household head does not significantly affect the adoption of Lakech charcoal stoves. In terms of children, although the sign does agree with our hypothesis, the effect is insignificant across both types of improved cook stoves, although this result could be due to the inability to separate very young children from older children in the analysis

The analysis also included substitute technologies, and their effect on the adoption of Mirt and Lakech cook stoves. In the analysis, the electric Mitad is assumed to be a substitute for the Mirt stove; however, the empirical results do not support the hypothesis that the availability and use of substitute technologies will reduce the speed of adoption of other related technologies. Possibly, the result is due to differences in relative costs. For example, the relative cost of using electric Mitad might be too high, compared with the cost of using the Mirt *injera* biomass cook stove. Zenebe et al. (2010) find that the high cost of the stove was the main reason for not adopting the electric Mitad stove in the Tigray region in Ethiopia, despite the fact that about 80 percent of sample households used electricity in the region. Another possible justification for this is that the two stoves use different fuel type (i.e. biomass and electricity). Hence the unreliability of power supply in the country may also force some households to possess Mirt *injera* stove. On the other hand, the metal charcoal stove is assumed to be a substitute for the Lakech charcoal stove, and the results do support the substitution hypothesis. Households with a metal charcoal stove are less likely to adopt the Lakech charcoal stove. Given the better performance of the Lakech stove, over that of the metal stove, this reduced adoption rates for substitute stoves, although understandable, implies that additional policies and programs may need to be put in place to increase the rate of adoption of the technically superior Lakech stove.

Finally, as noted above, location variables were included in the analysis to control for effects that differ across regions. The results show that there are regional differences in the speed of adoption of the Mirt stove, but not for the Lakech stove. The speed of adoption of the Mirt stove is lower for households in Amhara and Tigray, compared to households residing in Oromiya. Since the former regions are associated with low levels of biomass, a different result might have been expected. However, the result would be justified if households in the Oromiya region have either better exposure to the new technologies, or face lower prices, due to the level of involvement of NGOs in the region. Unfortunately, our data does not allow us to further test this hypothesis.

5. CONCLUSIONS AND POLICY IMPLICATIONS

The heavy dependence and inefficient utilization of biomass resources for energy have resulted in high depletion of the forest resources in Ethiopia. Traditional cooking technologies, one source of inefficient utilization of biomass resources, as well as a source of indoor air pollution and ill health associated with the inhalation of smoke, has led policymakers to seek the advancement of affordable alternative cooking technologies that use fewer resources and result in less pollution. In Ethiopia, two different alternative cook stove options have received the most attention, the Mirt biomass cook stove and the Lakech charcoal stove. Although a number of studies have shown that these stoves use less biomass resources, and can, thus, be assumed to result in less innocuous health effects, these technologies have not been universally adopted in Ethiopia. This study, therefore, examines the adoption of these technologies through the application of duration analysis to data recently collected in selected towns in three regions of Ethiopia to understand the determinants of adoption.

The analysis of the speed of adoption of improved stoves is important for many stakeholders, both governmental and non-governmental organizations, in many ways. For example, if richer households adopt more quickly than poorer households, as shown here, then the design and dissemination of the stoves should reflect the interest, or preference, as well as the income level of the household. If, on the other hand, the speed of adoption is affected by the lack of awareness of the potential benefits of these stoves, which could not be considered here, due to inconsistencies in the data, it is likely that different strategies could be devised to introduce and disseminate the technologies, or at least educate the population about the benefits of these technologies via demonstrations, posters, and radio or TV advertisements. Furthermore, the analysis can provide information for stove producers and other stakeholders, regarding the pattern of demand for new stoves and, hence, can be good for production planning. Finally, as already noted, given the importance of reducing pressure on biomass resources, increasing land productivity and reducing the ill effects of indoor air pollution, understanding the determinants of adoption, as well as the speed of adoption, can provide information that policy makers can use to increase the speed of adoption.

The results of the analysis support the argument by Barnes et al. (1994), in which energy efficiency might be an intermediate step along the road to more modern energy services.

Along these lines, both Mirt and Lakech stove adoption is shown to increase with income. Similarly, since lower income households are less likely to adopt these more efficient cooking technologies, the research also suggests that other policy options must be implemented, most likely policies to reduce the initial purchase price, if adoption rates are to be increased. The survival analysis also supports the contention that, as adoption becomes more widespread rates of adoption tend to increase. Furthermore, substitution, at least in the sense that the alternative is readily accessible, matters. In the case of the Mirt stove, the availability of the electric Mitad alternative does not affect adoptions rates, which could be due to the better performance of the Mirt stove in reducing the energy cost of preparing the staple food, injera. Due to data limitations, our analysis could not speak directly to the reasons as to why households did or did not adopt the various technologies; thus, further analysis is warranted such that policy makers and/or energy planners can further assess the potential impact of electric Mitad stoves, and other improved biomass cook stoves, on overall welfare and biomass use (forest pressure). However, in the case of the Lakech stove, the metal alternative does significantly reduce adoption rates.

Given the importance of the improved stoves in saving biomass resources and reducing indoor air pollution, as well as the inability of this study to control for differences in prices and perceptions related to the benefits of improved cook stove technologies, future research must give more attention to collecting information related to prices, and examine the impact of prices on the adoption of improved biomass cook stoves. However, Muneer and Mohamed's (2003) study in Sudan shows that the convenience of new stoves over the traditional stoves has increased the consumption of fuel wood and/or charcoal. This rebound effect, as it is called, could not be examined here, since data on fuel use was not included in the study. Therefore, future research in this area should also address the rebound potential, by collecting additional data on biomass fuel consumption across households with different types of cook stoves, in order to determine whether or not the presumed reductions in forest degradation can be realized through the adoption of energy saving technologies, such as improved biomass cook stoves.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Ethiopia is endowed with different types of natural resources. Forests are vital for the welfare of tens of million of Africans, especially the poor and marginalized, and over two thirds of the world's population rely directly or indirectly on forests for their livelihoods (CIFOR, 2004). The reliance of poor people on natural resources for survival, leads to depletion of resources and exacerbating environmental stresses. Since the majority of the population in Ethiopia are rural households (85%), the management and use of these resources directly affects the lives of the people. Many depend on forests for fuel wood, timber, food, grazing, shade, medicinal values, etc. However, the proportion of land with forest cover has been diminishing at an alarming rate. Land area covered by forests has gone down from approximately 40% at the turn of the century to approximately 3.6% at the present time (WBISPP, 2004). Although reliable statistics are absent, a widely quoted estimate indicates that the deforestation rate in Ethiopia ranges between 150,000-200,000 ha per year. Depletion of these resources have resulted in reduced agricultural productivity and subsequently in reduced quality of life of the rural people (EPA, 1998).

In the literature various factors are mentioned as causes of forest degradation and/or deforestation in developing countries. According to the world Growth report (2009), conversion of forests to other land uses, particularly for agricultural expansion and acquisition of fuel wood is generally recognized as the main driver of land-use change and deforestation in the developing world. In Africa illegal logging, fire, fuel wood collection, and shifting cultivation are the four main reasons but their importance varies between countries (FAO, 2009). The demand for agricultural land, fuel wood, construction materials, and policy failure and institutional factors are the main drivers of the change in the forests cover in Ethiopia. Poverty also plays a major role in the current environmental degradation problem in Ethiopia as in many other developing countries.

Despite the importance of forests and forest products to the livelihood of the people, empirical evidences on the forest people interaction are still scanty in Africa in general and Ethiopia in particular. Cavendish (2000) has also explained that we do not have enough empirical evidences on the interaction between natural resources and people in Africa. This is because data on environmental resources in Africa is generally absent as survey data collection on environmentally resources is costly (Cavendish, 2000). A detail review by Cooke et al. (2008) on fuel wood related studies conducted in various parts of Asia and Africa clearly indicated that there are very limited empirical evidences on the nature of the link between consumption, production and households' behaviour towards fuel wood scarcity in developing countries. Rigorous empirical evidences on the link between people's livelihood and forest degradation are still scanty. The limited available empirical evidences are not consistent and convey mixed results. Understanding this gap, this thesis focuses on investigating the relationship between rural household energy use and forest degradation, and empirically examine and understand the link between local level institutions, property rights and forest dependency. Moreover, the determinants of one of the demand side approaches, adoption of fuel saving technologies, were also examined in urban Ethiopia. Therefore, the thesis has tried to address the following issues: How do people respond when faced with scarcity of environmental goods (fuel wood) under different environmental conditions? What are the socioeconomic and environmental factors that affect the preference of rural households to collect forest resource (fuel wood) from a particular source? How is the level of dependence of these households on forest products and what factors determine the amount of income derived from forest resources? How is the nature of the link between different property right regimes and use of forest resources? Are local level institutions affecting the use of forest products, especially non wood forest products in rural Ethiopia? Finally, the thesis addresses the socioeconomic and environmental factors that help to speed up the adoption of fuel saving technologies in urban Ethiopia.

This study has contributed to the literature in many ways. First, it tries to examine the response of rural households by classifying the study area in to low and high forest cover regions. Many studies do not link the fuel wood problem with the state of forests. This study used GIS data to relate forest degradation level with the coping mechanisms of rural households when faced with fuel wood shortages. Second, it adds to the limited empirical literature on the role and determinants of forest dependency by emphasizing the role of local level institutions and property right regimes. Here the role of forest products in the livelihood of the people and the various socioeconomic and environmental factors that affect forest dependency in rural Ethiopia are analysed by using appropriate econometric strategies. Third, it applies duration econometrics to the analysis of the adoption of biomass cook stoves in Ethiopia. Last, each chapter in the thesis adds to the limited empirical studies in Africa in general. Most available studies focus on few countries in Asia and additional studies from other countries in other regions will help to make inference about the forest people interaction (Cooke et al., 2008).

In order to address the various issues indicated above, household survey data collected in different pars of the country (urban and rural) were used for the empirical analysis. Sample households were chosen based on a simple random sampling technique. In addition, community level surveys were also gathered to get villagers' attitude and perceptions on their local forest management, and use. Secondary information from various government organizations was also collected. A different household survey data conducted in different towns of the country was used for the analysis of covariates of fuel saving technologies in urban Ethiopia.

To achieve the above stated objectives this study combined various approaches. The theoretical framework is based on farm household model that assumes that both production and consumption decision of the household are inseparable. The random utility framework was employed for the analysis of the choice of fuel wood sources. Empirically, the thesis employed different econometric models depending on the nature of the problem to be addressed. Econometric models such as Heckman sample selection, discrete choice model, OLS and duration econometrics were employed for the empirical analysis. Finally, based on the results of the empirical analysis**,** important findings and policy implications from each chapter are discussed. At the end, issues for further research in related areas are also highlighted.

The empirical part of the thesis starts with analysing the coping mechanisms of rural households to fuel wood scarcity by using a survey of randomly selected rural households in Ethiopia. As described earlier, as opposed to most other studies, it uses information from a GIS survey to classify the study area into relatively low and high forest cover regions. Rural household's behaviour towards fuel wood was examined separately for relatively low forest cover and high forest cover areas, while pooled regressions were considered for the collection or production of other biomass sources, i.e., dung and crop residues.

The results of the empirical analysis show that rural households residing in forest degraded areas respond to fuel wood shortages by increasing their labour input to fuel wood collection.

However, households in HFC areas respond neither to the physical measure nor to economic measure of fuel wood scarcity. For households in HFC regions forest stock (negatively) and biomass availability (positively) may be more important factors than scarcity of fuel wood in determining household labour input allocation. The study also finds that there is no evidence for substitution between fuel wood and dung or fuel wood and crop residues. The implication of our finding is that supply-side strategies, alone, may not be effective, if the aim is to reduce forest degradation and biodiversity losses, and simultaneously increase the supply of dung and residues for soil management. Any policy intervention that adopts demand side strategies (for example, adoption of improved biomass cook stoves) should give priority to the relatively forest degraded areas in order to reduce fuel wood consumption (and hence decrease the burden of the household) and release dung and residues to the soil for agriculture. Population pressure in all regions, in general, and in LFC regions, in particular, contributes to forest degradation and a loss of biodiversity, in rural Ethiopia, where encroachments for agriculture and grazing are common. As explained by Heltberg et al. (2000), the underlying factors responsible for forest degradation or deforestation in the area need to be addressed if specific forest policies, such as afforestation and area enclosure establishments, are to be effective at the local level. Moreover, specific forest polices on increasing forest stock will be more effective if it takes into account the population pressure in the local area. We have also learned that rural households behaviour in the use of natural resources in general and fuel wood in particular varies in different level of forest degradation. The implication is that policy instruments that are designed to reduce forest degradation and deforestation and improve the forest status of the country should consider the role of agro-ecological and geographical factors. Instead of a one-size-fits-all approach, policy makers need to address environmental degradation problems based on the specific environmental conditions of each region.

Standard household characteristics were also included and results were discussed in this thesis. We found that the age, sex and education level of the household head (except for HFC areas) do not affect the time spent in fuel wood collection. The findings indicates that it is necessary to increase the level of awareness of the people in order to reduce consumption of energy sources such as dung and crop residues. As increasing scarcity of fuel wood does not induce households to shift to other lower quality energy sources, we argue that, as opposed to the energy ladder hypothesis, dung and residues are not perceived as inferior goods in this sample of Ethiopian households.

In addition to the above suggestions, planners need to give more attention to the open access nature of forests in the country. Rural households collect forest products from different sources i.e. either from private, community, state (*de facto* open access). Identifying the factors that drive households to collect forest products, fuel wood in this case, especially from open access sources is very important from the point of forest conservation and enhancing the contribution of forests to the livelihoods of rural people, as well as keeping their ecological functions. With this in mind the third chapter of this thesis deals with property rights and the choice of fuel wood sources in rural Ethiopia using a discrete choice model, multinomial logit regression, developed within the context of random utility. The results of the empirical analysis show that active local level institutions reduce dependency on community forests, but are positively correlated with the decision to collect from open access areas. With respect to policy, the results are positive, in the sense that the demand for community forests resources appears to be lowered by community forestry institutions, the results are also negative, in the sense that the demand for open access forest resources rises, in the face of better community forestry institutions. In other words, there is a need to bring additional open access forests under the management of the community and increase local awareness regarding the use and rules associated with forestry management.

The impact of tenure security (land certification) was also included and found not to have any impact on household's decision to collect from private sources. Although the literature suggests that land certification is responsible for increased investment in the land's productivity, through better soil conservation and the planting of trees (Deiningeret al., 2009; Holden et al., 2009), our results suggest that these investments have, as yet, not resulted in significantly increased use of private forests for fuel wood. However, additional empirical research on the role of land certification, as well as farmers' investment and use decisions may be required to supplement these findings.

Other household characteristics such as education, land size, the number of livestock, and distance to forest were also included to examine their effect on the choice of fuel wood sources. Regional variation also matters for the choice of fuel wood sources, which suggests that promotion of tree planting as a source of fuel wood may be more successful in a relatively degraded environment or fuel wood shortage is a concern.

As repeatedly mentioned in the thesis, forests in addition to fuel wood provide many other non timber or non wood forest products. Different studies such as Fisher (2004), Cavendish (2000), Angelsen and Wunder (2003) indicated the importance of non timber forest products in the livelihood of the people in many developing countries. As a result many efforts are being undertaken to sustain the forestry sector and hence increase the benefits obtained from the sector. This will in turn enhance the poverty alleviation efforts of the country. As has been stated and described earlier, the low and decreasing forest cover in Ethiopia is due to, among other factors, policy failure. For example, forests are typically owned and managed by federal and regional governments. This will lead to more deforestation and forest degradation as this may, among other things, create a property right regime closer to open access (Mekonnen and Bluffstone, 2008). Several studies have reported that devolution of forest management to the local people improves the forest cover and biophysical conditions thereby providing economic benefits to the local people. Though the management of common property resources (CPRs) and the implications for environment and poverty have been relatively well studied in India and Nepal, there are no such systematic studies in Ethiopia. In this regard additional empirical evidences would help policy makers understand the role of forest products in the current poverty alleviation efforts in the country. A full understanding of the relationship between local level institutions, resource use patterns and forest management will be a major step toward formulating policies and programs that aim to increase equity and enhancing the sustainability of resource base at the community level.

In chapter four of this thesis, we have examined the role of local level institutions and property right regimes on the level of forest dependency. Forest products are important in the study area and farm households collect them from different sources. In line with other similar studies (e.g. Mamo et al., 2006) forest products contribute, on average, 8.7 percent of total income of households in our study area and this can go up to 41 percent for some households. This is obtained by taking only non wood forest products. Including the contribution of fuel wood and charcoal would further increase the contribution of all forest products. The study, as also agreed by some scholars, is another evidence to argue that forests can play an important role to poverty alleviation and food security in Africa including Ethiopia.. This indicates that more emphasis need to be given to the management of forests as they contribute significantly to the livelihood of the people especially the poor. Moreover, with proper management it is possible to keep the environmental and ecological benefits from forests.

The results of the analysis suggest that the level and contribution of forest products to the livelihood of the people depend on so many factors such as household demographic and socioeconomic characteristics, institutional and environmental factors. Forest dependency is negatively related to the wealth status (using livestock and land as indicator) of the household. On the other hand, forest resource use from open access areas are positively correlated with wealth suggesting that there is a need to expand the current practice of participatory forest management (PFM) to other open access forest areas. In line with the above argument, it is necessary to identify the constraints for rural households to participate in community forestry. The role of local institutions and socioeconomic characteristics of households on forest dependency in a community forests were also examined. The findings show that local level institutions are not significant factors in determining the use of non-wood forest products, unlike major forest products such as timber or woody materials in general. However, we cannot conclude that local level institutions are not important for proper natural resource management. Importantly, institutional conditions are well understood by the PFM participants, meaning that households are fully aware of the forest use rules, regulations and management policies of the community forest. Finally, we conclude that generalization on the forest-poverty link depends on the type of forest management and the specific characteristics that prevail in the area. These results are suggestive for policy. Improving property rights, either through community forestry or private ownership, is likely to reduce the exploitation of forest resources, and may provide equity benefits for the rural population. Moreover, with such measures, it is possible to maintain, or even improve, the environmental and ecological services provided by forests. In this regard, the distribution of seedlings and provision of technical assistance to rural households could also be beneficial, although such activities could not be addressed in this study.

In order to sustain the contribution and maintain the ecological functions of forests, it must be managed in a more holistic manner. Ethiopia follows both a demand side and supply side strategies to solve the problem of the forestry sector which is under serious threat currently. Tree planting, strengthening property rights, plantation, etc are the supply side strategies while reducing the demand for fuel through the dissemination of energy efficient technologies such as improved biomass cook stoves and transition to other fuel types are the demand side strategies employed to address the aforementioned problems related to forestry in the country. While these strategies can be applied in both rural and urban areas, the role of the urban population in the current environmental problem is usually given less attention. That means the importance of forests and causes for forest degradation and deforestation is usually linked with the rural people in Africa including Ethiopia. However, the urban population in many developing countries including Ethiopia also contribute to the environmental problem as they depend on biomass energy sources such as charcoal, fuel wood, and construction materials. Various governments and non-government organizations are trying to address the problem through the introduction and dissemination of different types of fuel saving technologies. Although a number of studies have shown that these stoves use less biomass resources, and can, thus, be assumed to result in less innocuous health effects, these technologies have not been universally adopted in Ethiopia. Moreover, households take different amounts of time to adopt the technology. By recognizing the role of urban population in the current environmental problem of the country, this thesis also emphasize the need to adopt energy efficient technologies such as improved biomass cook stoves in both rural and urban Ethiopia. Therefore, we have tried to examine and understand the determinants of the speed of adoption of fuel saving technologies in urban Ethiopia by using data collected from selected towns in three regions of the country.

We were able to identify several socioeconomic, geographic and substitute technologies important to the speed of adoption of fuel saving technologies (Mirt biomass *injera* stove and Lakech charcoal stove). The results show that both Mirt and Lakech stove adoption increase with income. Similarly, since lower income households are less likely to adopt these more efficient cooking technologies **,** the research also suggests that other policy options must be implemented, most likely policies to reduce the initial purchase price, if adoption rates are to be increased. Education is positively and significantly related to the speed of adoption of Mirt biomass cook stoves but its effect on the adoption of Lakech charcoal stove is insignificant. The impacts of substitute technologies were also examined. We found that the possession of Electric Mitad (a substitute for Mirt *injera* stove) does not have any effect on the adoption decision of Mirt biomass cook stoves, which may be due to the better performance of Mirt in reducing the energy cost of preparing the staple food, *injera*. However, in the case of the Lakech stove, the metal alternative does significantly reduce adoption rates. This may suggest that there is a need to reconsider the promotion strategy given the better performance of Lakech charcoal stove over Metal charcoal stove. The findings further show that the probability of adoption of Mirt biomass cook stoves will increase for households with private houses and separate kitchen facilities for cooking. Other household characteristics, such as the age and gender of the household head, the number of adults, and the number of children and youths were also important factors in the adoption decision of the improved biomass cook stoves. Finally, we argue that any forest or energy policy that tries to solve the problem of the forestry sector should also address the roles and contributions of the urban population.

In conclusion, sustainably managed forestry provides positive economic and environmental benefits. The results from this study provide valuable insight for Ethiopia's current demand-side and supply-side strategies for addressing rural energy problems, especially policies related to forests and forest resource conservation, as well as halting, and hopefully reversing, the unsustainable use and exploitation of those resources. In order to maintain this, the thesis suggests that no single strategy will work for Ethiopia. We need to approach the problems of forest degradation and deforestation from both rural and urban side; demand as well as supply side. In addition, the findings of this research can be considered as a basis for similar analysis in other African countries in particular and developing countries in general.

Further research may focus on the following issues: With regard to the discussion in chapter two, further research may focus on analyzing whether the increase in labour inputs comes at the expense of other productive activities such as agricultural production in forest degraded regions. In addition, one can examine the relationship between different groups of households and forest scarcity in environmentally degraded regions. In line with chapter three of this thesis, we suggest further research on evaluation of the long-term effect of land tenure security (land certification) on farmers' investment decision and the implication of this on rural energy and forest degradation in the region. As a continuation of chapter IV, analysing and understanding the nature of the link between forest resource uses, institutions and household wellbeing over time will enable us to understand the dynamic aspect. This, however, may be very difficult in many sub-Saharan African countries, as it demands more resources. Finally, our last chapter of the empirical analysis focuses on the adoption decision of fuel saving technologies, but not the efficient use. Future research should examine the quantity of fuel wood and charcoal that were saved, due to these improved biomass cook stoves. Given the importance of the improved stoves in saving biomass resources and reducing indoor air pollution, as well as the inability of this study to control for differences in prices and perceptions related to the benefits of improved cook stove technologies, future research must give more attention to collecting information related to prices, and examine the impact of prices and perceptions on the adoption of improved biomass cook stoves. Contrary to the argument on the benefits of these technologies, some literature indicated that the convenience of some improved biomass stoves has increased consumption of biomass fuels, called the ‘rebound effect’. Whether this is the case in Ethiopia should also be addressed, by collecting additional data on biomass fuel consumption across households with different types of cook stoves, in order to determine whether or not the presumed reductions in forest degradation can be realized through the adoption of energy saving technologies, such as improved biomass cook stoves.

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APPENDIX A: HECKMAN WAGE REGRESSION ESTIMATES

Participation Equation

Variables	Coef
Age	-0.371
	(0.31)
Sex of the household head	-0.213
	(0.21)
Distance to town in km	0.097
	(0.11)
Livestock ownership in TLU	-0.322***
	(0.13)
Land size in hectare	-0.569***
	(0.18)
Location dummy 1 for Amhara & Tigray , 0 otherwise	0.368***
	(0.13)
Number of children under five	-0.108
	(0.07)
Average schooling level of the family	0.090***
	(0.03)
Amount of Nonlabor income	-0.005
	(0.02)
Number of male members of the family	0.016
	(0.04)
Constant	1.023
	(1.12)

The dependent variable (wage rate), age, land size, distance to town (in the participation equation) and non- labour income are in log form.

Wage Regression Equation

Variables	Coef.
Average schooling level of the family	0.062**
	(0.03)
Distance to town in km	-0.020**
	(0.01)
Location dummy 1 for Amhara & Tigray , 0 otherwise	0.232
	(0.15)
Whether any member of the family has attended any type of training or not	-0.112
	(0.13)
Number of male members of the family	-0.093**
	(0.04)
Inverse mills ratio	2.18**
	(0.99)
Constant	1.35*
	(0.70)

APPENDIX B. PARTICIPATION IN COLLECTION FROM COMMUNAL FORESTS

Variable	Coef
Predicted wage	-0.360
	(0.43)
Distance to town in km	0.103***
	(0.02)
Land size in hectare	-0.071
	(0.16)
Education of the HH head	-0.222**
	(0.12)
Government rules	0.114
	(0.11)
Family size in adult equivalent	-0.029
	(0.03)
Distance to market in km	-0.081***
	(0.02)
A dummy variable if the head is a member of any organization	0.137
	(0.12)
Forest Access	-0.053**
	(0.03)
Biomass availability	0.001
	(0.00)
Constant	0.820
	(1.18)

APPENDIX C. SELECTION REGRESSION OF TIME SPENT PER UNIT OF FUEL WOOD COLLECTED IN COMMUNAL FORESTS

Variable	Coef
Predicted wage	0.014
	(0.06)
Land size in hectare	0.017
	(0.02)
Education of the HH head	0.026
	(0.03)
Distance to town in km	-0.008
	(0.01)
Government rules	-0.026*
	(0.02)
Family size in adult equivalent	0.002
	(0.01)
Distance to market in km	0.008*
	(0.00)
A dummy variable if the head is a member of any organization	-0.034*
	(0.02)
Forest Access	0.002
	(0.01)
Inverse mills ratio	-0.181
	(0.45)
Constant	0.253
	(0.22)

APPENDIX D. PARTICIPATION IN DUNG COLLECTION

Variable	Coef
Collection time	1.598
	(4.77)
Wage rate (predicted)	1.602**
	(0.76)
Education of the HH head	-0.095
	(0.17)
Sex of HH head	-0.275
	(0.26)
Amount of Nonlabor income	0.000
	(0.00)
Livestock ownership in TLU	-0.154
	(0.15)
Land size in hectare	-0.786***
	(0.30)
Family size in adult equivalent	0.123**
	(0.05)
Government rules	0.062
	(0.20)
Forest Stock	0.002
	(0.01)
Biomass availability	-0.023*
	(0.02)
Forest Access	-0.067*
	(0.05)
Average schooling level of the family	-0.082*
	(0.06)
Constant	-3.210*
	(2.12)

APPENDIX E. PARTICIPATION IN CROP RESIDUE COLLECTION

Variable	Coef
Collection time	-0.079
	(3.53)
Wage rate (predicted)	0.012
	(0.32)
Education of the HH head	-0.185*
	(0.14)
Sex of HH head	0.314*
	(0.23)
Amount of Nonlabor income	0.000
	(0.00)
Livestock ownership in TLU	-0.214**
	(0.12)
Land size in hectare	0.263*
	(0.17)
Family size in adult equivalent	0.040
	(0.04)
Government rules	-0.739***
	(0.14)
Forest Stock	-0.020***
	(0.01)
Biomass availability	0.001
	(0.00)
Forest Access	0.201***
	(0.05)
Average schooling level of the family	0.017
	(0.03)
Constant	-0.597
	(1.03)

Appendix F: Institutional indicators used for constructing institutional index

Indicators of institutional variables at household level	**Mean**
INSVAR1	
Is there any system for controlling fuel wood collection from communal lands	2.6774
INSVAR2	
Is the amount of fuel wood collected on communal lands limited?	3.8367
INSVAR3	
Do the kebele officials follow who takes products of forest from the communallands.	2.646166
INSVAR4	
Is there a penalty if someone takes fuel wood beyond the amount?	2.671268
Average institutional index	2.974268

Note: Average institutional index for the household*i* is calculated as $I_H = \frac{\sum INSVAR_i}{4}$and theaverage index for the community is calculated as $I_C = \frac{\sum I}{N}$, where *N*is the number of households in a community.

Appendix G: One way ANOVA for testing whether the means of some of the variables are different across the different fuel wood sources

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Dummy for Education	Between Groups	4.129	4	1.032	4.166	0.002
	Within Groups	381.595	1540	0.248		
	Total	385.724	1544			
size of land	Between Groups	56.432	4	14.108	16.989	.000
	Within Groups	1278.836	1540	0.83		
	Total	1335.268	1544			
Numberof livestock	Between Groups	619.457	4	154.864	17.773	.000
	Within Groups	13418.801	1540	8.714		
	Total	14038.259	1544			
Dummy for certificate	Between Groups	4.834	4	1.209	7.568	.000
	Within Groups	245.942	1540	0.16		
	Total	250.777	1544			
Dummy for region	Between Groups	13.96	4	3.49	14.456	.000
	Within Groups	371.801	1540	0.241		
	Total	385.761	1544			
Distance of forest	Between Groups	49.575	4	12.394	2.739	0.027
	Within Groups	6969.413	1540	4.526		
	Total	7018.988	1544			
A dummy for Institutions	Between Groups	10.134	4	2.533	10.393	.000
	Within Groups	375.39	1540	0.244		
	Total	385.524	1544			