CLIMATE CHANGE IMPACTS, VULNERABILITIES AND OFF-FARM DIVERSIFICATION AS AN ADAPTATION STRATEGY: EVIDENCE FROM ETHIOPIA

Ph.D THESIS

by

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INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
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INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

STUDENT'S DECLARATION

I hereby certify that the work presented in the thesis entitled "**CLIMATE CHANGE IMPACTS, VULNERABILITIES AND OFF-FARM DIVERSIFICATION AS AN ADAPTATION STRATEGY: EVIDENCE FROM ETHIOPIA**" is my own work carried out during a period from August, 2017 to September, 2020 under the supervision of Dr. Subir Sen, Associate Professor, Department of Humanities and Social Sciences, Indian Institute of Technology Roorkee, Roorkee.

The matter presented in this thesis has not been submitted by me for the award of any other degree of this or any other Institution.

Dated: 25/01/2021 **(HARON AGEGNEHU ENDALEW)**

SUPERVISOR'S DECLARATION

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

Dated: **(SUBIR SEN)**

Abstract

Climate change is a worldwide problem with much larger adverse impact on the developing economies. The manifestations such as, extent of vulnerability to climate change and impacts from climate change as well as adaptation capacities to the changing climate are locally varying processes. This thesis presents the results of an investigation of aggregate economic impacts of climate change and local level rural livelihood vulnerability assessment to climate change in Ethiopia. In particular, the vulnerability differences between off-farm diversified and non-diversified rural households in selected rural villages of South Gondar Zone is examined. Along with this, the off-farm growth determining factors and their linkage with the farming sector are investigated.

The aggregate economic impact of climate change in Ethiopia is investigated over the period 1960 to 2015 using a simple economic growth model that incorporates climatic variables such as annual rainfall, mean annual temperature and CO_2 emission using the Auto Regressive Distributed Lag (ARDL) technique. ARDL bounds testing approach has an advantage of providing explicit tests for the existence of a single cointegrating vector in its single equation setup with a simple implementation and interpretation. The study shows that climate change, captured by rainfall changes mainly its deviations from long-term average and its variability (including high probability of decrease in rainfall), increase in temperature and rise in co_2 emission would jeopardize growth in the long-run. The significant negative effect of these climatic variables on GDP is further confirmed by the (Nonlinear Autoregressive Distributed Lag Model) NARDL estimation. However, the NARDL analysis further shows statistically different effects from the positive and negative changes of these climatic variables on GDP. The country, therefore, needs to implement all adaptation strategies strongly towards reducing the negative impacts of climate change. Having the evidence of unidirectional causality flows from climatic variables to Ethiopia's economic performance; domestic policy responses for climate change that directly hinders domestic economic progress may not be effective. Instead, climate change adaptation policies that help economic progress in parallel are more advisable. In addition, Ethiopia should continue active participation in climate change negotiations at the global level.

Local level climate change vulnerability assessment is also conducted on a sample of 323 off-farm diversified and non-diversified rural households in selected rural villages of south

Gondar zone of Amhara region of Ethiopia using the integrated livelihood vulnerability assessment approach, namely LVI-IPCC framework and econometric method. The approach is preferable for policy decisions as it allows an explicit examination of the complete picture of vulnerability through integrated analysis of the three major contributing factors. It is revealed that rural household's livelihood is significantly and adversely influenced by climate shock; particularly poor rural households that do not diversify into any rural off-farm activity are highly vulnerable to climate shock. Income inequality and adaptive capacity differences across rural households are further aggravated by climate change. Therefore, attention should be given for the off-farm diversification as an effective pro-active strategy in place of the usual reactive relief oriented strategy to adapt the exposure from exogenous climate shocks and reduce the adverse impacts of climate change at household level. Irrigation, improvements in the access of water, health and other rural-infrastructure are also found to be indispensable.

Effects of climate shock on rural households' off-farm diversification and earnings along with other determinants are also examined using the Multinomial logit and Tobit models respectively. Empirical results from the Multinomial logit model confirmed that climate shock increases the likelihood of rural households' off-farm diversification. Rural households that anticipated climate shock are more likely to diversify into off-farm activities. The distinction in rural households' diversification decision between two mutually exclusive categories of off-farm activities is better explained by other non-climatic variables of the model. Climate shock is the dominant push factor. Most of the off-farm participant rural households' used the sector as climate shock copying mechanism. The sector is also confirmed as being less climate sensitive than the farming sector. The Tobit model also revealed that determinants of off-farm diversification consistently affect off-farm earnings. The current status of off-farm economy is very low. Lack of capacity is considered to be an important constraint for off-farm participation and earnings. Therefore, rural households' capacity development in rural infrastructure, irrigation, awareness creation, education and training in off-farm skills among others promote the overall growth of off-farm economy.

To generate plausible suggestions on the necessity of promoting rural off-farm sector, economic linkages between farm and rural off-farm sectors are also examined through the explicit evaluation of the effect of rural households' off-farm diversification and the resulting income on their farm income. The instrumental variable regression method is

employed so as to solve the endogeneity problem that occurred due to the reverse causality between farm and off-farm sectors. Significant positive effect or complementary linkage between the farm and off-farm sectors is evidenced. The thesis therefore asserts that off-farm diversification by rural households is an important climate change adaptation option and sustainable source of income that enable to sustain rural livelihood. There is a possibility to promote the off-farm sector without any cost to the farm sector. This inevitably lead to rural development through focusing and working on the positive synergy between the farming and off-farm sectors, instead of concentrating on the farming sector alone.

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Date: 24/01/2021
Place: Roorkee

HARON AGEGNEHU ENDALEW

Dedicated to My Parents & Family

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Abbreviations

ADF	Augmented Dicky-Fuller
ARDL	Auto Regressive Distributed Lag
CCVI	Climate Change Vulnerability Index
CMIP5	Coupled Model Intercomparison Project, Phase 5
CRGE	Climate Resilient Green Economy
ECM	Error Correction Model
ECT	Error Correction Term
ETB	Ethiopian Birr
FDRE	Federal Democratic Republic of Ethiopia
GDP	Gross Domestic Product
GHG	Green House Gas
GTP	Growth and Transformation Plan
IPCC	Intergovernmental Panel on Climate Change
KPSS	Kwiatkowski, Phillips, Schmidt, and Shin
LEI	Livelihood Effect Index
LVI	Livelihood Vulnerability Index
NARDL	Non-linear Auto Regressive Distributed Lag
NDCs	Nationally Determined Contributions
ND-GAIN	Notre Dame Global Adaptation Initiative
NDRMC	National Disaster Risk Management Commission
NPC	National Planning Commission
PPS	Probability Proportional to Sample size
SDGs	Sustainable Development Goals
SNNP	Southern Nation Nationalities and People
UNDP	United Nation Development Program
UNEP	United Nation Environmental Program
UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development
VEP	Vulnerability as Expected Poverty
VER	Vulnerability as uninsured Exposure to Risk
VEU	Vulnerability as low Expected Utility
WRI	World Resources Institute

Chapter 1
Introduction

1.1 Background

The Intergovernmental Panel on Climate Change (IPCC) (2018) refers climate change as "a change in the state of the climate that can be identified (for example using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer"[1]. To understand climate change, it is meaningful to start with a review of the broader concept of global warming. Global warming is the "estimated increase in global mean surface temperature (GMST) averaged over a 30-year period, or the 30-year period centered on a particular year or decade, expressed relative to pre-industrial levels unless otherwise specified". According to the US Geological Survey (USGS)[2], global warming is just one aspect of climate change and is scientifically established as an important driver. The fossil fuel-based industrialization beginning roughly 200 years ago reversed the decline in the global average temperature (Neukom *et al*., 2019). Global warming has intensified in recent decades. For example, from 1970 onwards, it has increased by about 0.6 ± 0.2 °C (1.1 ± 0.4 °F) (IPCC, 2013; Shaftel, 2016). The Earth's average surface temperature has already risen about 1 °C (about 2 °F) above pre-industrial levels[3] (IPCC, 2018).

It is extremely likely that human influence in the form of emission of greenhouse gases (GHGs) has been the dominant cause behind the observed warming (IPCC, 2013). The use of fossil fuels like coal and oil, as scientists reveal emits carbon dioxide into the air. The situation worsens as deforestation implies less carbon dioxide removed from the atmosphere by those plants (IPCC, 2013; IPCC, 2014). Climate models (for example, Coupled Model Intercomparison Project, Phase 5 (CMIP5)) projections indicate that in the 21^{st} century global surface temperature may rise by 0.3 ^{0}C to 1.7 °C in a low emission

[1] Refer https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_AnnexI_Glossary.pdf; page 544
[2] https://www.usgs.gov
[3] IPCC uses the period 1850-1900 as a reference period to estimate the pre-industrial global mean surface temperature (GMST). The pre-industrial period is the multi-century period prior to the 1750 industrial revolution (IPCC, 2018)

scenario and as much as by 2.6 °C to 4.8 °C under a high emission scenario (IPCC, 2013)[4]. The climate system has a large inertia, the GHGs remain in the atmosphere for a longer time and climatic change continue to become more pronounced affecting the frequency and severity of disasters.

Past decades saw scientists investigating how much warming humanity can tolerate (carbon budget) before experiencing the most destructive and dangerous effects of climate change. This is where a threshold of 1.5°C or 2 °C came about as a target in the Paris Agreement (IPCC, 2018). Countries that formally accept or ratify the Paris Agreement submit their own pledges, referred to as Nationally Determined Contributions (NDCs). Different groups of researchers (such as IPCC, UNEP) analysed the combined effect of efficient implementation of the NDCs. The current pledges seems inadequate to limit global warming to 1.5°C above preindustrial levels (IPCC, 2018). According to the UNEP (2019), the full realization of current pledges made as part of the Paris Agreement would lead to about 3.2 °C of warming at the end of the 21st century, relative to pre-industrial levels. Further, countries have to raise their collective ambition more than fivefold (threefold) over the current level to achieve the GHG emission cuts of 7.6 percent (2.7 percent) each year between 2020 and 2030 for the 1.5°C (2°C) target respectively. A world that is consistent with holding warming to 1.5°C may see GHG emissions rapidly decline in the current decade, with strong international cooperation and a scaling up of countries' combined ambition beyond current NDCs. In contrast, delayed action, limited international cooperation, and weak or fragmented policies that either hold or increase GHG emissions may jeopardise the possibility of limiting global temperature rise to 1.5°C above pre-industrial levels out of reach. Although, few countries (for example,. Bhutan) are trying others are reportedly free riding as climate is a global public good facing the problems 'tragedy of the commons'. Climate change scepticism and denial is one powerful factor in preventing climate action. If the business as usual pace of emission continues, global warming is likely to reach 1.5°C between 2030 and 2052 (IPCC, 2018). This means only about a decade is left to make drastic changes, or to miss the target.

Small increases in global average temperature contribute to very large changes in other aspects of local climate. Climate change encompasses global warming, but refers to the

[4] For details refer https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter12_FINAL.pdf

broader range of changes that have imposed potentially irreversible threat to the earth and its inhabitant. These include shrinking of glaciers, rapid melting of ice in Greenland, Antarctica and the Arctic, rising sea levels, shifts in the flower/plant blooming times, regional changes in precipitation and more frequent extreme weather events (IPCC, 2014). Therefore, climate change may have contributed to extreme events such as more extreme rainfall and flood in some regions, but for other regions, there are increased incidences of droughts and wildfires. Climate change impact human beings by threatening food security through decrease in crop yields, abandonment of populated areas due to migration, natural resource scarcity induced conflicts, damage to infrastructure in low-lying areas due to rising sea levels, to mention few (IPCC, 2014; Campbella *et al.*, 2016). Given the evidences of increasing number of natural hazards globally and probability of increase in the threat of disasters, climate change is leaving its mark on Ethiopia as well. However, scepticism and denial persists among policy makers threatening lives and livelihoods and especially the sectors heavily dependent on climate such as agriculture.

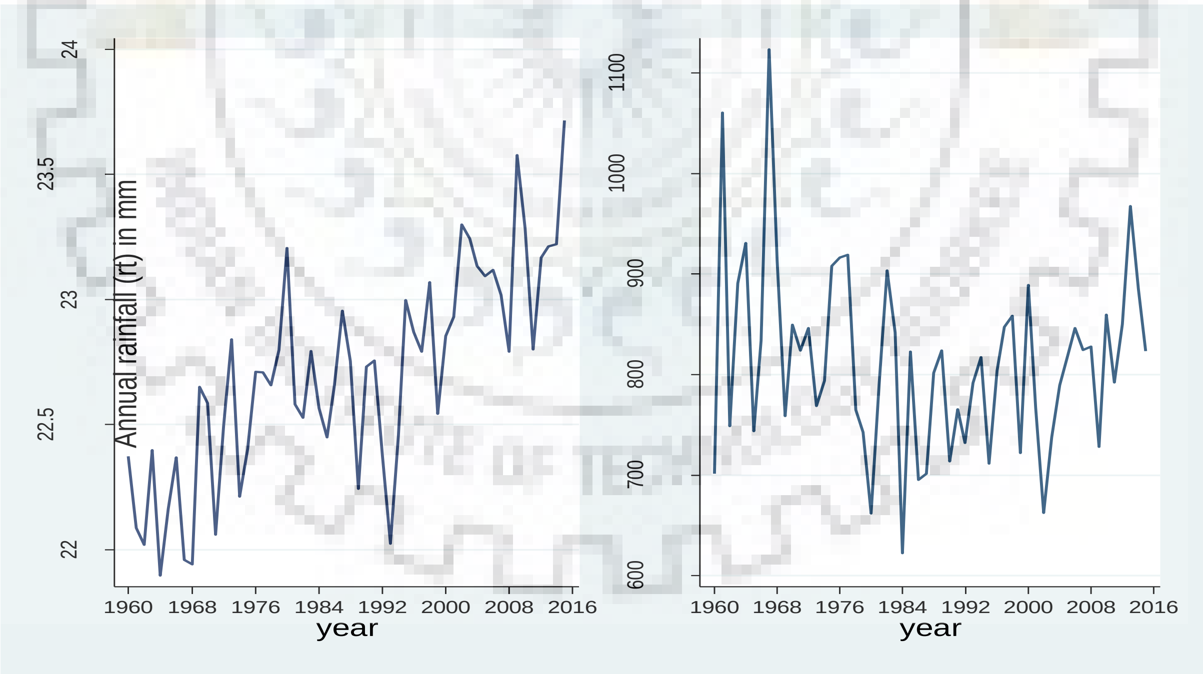
Africa, the least industrialized continent, is highly vulnerable to climate change though it contributes the least to the global warming (Althor *et al.*, 2016). Its contribution to the global GHG emission is less than 4 percent[5]. In the list of top 10 countries vulnerable to climate change, there are 7 African countries including Ethiopia. Ethiopia is one of the world's lowest GHG emitters. Nevertheless, Ethiopia was identified to be in a condition of extreme climate risk (Maplecroft, 2015). Ethiopia ranks 182 of 188 countries in per capita emission[6] and contributes only 0.27 per cent of global emissions[7]. Based on the ND-GAIN index[8] that summarizes a country's vulnerability to climate change in combination with readiness to improve resilience, Ethiopia ranks 159 (out of 181 countries) in 2014 with a vulnerability score of 0.56. A higher score and a higher rank indicates more vulnerability to climate change. It also ranks 162 out of 191 countries with the readiness score of 0.26. Again, a lower readiness score and higher rank shows lower level of readiness to improve resilience. Further, Ethiopia is in the list of most vulnerable (22nd rank) and least ready (29th

[5] The African Development Bank, AFRICACOP24, UNCCC, Katowice 2018 https://www.cop24afdb.org/en/page/implications-africa
[6] https://en.actualitix.com/country/eth/ethiopia-co2-emissions-per-capita.php
[7] WRI (2017) http://cait2.wri.org
[8] http://index.gain.org/country/ethiopia, https://www.climatewatchdata.org/countries/ETH#ghg-emissions. ND-GAIN refers Notre Dame Global Adaptation Initiative which is a project of the university of Notre Dame that summarizes a country's vulnerability to climate change in combination with its readiness to improve resilience

rank) countries. In this backdrop, it becomes pertinent to explore the impact of climate change on Ethiopia and assess the preparedness at various levels.

The extant literature reports that the mean annual temperature in the country rose by an estimated 0.5 °C to 1.3 °C since the 1960s implying a rise of about 0.1^0C to 0.4^0C per decade (McSweeney *et al.*, 2008; Keller, 2009; Aragie, 2013; Eshetu *et al.*, 2014; FDRE, 2015). Increases in the minimum and maximum temperatures, the spike in the number of hotter and colder days and nights are also recorded (McSweeney *et al.*, 2008). According to the projections, further warming up to 2.2°C by the 2050s is expected (Conway and Schipper, 2011). Inter-annual rainfall variation is 25 percent and the variability is observed to move upwards to 50 percent in few regions. Given these variability, there is evidence of a 20 percent decrease in the rainfall in the *south central region* of the country (FDRE, 2015). Although, erratic and frequent variability of rainfall complicates detection of possible long-term trends, declining trend in rainfall is observed since the 1980s as depicted in Figure 1.1.

Figure 1.1: Trends of mean annual temperature and annual rainfall in Ethiopia



Data source: World Bank (https://climateknowledgeportal.worldbank.org)

The observed changes in temperature and rainfall may increase the frequency and severity of extreme events[9]. Drought is one of the most severe climate shock affecting Ethiopia. The devastating droughts are reported to be El-Niño induced and associated with the failure of major rains (*Kiremt*, June to September) that account for 50 to 80 percent of the total annual rainfall important for agricultural production and major water reservoirs (FDRE, 2015). Ethiopia's drought history suggest that there were widespread droughts in terms of frequency, severity and geospatial coverage, occurring in different periods[10]. For example, the EM-DAT reports 16 major drought events over the period 1960 to 2018 affecting 77.5 million lives. These series of droughts created poverty traps for many households by constantly hampering efforts towards consolidating assets and increase income. At the same time, drought and post drought incidences of epidemic affected the country in general (Gebreegziabher *et al.*, 2016).

Historically the recurrence of severe droughts in Ethiopia was once per decade. In recent years droughts have become more frequent, erratic and widespread (FDRE, 2015; Ali, 2012). It destroyed the livelihood of millions of people covering large part of the country. As a result, there are fiscal implications related to increase in demand for funds for humanitarian responses by diverting public budget from mega development projects, which in turn deters the structural transformation of the national economy. For example, the 1984 and 2002 droughts created unprecedented food shortages. In particular, the famine following the 1984 drought destroyed the livelihood of millions of people covering large part of the country and is recognized as "*Kefu Qen*" or 'evil day' by the affected people (Dercon and Porter, 2014). In general, drought affected the entire economy through reduction in agricultural production and productivity including reduction in livestock, creating water stress for all demanding sectors including hydropower dams and reservoirs which lowered hydroelectric power production, damage to ecosystems and imposing many indirect socio-economic and political problems (Ali, 2012; Gebreegziabher *et al.*, 2016). The drought in 1974 and 1984 caused political instability leading to removal of Emperor Haile Selassie regime and subsequent succession of the military government (*Dergue)* regime to a major shakeup and eventually removal by a rebel group.

[9] For an list of studies connecting extreme events to climate change and weather parameters refer https://www.ucsusa.org/sites/default/files/attach/2018/06/extreme-weather-Appendix-A2.pdf

[10] See the appendix section- an overview of selected droughts in Ethiopia for the last 50 years

Another source of the inter –annual rainfall variability commonly following the El Niño event is La Niña which results abnormally above the long-term average rainfall and causing floods (FDRE, 2019). Flood events are also common in the country causing significant disruptions in economic activities. The EM-DAT records show 57 flood events of various intensities affecting close to 4 million lives over the period 1960 to 2017. The study Mamo *et al.* (2019) suggest 16.7 percent area of the country was affected by floods in the year 1997 followed by 15.7 percent and 13.9 percent flood affected areas in the years 2005 and 2013 respectively. Floods occurred with heavy *Kiremt* rains and resulted in localized flash floods, overflowing of rivers, landslides, damaging infrastructure and settlements, triggering internal displacements, crop damages/losses, human and livestock deaths across the country, among others. The overflowing rivers Awash in the Afar region, Rib in South Gondar zone of Amhara region, lake Abaya in West Guji zone of Oromia region were few identified major sources of floods in the country. For example, according to the United Nations Office for the Coordination of Humanitarian Affairs (UN OCHA)[11] seasonal flooding has affected more than 470,000 people before the end of the rainy season of the year 2020. Thus, the periodic prevalence of severe and frequent climatic shocks is believed to be significant determinant of the dynamics of the Ethiopian economy. Due to rainfall variability Ethiopia's actual real per-capita GDP was 4 times lower from what it would be if rainfall variability is reduced by half (Ali, 2012). Recent droughts drag up to 4 percent of Ethiopia's GDP (FDRE, 2015). Though, the lives of affected people are saved in collaborated efforts, the recent El Niño induced drought (2015-2017) alone significantly hold back the double digit economic growth of the past few years that the Ethiopian government was boosting of. Climate change in general is anticipated to impede economic progress, or nullify the development efforts made and could worsen social and economic disruptions (McSweeney *et al.*, 2008; FDRE, 2015) and reduce Ethiopia's economic growth anywhere between 0.5 percent and 2.5 percent each year unless effective measures are taken (World Bank, 2010). In this backdrop of rising global concerns regarding the impact of climate change at the aggregate level and the experiences of the households dependent on the agricultural sector in Ethiopia, this study is an attempt to understand the linkages between climate change, economy at the macro and micro levels. Along with this, the thesis explores the local household level vulnerabilities and the current practices that

[11] https://www.unocha.org/story/ethiopia-floods-impact-thousands-people

can be broadly identified as *climate adaptation*. The focus is also on identifying the factors explaining the sudden demand for off-farm employment especially in the rural areas. It is also pertinent to investigate the behaviour of farm households' and how the off-farm and farm linkages make climate adaptation efficient. In the next section, the problems identified for this research are briefly presented.

1.2 Problem statement

In climate dependent economies, climate change impact and adaptation studies are vital in addressing the concerns and identification of strategies towards minimising climate shocks. Given the ongoing controversies surrounding climate actions, measures towards efficient climate change adaptation (CCA) require a *priori* estimation of the economic impact of climate change. Previous works on the economic impact of climate change in Ethiopia (Deressa, 2007; Deressa and Hassan, 2009; Aragie *et al.*, 2013; Evangelista *et al.*, 2013; Ferede *et al.*, 2013) focused on the agriculture sector and studies have largely underestimated the aggregate effects. Climate change affect all sectors of the economy directly and indirectly. Since agriculture has backward and forward linkages with the other sectors of the economy, a direct effect of climate change on agriculture would trickledown to other economic sectors. Moreover, energy, an engine for all economic sectors, is also rain-fed in Ethiopia and directly affected by climate change. Therefore, only structural transformation of the economy does not save the country from the adverse impact of climate change (Ali, 2012) unless energy sources are diversified and limiting the dependence on hydroelectric power. Climate change imposes multidimensional direct and indirect disruptions on the entire economy. Aggregate indicators are needed to show aggregate economic effects of climate change. This may help account for all direct and indirect impacts of climate change besides capturing only the pure effects largely felt by the primary sector. Such an exercise may help proper formulation of national CCA plan and enable mobilization of investment and/or climate finances for adaptation measures. Moreover, it is important to understand the problem clearly and situate the issue in the present and future development plans of the country. Though number of studies exists in the extant literature, yet research on analysis of the aggregate effects is in its infancy due to contradictory outcomes (The Royal Swedish academy of sciences, 2018). While there have been studies at the continent level (Abidoye and Odusola, 2015; Lanzafame, 2012; Alagidede *et al.*, 2016) and global level (Dell *et al.*, 2008; Nordhaus, 2006), there are lack of empirical evidences on the macroeconomic impact on the Ethiopian economy.

Moreover, the disproportionate nature of the impacts across countries and regions (Dell *et al.*, 2012; Burke *et al.*, 2015) makes it difficult to draw a uniform national CCA policy. Therefore, lessons from regional and cross-country, global and continental studies on climate change impact becomes necessary. These help in formulating a country specific study, as is in this current research. These observations following review of literature provide the rational for analysing the impact of climate change on Ethiopian economy.

It is important to note that although climate change is a global phenomenon, but the effects and adaptation strategies are locale specific and dynamic in nature. These vary across space and temporal scales. The effects of climate change are felt primarily at the household level. Estimation of aggregate economic impact of climate change fails to emphasize local level impacts and vulnerabilities, while they are important to reach national consensus on climate action and strengthen commitments (Narayanan *et al*., 2016). Fussel (2010) highlight that aggregate indicators could not adequately consider special circumstances that make a local system particularly vulnerable to climate shock. Downscaling under such situations may provide more information on local impacts (Jacques, 2006). Effective adaptation measures would require a thorough understanding of the local community and interests of those affected and exposed. However, these may not be sufficiently addressed in the national policy. In this backdrop, local rural household level vulnerability assessments are required to substantiate estimations of the aggregate economic impacts of climate change for making CCA measures efficient.

A local household level vulnerability assessment is considered assuming the endogenous adaptive capacity differences instead of the exogenous ecological differences, a major departure from the previous studies. Poor adaptation capacity is one reason for the adverse impact of climate change. For example, rural households in Ethiopia have faced multiple barriers such as lack of weather information, credit services and other supports from the local authorities and the distance to input/output markets. These limit desired outcome of the possible climate change adaptation keeping the population at large highly vulnerable to climatic risks (Bryan *et al.*, 2009; Moroda *et al.*, 2018). CCA in Ethiopia is mostly focused on relief oriented disaster management. The implementation of effective prevention and preparedness based pre-disaster management strategies in Ethiopia is practically intangible (Abebe, 2010). The recent 2015 El Niño induced drought is an example in which the government spent huge budget for direct relief, transferring funds from the mega development projects that in turn affected the economic structural transformation process. Enhancing CCA capacities of rural households was overlooked (Abebe, 2010). Climate change had imposed frequent shocks, risks and uncertainties first and foremost on the farming sector. Therefore, strengthening the adaptive capacity of rural households through diversification beyond the farming sector may be prioritized. In this regard, rural households' diversification into off-farm activities could be among the few possible climate change adaptation options (Yaro, 2013; IPCC, 2014).

This study presents an analysis of how the untapped rural off-farm sector may grow and utilised as a relevant climate adaption strategy. Moreover, to generate a statistically supporting suggestion for framing policy that recognize off-farm diversification as an important climate adaptation option, promote rural off-farm economy, the study undertook examination of the farm and off-farm economic linkages. Few available studies such as Gebregziabher *et al.*, (2012) in Ethiopia, Babatunde (2013) in Nigeria, Ercolani and Wei (2010) in China, and Nguyen (2019) in Vietnam, among others found a complementary linkage. On the other hand, Kilica *et al.* (2009) in Albania, Pfeiffer *et al.* (2009) in Mexico, Egyei and Adzovor (2013) in Ghana and Nasir and Hundie (2014) in Ethiopia, for example found competing effects. The conflicting results on the farm and off-farm economy linkages in the existing literature motivate the empirical examination through explicit evaluation of the effect of off-farm income on the farm income. With these motivations and the research problems, the following four key policy questions emerge for this study.

First, what is the macroeconomic implication of climate change? Second, what are the local or household level implications of climate change? Are rural households equally vulnerable to climate change? Could the untapped and least exploited rural off-farm diversification reduce vulnerability of the households? Third, how rural off-farm sector may grow and could be used as relevant option for adapting to climate change? Fourth, does the link between off-farm and the farming economy allow it to be a possible climate change adaptation option?

1.3 Scope and limitation of the study

The thesis broadly focuses on climate change impacts and adaptation. It focuses on the macroeconomic impact of climate change in Ethiopia over the study period 1960 to 2015. Further, the micro or local rural household level climate change vulnerability and adaptation efforts in selected rural villages in the *South Gondar Zone* of *Amhara region* of Ethiopia is explored. The thesis, in particular deals on the suitability of rural off-farm diversification as a climate adaptation strategy. Climate change effects on the rural household's off-farm diversification decision making and other potential determinants for the overall growth of the off-farm sector are examined. The thesis attempted to unearth the link between the off-farm and farm sectors so as to strongly understand the CCA role of the off-farm sector. The study uses only annual rainfall, mean annual temperature and CO_2 emissions, among many manifestations or parameters detailed in the literature to represent climate change. The unique exercise is the evaluation of the livelihood vulnerability index to assess the effect of climatic shocks in the identified rural households in the selected sample. Due to time and resource constraints, the thesis could consider only limited number of rural villages in the South Gondar zone of the Amhara region. The results may provide sufficient insight to provoke policy towards reducing exposure and vulnerability of the local rural households in the selected sample. The results from this thesis may be substantiated by future research that could consider expanding the scope of the study and include more sample rural village households spread across the country. Therefore, the results for Ethiopia are as reported in this thesis are generalised based on the sample identified for this study.

1.4 Research objectives

The research has the following objectives:

1. To estimate the aggregate economic impacts of climate change in Ethiopia over the study period 1960-2015,
2. To investigate the local household level vulnerabilities due to climate shock in selected rural villages of the South Gondar Zone and identify climate change adaptation (vulnerability reduction) role of rural off-farm diversification strategies,
3. To identify the factors affecting the growth of rural off-farm sector that could be an adaptation option,
4. To examine the rural off-farm and farm economy linkages to highlight the formers role for climate change adaptation.

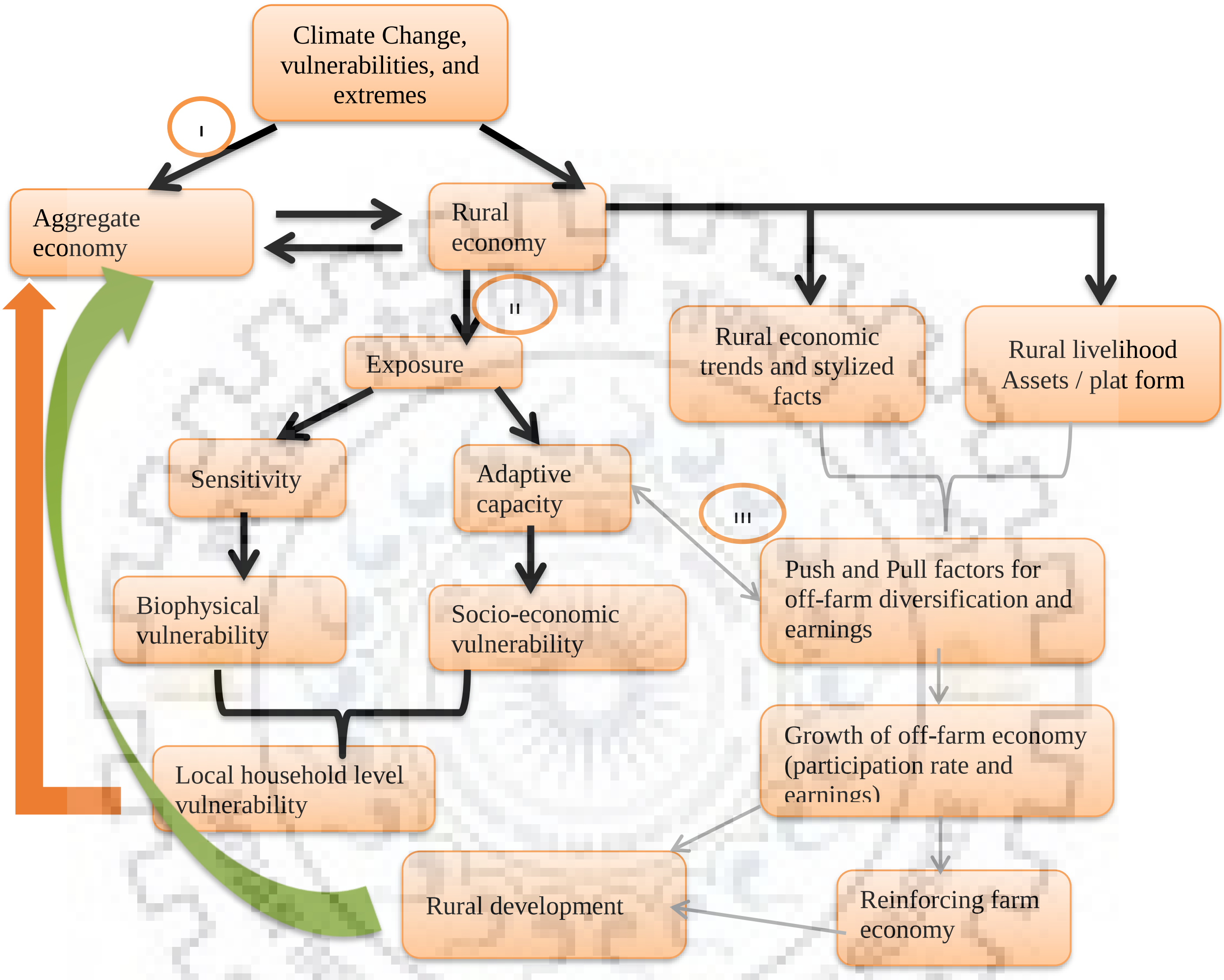
1.5 Conceptual and methodological framework

As a starting point, the study examines the impact of climate change on the aggregate economy. The second exercise is the use of the integrated local level vulnerability assessment framework that accounts for both the biophysical and socio-economic aspects of vulnerability of a particular local system. Through this, the study explores the implications of climate change on the rural households' livelihood and examines the role of adaptation in general and in particular that of rural off-farm sector. The third analysis emphasises on the socio-economic aspects of vulnerability particularly adaptive capacity of the rural economy. The thesis investigates the determinants fostering the growth of the rural off-farm sector. Further, it explores its role in climate adaption, contribution to the farm sector, rural development and safeguard the overall economy.

1.6 Research design

The study follows both time series and cross-sectional research designs. The time series research design using secondary data was employed to achieve the first objective of the study. For the remaining objectives the study follows a cross-sectional research design. Prior to the household survey, few selected district administrators, experts and key informants were interviewed. The information emerging from the discussions helped development of the structured questionnaire for the household survey. The survey was accomplished over the period December, 2018 to January, 2019. The enumerators for the survey were trained *a priori* for this purpose. Further, the enumerators conducted personal interviews in the local language (*Amharic)*. This allowed collection of the required information from the sampled rural households. The familiarity with local conditions and ease of communication helped collection of reliable information. However, no person-specific, easily identifiable information were recorded during the survey to ensure ethical standards.

Figure 1.2: Conceptual and methodological framework for aggregate and local level climate change impact assessment and off-farm diversification as an adaptation option



Source: Author's conceptualization

The study area[12], South Gondar Zone, is a zone in Amhara region of Ethiopia. The zone has an estimated area of 14,095.19 square kilometres. The rational for choosing South Gondar Zone as the study area includes its known vulnerability to agro-climatic shocks, high population growth rate, high land degradation, presence of marginal farmers, and presence of off-farm activities. The Zone has 41.5 percent arable land with different agro-ecologies. The sub-tropical (*Woina Dega*) and temperate (*Dega*) agro-ecologies account for 27 percent and 54 percent of the total coverage in the Zone respectively (Getachew,

[12] The study area shown in the figure is based on the administrative classification of zones and districts as available from https://www.gadm.org.

2017). The other agro-ecologies have relatively smaller coverage[13]. The long history of settlement, poor land use management and other socio-economic conditions as well as policy-related factors, large parts of the zone is devoid of vegetation cover. Along with the global climate change, the rate of desertification in the zone is increasing and the change in agro-ecologies from temperate (*Dega*) and sub-tropical (*Woina Dega*) to warm semi-arid or tropical (*Kola*) and hot arid or desert (*Berha*) is intensified (Alemu *et al*. 2009). A decreasing trend and increased variability in rainfall during the rainy season over the months June to August along with shortening of rainy season during the months of February to April was observed. In comparison to other regions, the Amhara region, which comprises of South Gondar Zone, is one of the most vulnerable areas to climate shocks. El Niño induced droughts, La Niña induced floods and other agro-climatic shocks like crop-pest, livestock epidemic, hailstorm, etc. are common in the zone (Atinkut and Mebrat, 2016). Land degradation, loss of soil fertility, water stress, low production and productivity, crop damage, livestock disease, loss of grazing land, damage of infrastructure, dwellings and other properties, loss of assets and income, social inequality and poverty, migration, death of humans and livestock are common climate change induced effects in the region as well as in the zone (USAID, 2015).

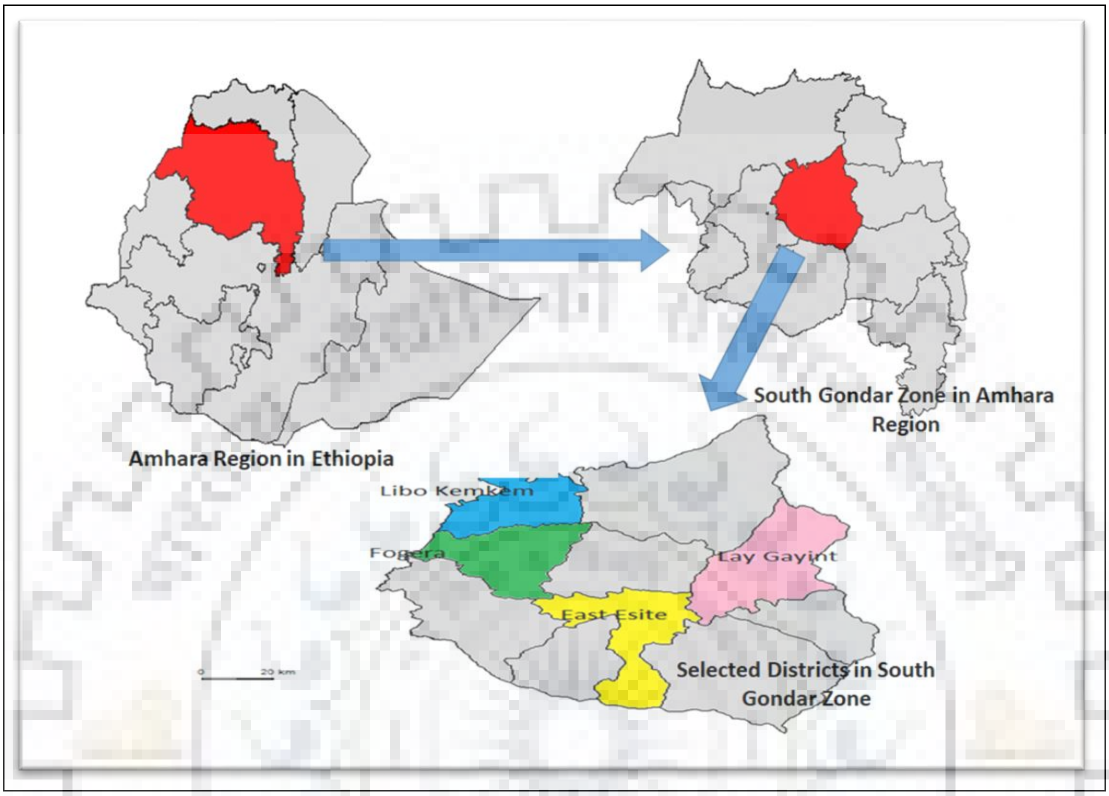
According to the official statistics[14] and some unpublished reports such as USAID (2015), rural households are mostly engaged in traditional farming without diversifying into other non-farm activities. Population was estimated to be 2,395,981 in 2015-16 with an average family size of 4 members per family and population density of 170 people per square kilometres. Urbanization is low and only accounts for 9.53 percent. Rapid population growth has increased the fragmentation of land leading to a decrease in the farm size and even an increase in landlessness. Therefore, the average farm size is 1 hectare, which is lower than the country average of 1.01 hectares. Access to electricity and road density are very low in comparison to the minimum standards and the national average. Rural infrastructures that reduce the sensitivity of rural households to climate shocks such as rural health and water facilities are too negligible. The urban adjacent districts are comparatively

[13] South Gondar Zone has diverse agro-ecological zones with altitudes ranging from 1500m to 4231m above sea level. The agro-ecologies are: cold and moist (*Wurch*), temperate (*Dega*), sub-tropical (*Woina Dega*), and warm semi-arid or tropical (*Kola*) (Getachew, 2017, Alemu *et al*., 2009).

[14] Unpublished reports from Village and district administration offices

better off in this regard. Agricultural insurance and credit markets for rural households are missing as well as there is absence of government initiatives.

Figure 1.3: Map of the study area



Source: Prepared using maps available from https://gadm.org/maps/ETH.html. (Accessed on 15th April 2020)
Note: Do not scale. For representational purpose only.

There is heterogeneity in socio-economic and demographic status as well as livelihood diversifications among rural households in the study area. The study area considered in this thesis is geographically vast making a zonal survey practically impossible. Therefore, the study applies a stratified multi-stage sampling technique to select the sample rural households. The first stage involved purposive selection of the four districts namely, *Kemkem, East Estie, Lay Gayint and Fogera*. They are selected under the assumption that they would be representative of the entire zone. In the second stage, three villages[15] are selected in each of the above districts and one village in the Fogera district. Following discussions with the Agriculture and Rural Development Office experts[16] and the need to

[15] Village represents *kebelle* which is the lowest administrative unit in Ethiopia

[16] A priori interview with the informants selected from Zonal and district level Agriculture and Rural Development Office experts provided important information over the issue to select sample study districts and villages

include different environmental and socio-economic characteristics of the districts, the study identified 10 villages.

Using a stratified multistage sampling, the study finally identified a sample of 323 rural households. Stratified multistage sampling technique considers the existing variability or heterogeneity in the target population. It draws samples from all the available heterogeneous groups in a population. It does not use only a part of the target population for sampling. This helps in reducing the sampling error and allow for increasing the margin of error level (e) even beyond 0.5 percent. The margin adopted is 0.55 percent in this study so as to have a manageable sample size which may reduce non-sampling errors as well.

Following Yemane (1967), the sampling formula is:

$$n = \frac{N}{1 + N(e)2} = \frac{13634}{1 + 13634(0.055)^2} = 323$$

where, n is the sample size; N represents the total number of households in all sampled villages, and e represents maximum variability or margin of error (0.55 percent is assumed).

Following the determination of the sample size, participatory household wealth assessment information in each village was captured in order to further stratify households under three different wealth categories (or strata) namely, *poor, medium (less poor) and affluent (better-off)* households[17]. The study required information on the households' off-farm diversification status as a sample stratifying criteria. This information is not easily available. Using the strata that are based on the household wealth assessment information, sample rural households are selected randomly and their off-farm diversification status subsequently identified through the primary survey. There is an inequality in the size of the three strata of households thus identified. Therefore, it is appropriate to use a random selection process where the probability of elements in each stratum being included in the sample is proportional to the size of their respective stratum. The probability proportional to sample size (PPS) method is in use to select the sample households from each wealth category in each sampled village. The identified rural households' off-farm diversification status are systematically associated with the households' wealth category in a manner that

[17] Each village administration office has a sampling frame with wealth category as poor, medium (less poor) and affluent (better-off) based on the usual rural life style (living standard) and asset (income) level.

the non-diversified households are poor, the low return off-farm diversified are labeled as medium and the high return off-farm diversified are considered affluent as shown in Table1.1.

Table 1.1: Sample size distribution in the sample villages

No.	District	Village	Village Population	Number of village household heads				Number of sampled households				Number of sampled households w.r.t off-farm diversification status			
				P	**M**	**B**	**T**	**P**	**M**	**B**	**T**	***Non-off-farm diversified***	***Diversified into low income off-farm activity***	***Diversified into high income off-farm activities***	***T***
1	Kemkem	Bira Abo	8393	592	423	338	1353	14	10	8	32	14	10	8	32
		Angot	8990	666	458	375	1499	16	11	9	36	16	11	9	36
		Buraegziabhiarab	8717	767	383	256	1406	18	9	6	33	18	9	6	33
2	East-Estie	Newaye	6790	625	292	208	1125	15	7	5	27	15	7	5	27
		Alemaya	7820	581	374	249	1204	14	9	6	29	14	9	6	29
		Koma	8250	803	296	211	1310	19	7	5	31	18	8	5	31
3	Lay Gayent	Checheho	9070	848	339	254	1441	20	8	6	34	18	10	6	34
		Ambamariyam	9101	635	465	296	1396	15	11	7	33	15	11	7	33
		Gunagedeba	10900	1015	592	211	1818	24	14	5	43	24	14	5	43
4	Fogera	Aweraba	6270	563	346	173	1082	13	8	4	25	4	17	4	25
Total							13634	168	94	61	323	156	106	61	323

Notes: P – Poor, M – Medium, B – Better off are different categories of households. T stands for Total households.

Source: Author's own preparation with data from each village administration office, 2018.

1.7 Scientific contribution

The effect of climate change on agriculture and other climate sensitive sectors is commonly studied. However, its implications on the aggregate economy have received limited attention and more so for a country like Ethiopia, the evidences are largely inconclusive barring few. Therefore, this study contributes the analysis on the macroeconomic effect of climate change which helps to capture all direct and indirect effects of climate change in the Ethiopia's case. The thesis also contributes a special kind of local level vulnerability assessment which substantiates the aggregate level analysis. The local level vulnerability assessment used in the thesis emphasized on the endogenous adaptive capacity differences (socio-economic vulnerability) unlike the existing studies that are focused on the exogenous ecological differences (only biophysical vulnerability). In this regard the thesis examines the climate change adaptation role of the untapped and least exploited rural off-farm diversification in the study area. The thesis also contributes to the disaggregated analysis of off-farm diversification by considering off-farm activities into two mutually exclusive groups of off-farm activities unlike the existing studies those looking off-farm activities aggregately.

1.8 Outline of the thesis

This thesis is structured into seven chapters. The next chapter presents a detailed review of all the related literature on the economic impact of climate change, local level assessments of livelihood vulnerability and the adaptation efforts at the household level. The third chapter presents the analysis of the aggregate economic impact of climate change in Ethiopia. Chapter four investigates the local level climate shock vulnerabilities and the effects on selected rural village households in the South Gondar Zone of Amhara region using the integrated livelihood vulnerability assessment approach, namely the LVI-IPCC framework and the econometric methods. The implications of rural off-farm diversification by the rural household as climate adaptation is also presented. Chapter five examines the effects of climate change on the rural household's off-farm diversification decision and other potential determinants contributing to the expansion of the off-farm sector. Chapter six tries to further understand the climate change adaptation role of the off-farm sector through examining its linkages with the farm sector.

Chapter seven synthesizes the major research findings and how they could be translated into policy implications. Outlooks for further research are also outlined briefly in the chapter.

Chapter 2

Review of Literature

In this chapter, the review of literature undertaken to fulfil the research objectives is presented sequentially. The first section outlines all studies directly or indirectly related to the assessment of the impact of climate change on the economy at the aggregate level. It is followed by a section describing the specifics of the Ethiopian climate and economy. The third section presents a review of the local level assessments of the livelihood vulnerability to climate change. Climate change adaptation, rural-off farm economy, determinants of the off-farm diversification and the linkages between farm and off-farm linkages are discussed in the fourth section.

2.1 Economic impacts of climate change

The subject economics concerns the management of scarce resources for sustained long-term economic growth. Nature, particularly the climate, is a common scarce resource exposed to free-riding problem that constrain economic growth due to the '*tragedy of the commons*'. The growth models considered climate as control variable(s) and neither emphasized climate change related problems nor considered them as the centre of discussion (Mankiw *et al.*, 1992). For instance, the neo-classical growth models considered exogenous technology alone as a source of long-run economic growth (Solow, 1956). The endogenous growth model also focuses on human capital, research and development, among other factors as sources for long-run growth (Romer, 1986). Following the contributions by Nordhaus[18] (1991a, 1991b, 1993, 1994, 2007, and 2019, among many others), climate is recognized as an endogenous factor. Therefore, it is an integral part of the economic analysis as it simultaneously affect the economy and at the same time, affected by the economy. The prevalence of frequent and severe climatic shocks in developing economies necessitates explicit consideration of climatic conditions into economic analysis. Climate change has various manifestations and the channels through which it could possibly affect economy. The most important manifestations are sea

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[18] Prof. William D. Nordhaus was recipient of the Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel in 2018 along with Prof. Paul M. Romer

level rise, erratic and unpredictable precipitation patterns, changes in temperature (variability and extreme average values), ocean currents, wind direction and speed, intensity of cyclones, storms, earthquakes and the frequency, intensity and duration of droughts and floods. Existing studies that focused on the economic impact of climate change used either temperature and/or precipitation while natural disaster studies used variables related to extreme events. Manifestations such as sea level rise, ocean currents, wind direction, cyclones, storms, and earthquake and their economic impact or growth effects have drawn limited attention due to unavailability of data and complex methodological issues. In this thesis, the focus is mostly on climate-induced droughts and floods and therefore the review do not critically analyse scientific papers quantifying the impact of the remaining manifestations.

Introspection into the channels reveal that one way through which climate change may affect economic growth, is through savings. Climate change followed by massive and frequent drought and flood events significantly reduces savings and ultimately slows economic growth (Fankhauser and Tol, 2005). The other channel is through technology that requires human as well as physical capital. However, climate shocks induce poorer countries to produce and import subsistence food and health aid for survival rather than advancing education and import of capital goods so as to advance technology. These finally reduce labour productivity and in turn affect long-run economic growth.

Climate change leads to uncertainty and pessimism in economic agents' decision making. These shocks and experiences forces agents to prefer low risk low return investment over high productive risky investments thereby hindering growth prospects. Uncertainty also increases the costs of climate adaptation and decreases its effectiveness. Finally, climate change drags growth through reduction in the productivity of capital and other inputs of production. Consider for example, in a rain-fed economy the input productivity depends on the accessibility of optimum and timely rainfall apart from normal allied climatic properties. From meteorological evidences, it is evidenced that climate change is obviously happening and its adverse impact is nonlinear and disproportionally high for developing economies (Dell et al., 2012; IPCC, 2018; Burke *et al.*, 2015; Diffenbaugh and Burke, 2019). Following the studies by Fankhauser and Tol (2005), Nordhaus (2006) and Dell *et al.* (2012), to mention a few, the number of climate change impact studies have increased in the past decade. Kolstad and Moore

(2020) presents an exhaustive review of literature, highlights the methodological advantages and limitations of using cross-section data and panel data to analyse climate impact and identifies “a number of priorities for research”.

The “priorities” emanates due to the existing controversy in both the theoretical and empirical literature concerning climate impact. On one hand, the economic impact of climate change is over estimated and exaggerated. Mendelsohn (2009) estimates that the GDP impact of warmer temperature in the 21st century is only 0.1 percent to 0.5 percent, which has far too less significant impact in the most immediate period and argue that a significant intervention in climate change adaptation investment could have adverse impact on economic growth than the perceived threat posed by climate change. Milliner and Dietz (2015) opine that the macroeconomic impact of climate change is relative to the country’s level of development. The developed economies are relatively better off in comparison to developing and less developed economies in terms of climate adaptation capacities. Further, economic advancement may protect economies from the dangers of climate change and therefore, the allocation of resources for adaptation measures does not bring positive change since such reduces resources available for productive investment. The foregoing argument suggests that the developing economies may follow the path of the developed economies, those primarily focused on productive investment rather than investment for climate adaptation that achieved development first. In simple words, it means that the Environmental Kuznets Curve (EKC) works (Shafik and Bandyopadhyay, 1992; Panayotou, 1993; Grossman and Krueger, 1995).

On the other hand, the economic impacts of climate change were estimated to be significant mainly for developing economies. Environmental limits including climate change halts economic growth[19]. It is difficult to achieve continued growth that in turn work for environmental quality unless climate change is contained in advance. Moreover, the evidence of an actual EKC is rare, and therefore, the developing countries cannot sustain growth and adequately address the pressing environmental issues (Stern, 2018; Karsch, 2019). Warmer temperature hinders growth in developing economies than the developed ones (Dell *et al.*,

[19] Refer the study by Everett et al. (2010) for details. Available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/69195/pb13390-economic-growth-100305.pdf

2012). High average daily temperature is responsible for the income disparities between Africa and the rest of the world (Nordhaus, 2006) and it decreases the export performance of the developing countries (Jones and Olken, 2010). A percentage rise in temperature significantly reduces economic growth in Sub Saharan Africa (SSA) by about 0.13 percent, *ceteris paribus* (Alagidede *et al.*, 2016). Warming in the 21st century could lead to huge global-scale macroeconomic impacts that would decrease per-capita GDP by 23 percent below what it would otherwise be, with the possibility of a much larger impact on poor less developed economies with mean annual temperature greater than 13°C (Burke *et al.*, 2015). A non-linear relationship between temperature and various basic productive components of an economy exists. For example, labour supply (Graff Zivin and Neidell, 2014), labour productivity (Hsiang, 2010) and crop yields (Schlenker and Roberts, 2009) all decline beyond temperature thresholds located between 20 °C and 30 °C. According to Acevedo et al. (2020), the optimal temperature is between 13 to 15°C. At temperatures lower than this threshold, an increase in temperature boosts economic activity. At higher temperatures, an increase in temperature hurts economic activity. This study further shows that the channels through which warming affects economy are investment, health, labour and overall productivity. These empirical findings inform developing economies to priorities climate change adaptation and a move towards green economy, otherwise development efforts could never be fruitful.

Abidoye and Odusola (2015) find strong impact of climate change on African economy for the period 1961 to 2009 than for the sub-sample period 1961 to 2000. Furthermore, the adverse economic impacts of climate change worsen as time progresses and adaptation measures delayed. Lanzafame (2014) also concludes that African countries have not adapted well to climate change based on an investigation of the macroeconomic growth effect of climate change considering temperature and rainfall as proxies.

In Ethiopia, the observed evidences on the climatic conditions substantiate the problem of climate change. Mean annual temperature in the country increased by an estimated maximum of 1.3 ^{o}C since the 1960s, rising by about 0.1 ^{0}C to 0.4 ^{0}C every ten years (FDRE, 2015). The rise in temperature started from the second half of the 1990s. A decreasing trend in rainfall observed since the 1980s and increase in rainfall variability (alternate extreme values of annual rainfall) may be correlated with the drought incidences. Droughts are frequent, erratic and vast in spatial sense (FDRE, 2015), leading to famines and epidemics, further increasing the size of the population needing humanitarian aid (Yalew *et al.*, 2017). Due to rainfall variability, the actual Ethiopian real per-capita GDP was 4 times lower from what it could be if rainfall variability reduced by half for the period between 1961 and 2008 (Ali, 2012). The country already feels the negative impacts of climate change and by 2050, the impact, under an extreme scenario of higher temperatures and increased intensity and frequency of extreme events could cost 10 percent or more of its GDP. The worst impacts may be due to droughts, as recent droughts alone had reduced GDP by about 1 percent to 4 percent (FDRE, 2015).

Climate change reduces cultivated land (Evangelista *et al.*, 2013), farm and labour productivity, and agricultural employment (World Bank, 2010). It increases labour migration from rural to urban areas (Wondimagegnhu, 2015), making rural livelihoods unreliable and ultimately undermine aggregate economic growth. A reduction in the farm productivity alone has a potential to induce a 6 percent fall in GDP by 2050 (Ferede *et al.*, 2013), and a 10 percent fall in GDP by 2100 (Mideksa, 2010). Before moving to the next section where a discussion on the Ethiopian economy is presented, few studies exploring the impact of climate change on various outcomes at the community and individual levels are reviewed.

Muringai *et al.* (2019) elaborates that fish catches have reduced due to climate change based on a survey conducted on small-scale fisheries in Zimbabwe. The situation makes the community food insecure in subsequent periods. There are studies examining the risk perceptions of different stakeholders including the policymakers with regard to climate change and its impact on the economy. Studies have considered the case of Ethiopia (Hameso, 2018; Regassa and Stoecker, 2014), South Africa (Elum *et al.*, 2017), Malawi (Sutcliffe *et al.*, 2016), Tanzania (Brüssow *et al.*, 2019), to mention few. Finally, there are also studies showing significant negative impact of climate change on child learning and health outcomes (Hyder and Behrman, 2016). The gender and distributional aspects in the climate change discourse is also important (Asfaw and Maggio, 2018). In this thesis, the focus is not on the micro impacts of climate change. The focus is predominantly on the macro implications at least to fulfil the first research objective and to analyse the effect of changes in climate variables on the aggregate economy.

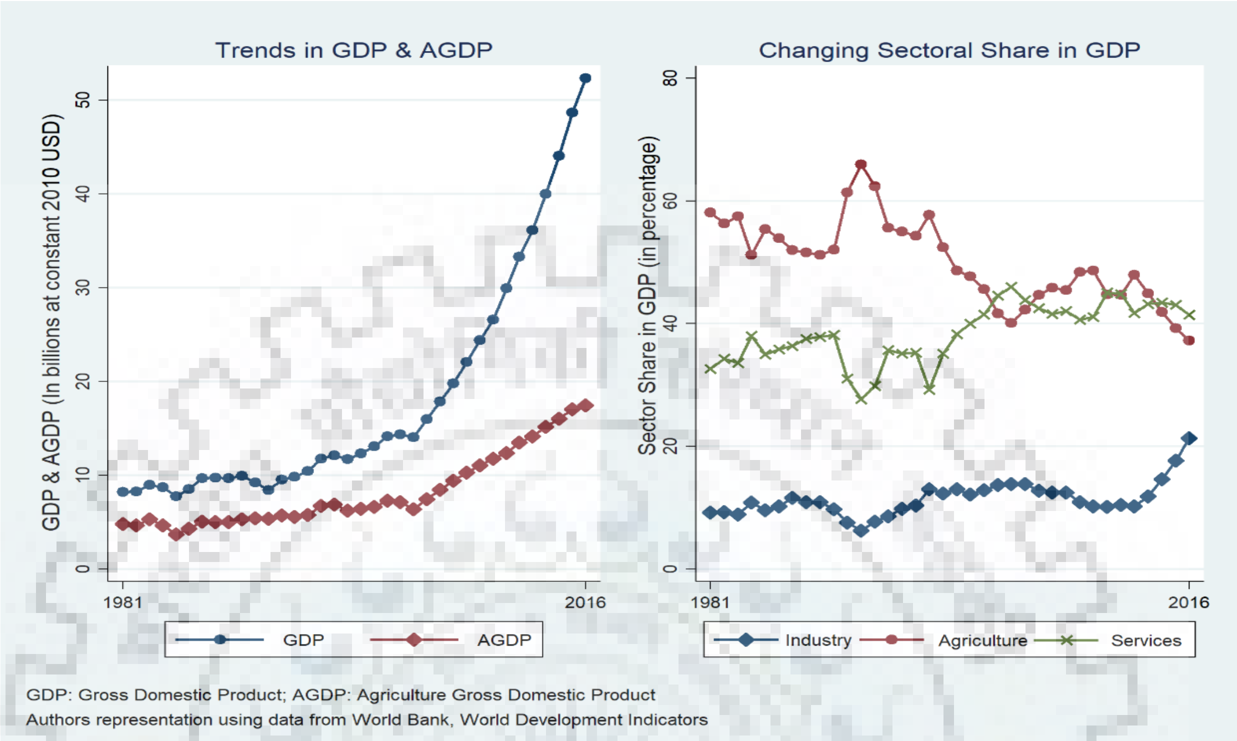
The analysis of net impact of climate change is challenging because there are multiple channels through which growth is impacted and manifestations too have their own diverse effects. A comprehensive assessment therefore requires three sets of knowledge. First is scientific knowledge (that is, an understanding of the meteorological underpinnings affecting global warming, greenhouse gas emissions, rainfall and temperature patterns, sea level rise, and oceanic patterns). Second are the direct and indirect impacts (that is, the repercussions of the hydro-meteorological changes on the ecosystems, infrastructure and human capital) and third, the economic impacts (that is, the costs to individuals, communities and governments.) Economists and climate scientists have developed complex computer based simulation models to capture the relationship between economic and climatic variables. Models follow either the partial equilibrium approach or the general equilibrium approach (Deressa and Hassan, 2009). Partial equilibrium models focus on the analysis of part of the overall economy such as a single market or subsets of markets or sectors, assuming no interrelationship between sectors. For example, the Ricardian analysis will fall under this group of climate change models.

The general equilibrium models, on the other hand are analytical models that assumes the economy as a complete, interdependent system, thereby providing an economy wide prospective analysis capturing links between all sectors. A popular model is the Integrated Assessment Model (IAM) from Massachusetts Institute of Technology (MIT) and another is the Dynamic Integrated Model of the Climate and the Economy (DICE) (Dell et al., 2014; Moore and Diaz, 2015; Nordhaus, 2019). For example, the Computable General Equilibrium (CGE) model in which the impacts of climate change are analysed by emphasizing only one period social accounting matrix (SAM) fall under this group of climate change models. Further, in the CGE model intertemporal effects are ignored. While these models vary in assumptions and other technical details, they all identify a trade-off between economic growth, climate change and long-run wealth. The seemingly complex climate change models such as IAM, DICE and Regional Integrated Climate-Economy model (RICE) are used mostly by climate scientists. Economists on the contrary analysed improved growth models that incorporates climatic variables. To link all the channels (micro foundations) to macro climate change impact, effect on GDP is taken as an aggregate indicator in this study. This allows one to capture all the direct and indirect effects of climate change on all sectors of the economy. The theoretical model and the analytical framework are discussed in the methodology section in the third chapter.

2.2 Climate and economy in Ethiopia

Ethiopia is one of the worlds least industrialized and greenhouse gas emitter. However, it has significant exposure to risks related to climate change. The subsistence agrarian economy, poor adaptation capacity particularly poverty, poor technology, and relief based disaster management by the government and lack of self-adaptive capacity among other factors aggravates the situation. The most climate sensitive sectors that are responsible for the adverse macroeconomic impacts of climate change are agriculture, energy (hydropower), road (transport) and other life supporting sectors. First, still the lion share of Ethiopian GDP is generated from rain-fed agriculture. Rain-fed agriculture in Ethiopia contributes about 38.5 percent of GDP, 80 percent of all national employment and up to 90 percent of export earnings by the end of the first GTP (NPC, 2016). Agricultural practices are traditional, subsistence oriented and thus highly sensitive to seasonal variations in temperature and rainfall. The country is significant cultivable land coverage with estimates vary between 30 to 70 million hectares. However, only about 15 million hectares is presently cultivated from which only 4 percent to 5 percent is irrigated (Awulachew *et al.*, 2010). Figure 2.1 presents the contribution of the agricultural sector to GDP. Second, energy, an engine for all economic sectors, is also rain-fed, about 95 percent of energy in Ethiopia is generated from hydroelectric power. In recent years, the country is experiencing power rationing due to insufficient water in the dams and reservoirs. The power rationing has adversely affected the non-agricultural sector of the economy directly. Lack of water in dams also hinders the performance of irrigation. According to Awulachew *et al.* (2010), about 640,000 hectares was irrigated in comparison to a potential of 5.3 million hectares assuming use of currently available technologies. Third, roads, the backbone of the country's transportation system are often hit by large floods disrupting supply chains and essentially hurting the supply of farm outputs. Floods have also other significant socio-economic disruptions beyond causing only pre and post-harvest damages in the agricultural sector. Other life-supporting sectors like health, water, ecosystem services were also severely affected.

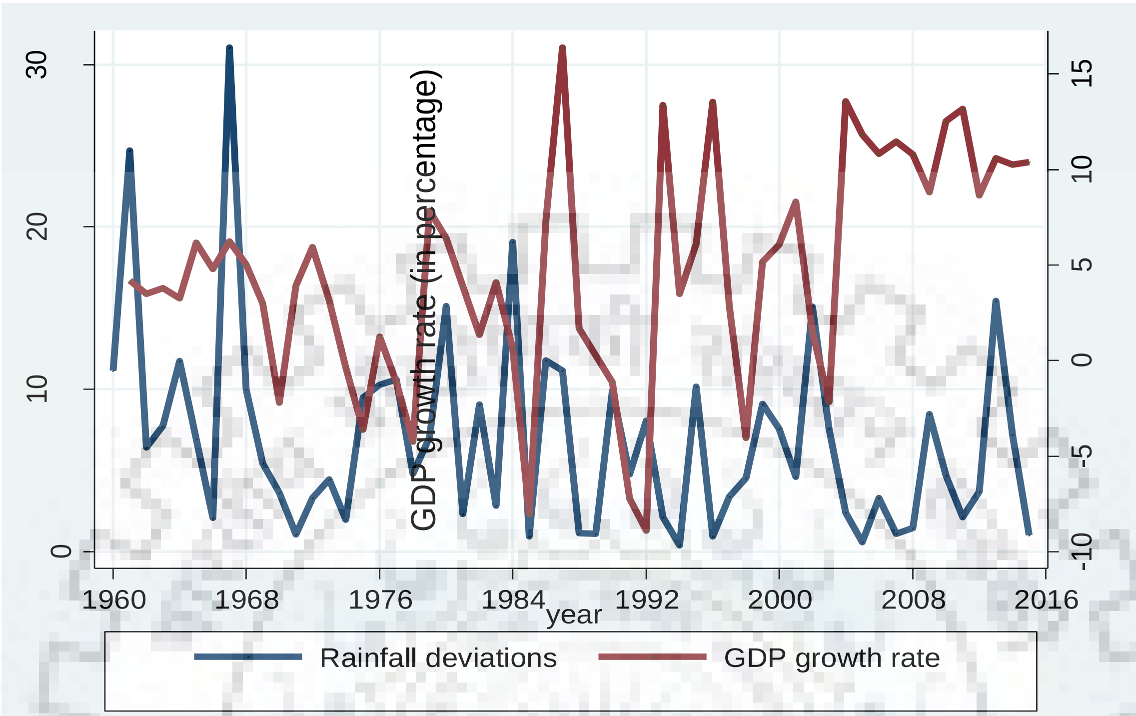
Figure 2.1: Select macroeconomic aggregates - Ethiopia



GDP growth in Ethiopia was non-existent in between 1960 and 2004. The real GDP growth averaged 1.5 percent during monarchy (1951-73), under the communist *Derg* regime (1974-91), -1.0 percent and while transition to market-based economy (1992-2003) it touched 1.3 percent (World Bank, 2015). However, after 2004, Ethiopia achieved relatively higher growth enabling the average long-run growth in GDP over the period 1960 to 2015 to be about 4.6 percent. Real GDP has tripled since 2004 although it remains well below regional and low-income levels. The observed shocks to GDP are associated with climatic shocks such as drought (less rainfall and high temperature) and unfavourable weather events (Manyazewal and Shiferaw, 2019). This indicates the fact that both the minimum and maximum rainfall from the optimal level may not be productivity enhancing. Finally, the absolute annual rainfall deviation[20] and GDP growth rate for the period 1960 to 2015 are plotted in Figure 2.2.

[20] For brevity the value of absolute annual rainfall deviation in each year is discounted by 10 percent

Figure 2.2: Trend of rainfall deviations and GDP growth rate for Ethiopia



Data source: Rainfall from World Bank and GDP from Penn World Table; Authors calculations and representations

The figure reveals that GDP growth may have a close relationship with rainfall deviation. When rainfall deviation increases, growth decreases and vice versa. However, there are exceptions to this systematic relationship in the year 1982, and over the period 1989-1992. Over these years, though rainfall was nearly optimal with minimum deviation from average, there was no growth in GDP primarily due to the Ethio-Eritrea war and the civil war. Due to the slow recovery after the war, Ethiopia records high growth rate in 1993. Given this review on the Ethiopian economy, now the focus is on the studies exploring the local level assessment of vulnerability.

2.3 Local level assessments of livelihood vulnerability to climate change

The aggregate level vulnerability indicators could not adequately consider circumstances that make a local system vulnerable to climate shocks (Fussel, 2010). It is important to reach on national consensus on climate action and strengthens commitments (Narayanan *et al*., 2016). However, effective adaptation measures require a thorough understanding of the local community characteristics. Downscaling provides more concrete information on local impacts (Jacques, 2006). Therefore, local level assessment of livelihood vulnerability to climate change is necessary for effective adaptation interventions. It is a process to determine the potential level of vulnerability along with contributing factors in a particular local system so as to develop possible responses. The available local level assessments of livelihood vulnerability to climate change (for example, Senbata, 2009; Demeke *et al*., 2011; Tesso *et al*., 2012; Gebrehiwot and van der Veen, 2013; Simane *et al*., 2016; Teshome, 2016a, 2016b and Amare and Simane, 2017) focuses on the agro-ecological heterogeneities. In local vulnerability assessments, however, heterogeneities across units of analysis are better explained with their adaptive capacity that is also an important source of vulnerability differences and intervention areas. Agro-ecological differences are less at the local level. A given agro-ecology comprises heterogeneous groups of rural households with varying degree of vulnerability to climate change. This necessitates a household level vulnerability assessment that would consider the endogenous adaptive capacity differences instead of the exogenous ecological differences.

There are different conceptual approaches and methodologies in different literatures to assess vulnerability based on the objectives to be achieved and the methodologies employed. There are three major conceptual approaches to analysing vulnerability to climate change: the biophysical, socioeconomic and the integrated assessment approaches (Deressa *et al., 2008*). The biophysical (top-down) approach is concerned with the physical impact of climate change on different attributes, such as yield and income. Vulnerability according to this approach is considered as end point or hazard-loss relationship in natural hazard research, or a damage function in macroeconomics. The approach focuses on sensitivity (change in yield, income, health) to climate change but fails to consider the adaptive capacity of individuals or social groups, which is more explained by their inherent or internal characteristics or by the architecture of entitlements (Ludena and Yoon, 2015).

The socio-economic (bottom-up) approach is a socio-economic vulnerability assessment that investigates vulnerable people to identify driving factors and solutions that are endogenous to policy decisions (Van Aalst *et al*., 2008). It focuses on the socioeconomic status of individuals or social groups to identify the adaptive capacity of individuals or communities based on their internal characteristics. Individuals in a community often vary in terms of education, gender, wealth, health status, access to credit, access to information and technology, formal and informal (social) capital, political power, and so on. These variations are responsible for the variations in vulnerability levels. Vulnerability is considered a starting point (that is, a variable describing the internal state of a system before it encounters a hazard event. It overlooks or takes as exogenous the environmental factors. It also fails to address the role of interaction between the social and natural system in the occurrence of the hazard.

The integrated assessment approach combines both socioeconomic and biophysical approaches to determine vulnerability. It is based on the vulnerability definition of IPCC (2001) which considers vulnerability to climate change as a function of adaptive capacity, sensitivity, and exposure. It corrects the weaknesses of the other approaches. However, there is no standard method for combining the biophysical and socioeconomic indicators.

2.4 Climate change adaptation

Climate change has primarily increased the risks and uncertainties associated with the farm sector. This necessitate identification of off-farm diversification strategies as measures to strengthen the adaptive capacity of rural households. Rural off-farm diversification and the related indigenous knowledge in the face of CCA are not yet well utilized (Anik and Khan, 2012) though they may help in adapting to climate change (Lebel, 2013; Yaro, 2013; IPCC, 2014). Exploring the CCA efforts in Ethiopia, it is found that the approach is mostly relief oriented disaster management (Abebe, 2010). Instead, enhancing CCA capacities of rural households was overlooked. Large proportion of rural households in Ethiopia has no access to non-farm income (Deressa *et al.*, 2008). Income diversification is not commonly used as CCA option in rural Ethiopia (World Bank, 2010). Rural households that participated into non-farm activities in Ethiopia were not more than 25 percent, of them very negligible amount about 2 percent were exclusively engaged in non-farm activities (Rijkers *et al.*, 2008; Asfaw *et al.*, 2017). Off-farm participation rate was among the lowest in Amhara regional state of Ethiopia (Bazezew *et al.*, 2013) which encompasses the geographical area of this study. Unlike other CCA measures rural off-farm diversification is not well investigated (Anik and Khan, 2012). Moreover, studies on the determinants of households' rural off-farm diversification decision (for example,. Dessalegn and Ashagrie, 2016; Asfaw *et al.*, 2017) did not explicitly account climate shock variables as determining factors. These studies also analysis off-farm activities in aggregate terms.

2.4.1 Rural off-farm economy

Off-farm diversification is one rural livelihood strategy (Sisay, 2010). Rural livelihood strategies are referred to the strategies or capabilities of rural households' in accessing productive assets and activities for better life under different institutions, policies, socio-economic contexts and constraints (Sisay, 2010; Khatiwada *et al.*, 2017; Yang *et al.*, 2018). The heterogeneity of activities create lack of definitional clarity among off-farm, non-farm, on-farm and agricultural activities. There is a distinction between on-farm and agricultural activities. Agricultural activities refers exclusively crop cultivation while on-farm activities includes other allied or auxiliary activities such as fishery, diary, animal husbandry, poultry and bee-keeping (Saith, 1992: 12). According to Babatunde (2015), rural off-farm diversification refers to participation of rural households into off-farm activities which consists all rural non-farm employments and agricultural wage employment on other people's farm. The difference between off-farm and non-farm is that the former is much broader than the latter as it includes the agricultural wage employment in addition to all other non-farm activities (Babatunde, 2015). Similarly, according to Saith, (1992: 12) the off-farm category also includes agricultural activities by rural households as hired labour on farms owned by others. Specifically rural non-farm activities are wage and self-employment income generating activities by rural households that are not agricultural (Haggblade *et al.*, 2010). Non-farm activities include mining, manufacturing, utilities, construction, commerce, transport, and other financial, personal, and government services. For example, agro-processing such as milling, packaging, bulking, or transporting and trading of raw agricultural products form a key component of the rural non-farm economy. Rural off-farm activities are usually categorized as low and high return wage and self-employment activities.

Agricultural wage employment on other peoples' farm, domestic servants and migrants for work, unskilled daily labourers and public food-for-work participants are typical examples of low paying wage employment off-farm activities. While collecting and selling firewood, compost and bio-gas preparation, carpentry, basketry, handcrafts or pottery, blacksmith or metal works, repair services, weaving, spinning, leather tanning, local food and drink preparation and petty trade are categorized as low return self- employment off-farm activities. The low paying wage employment off-farm activities and low return self- employment off-farm activities are considered as one group of off-farm activities due to the systematic similarity of rural households engaged in these activities. For simplicity, this study named this group of off-farm activities as low wage and/or self-employment (low return) off-farm activities.

High paying wage employment includes skilled labourers (wood house construction, builders/masons and painting, cobblestone construction) and formal international migration for work, while activities such as livestock and crop trading, stone and sand mining, traditional medicine, transport services (using small automobile and pack animals), afforestation, grinding mill are high return self-employment off-farm activities in the study area. Rural households engaged in high paying wage employment and high return self-employment off-farm activities have similar characteristics. Therefore, in this study both high paying wage employment and high return self-employment off-farm activities are named together as high wage and/or self-employment (high return) off-farm activities.

Low wage and/or self-employment versus high wage and/or self-employment categories are two mutually exclusive groups based on the existing nature of rural households in the study area but no exclusivity with in each category. In fact, there is no natural difference in the expected return from rural off-farm activities; the difference arises from the existing socio-economic and demographic as well as technical ability differences among rural households. Note that there are many economic activities under rural off-farm economy. These off-farm activities will have great role in enhancing rural households' CCA capacities, improving rural job employment generation, achieving overall rural development and solving the existing problems in rural-urban linkages and income differentials. However, the government emphasized on only farming and some allied activities; while, opportunities from the rural off-farm sector are overlooked.

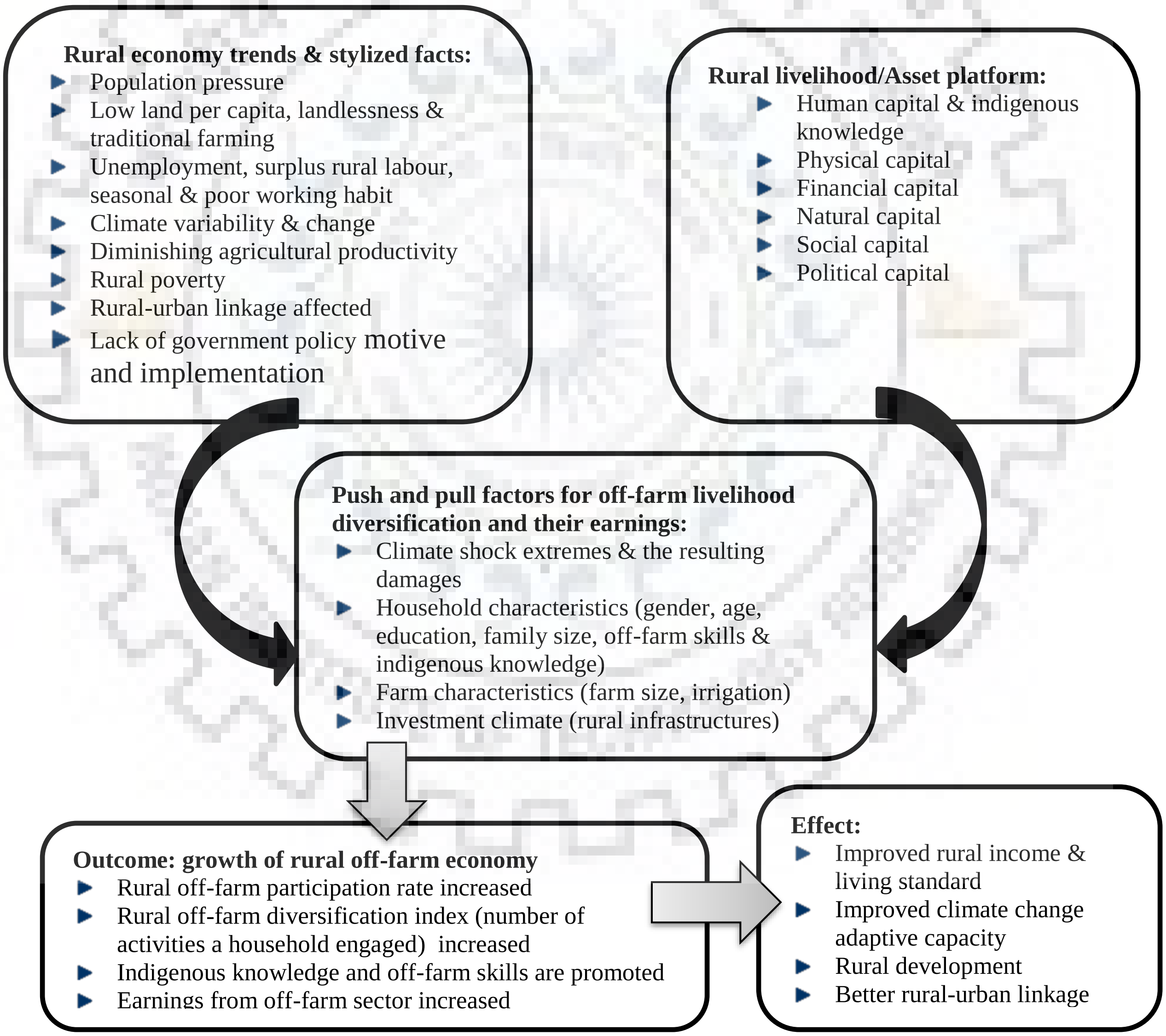
2. 4. 2 Effect of climate shocks and determinants of off-farm diversification and earnings

Following the decrease in the carrying capacity of the farming sector due to multifaceted reasons including climate change, some cross country studies (for example, Haggblade *et al.*, 2007; Davis *et al.*, 2010) showed that rural households' in developing economies have started to look at the off-farm opportunities and generates on average a 30 percent full-time rural employment in Asia and Latin America and 10 percent in Africa. Winters *et al.* (2009) includes the part-time off-farm employments and estimates a total off-farm participation rate of about 83 percent in Asia and Latin America and 78 percent in Africa. Non-farm income share was also estimated to be about 35 percent in Africa to 50 percent in Asia and Latin America (Haggblade *et al.*, 2007, 2010). Some available studies in different parts of Ethiopia (for example,. Demeke and Zeller, 2012; Kotu, 2014; Demie and Zeray, 2016; Dessalegn and Ashagrie, 2016; Asfaw *et al.*, 2017) found different levels of off-farm participation rate and off-farm income share may be due to the dynamic nature of off-farm activities and factors affecting off-farm participation and earnings across spaces and over time.

A number of studies were underlined the important contribution of rural off-farm diversification. The traditional perception that considers rural non-farm sector as low-productive and produces backward and low-quality goods and services was shifted towards the appreciation of the role of non-farm sector for overall rural development. Rural off-farm sector was reported as one path out of poverty for rural households (Loening *et al.*, 2008; World Bank, 2008). Yaro (2013) and IPCC (2014) argue off-farm diversification by rural households as a possible climate adaptation option besides to its rural job employment opportunity for the rural surplus labour and reducing the urban-rural income differentials and the resulting problems. Due to the less entry barrier nature of the rural off-farm sector Haggblade *et al.* (2007) suggests the sector as a base for rural economic transformation and as a possible climate change adaptation option at the same time. Babatunde and Qaim (2010) found that off-farm income has a positive net effect on food security and nutrition. A study by Seng (2015) in rural Cambodia showed that off-farm diversified rural households are more likely to meet their household basic needs and are more capable to adapt climate shocks. A study by Scharf and Rahut (2014) in the rural Himalayas found a positive welfare impact of off-farm diversification that specifically indicates that low-return off-farm activities reduce income inequality, while high return off-farm activities have a dis-equalizing impact.

Even though, the sector has a huge potential, rural households' participation in this sector and the actual earning from the sector was low in Ethiopia. The status of off-farm economy is different across countries. Countries are at different levels of recognition and utilization of opportunities from off-farm economy. The focus of this study is on how to achieve growth and efficiency of rural off-farm sector by enhancing the rural households' off-farm participation and the resulting return from the sector. Specifically, it examines the CCA role of the sector by assessing whether farm households participate in different rural off-farm activities as a response to climate shock. Therefore, the relevant literatures are mainly those that deal with on the determinants of rural households' off-farm participation decision and their returns. Availability of assets (resources), access to resources (the right to benefits from resources), capabilities (access to activities), institutions and socio-cultural-economic policy contexts and natural situations are important factors affecting rural households' off-farm livelihood diversification (Sisay, 2010). Literature has broadly generalized these factors into 'demand-pull or incentive factors' and 'distress-push or risk factors'. New market or technological opportunities, higher returns to labour and/or capital and the less risky nature of investment in the off-farm sector are some of the demand-pull incentive factors for rural households' off-farm diversification (Kilic *et al.,* 2009). The distress-push risk factors that forces rural households to diversify into off-farm activities include the following. The first is inadequate farm income even at favourable agro-climatic condition (Kilica *et al.*, 2009) and unstable farm income due to climate shock, market failure and longer term land constraint problems (Minot *et al.,* 2006). Jette-Nantel *et al.* (2011) found the positive effects of the uncertainty or variability of the farm market revenue on the likelihood of Canadian rural households off-farm work and the level of off-farm income. The second is, absence of crop insurance, consumption and farm input credit markets that force rural households to engage in low-return off-farm activities as a survival and coping strategy and farm investment finance option (Kilic *et al.,* 2009; Oseni and Winter, 2009). The availability of these financial services is also important for the growth of off-farm sector and for participation of rural households into high-return off-farm activities. These opposite push and pull factors support the existence of two mutually exclusive categories of off-farm activities, low and high return off-farm activities, used in this study. Generally, the investment climate influences the growth of off-farm sector. Investment climate includes factors that are incentives or disincentives for starting and running rural off-farm activities, such as financial services, infrastructure, and governance, regulations, taxes, labour and conflict resolution. The household's demographic characteristics, farm characteristics, awareness level, and other socio-cultural and economic basis are also potential determinant factors for both the participation into the sector and the return from the sector.

Figure 2.3: Rural off-farm livelihood diversification framework: determinants of off-farm sector growth



Source: Author's conceptualization

Rural households may participate in off-farm activities as accumulative strategy or survival strategy depending on the intensity of these factors. Based on literature, some rural households are mainly interested to diversify into rural off-farm activities to increase their earnings not on the aim of reducing adverse climate shock risks (Kilic *et al.*, 2009). These rural households are relatively not poor and have opportunities to engage in high wage and/or self-employment activities (Bezu & Barrette, 2010; Loison, 2015). According to these studies, diversification into high return off-farm activities is positively associated with household capacity, wealth or asset accumulation. Others are forced to participate for their survival rather than looking for better earnings (Minot *et al.*, 2006; Kilic *et al.*, 2009; Oseni and Winter, 2009). Such rural households are relatively poor and engaged in low wage and/or self-employment activities (Bezu & Barrett, 2010; Sisay, 2010). Given these groups there are also numerous rural households that did not diversify into any rural off-farm activities out of their subsistence farming. Since the analysis was on the aggregated off-farm sector, most of the available studies did not look the effect of each factor on different categories of off-farm activities; for instance, negative effect of irrigation to off-farm participation was identified (Dessalegn & Ashagrie, 2016), though it may have a positive influence on the likelihood of participation into high return off-farm activities. They do not also look the specific effects of climate shock on off-farm participation and so unable to conclude whether off-farm activities are practiced as a climate shock copying mechanism or not. Studies that specifically examined climate shock effects on rural households' off-farm participation are rare. Climate shock is supposed to be a dominant push factor for rural households' off-farm diversification (Bezu and Barrett, 2010; Demeke and Zeller, 2012). Kijima *et al.* (2006) in rural Uganda, Keil *et al.* (2007) in Indonesia and Deressa et al. (2009) in Ethiopia found that households tend to increase their low skilled labour supply into rural off-farm activities in response to negative agro climatic shocks to compensate for declines in agricultural income.

2.4 3. Farm – off-farm economic linkages

The rural economy consists of both the farm and off-farm sectors. According to Babatunde (2015), rural off-farm sector comprises all 'off the owners' own farm activities' including agricultural wage employment on other people's farm and rural non-farm activities regardless of location. Specifically, ‘rural non-farm activities’ are ‘wage and self-employment’ income generating activities by rural households that are not agricultural (Haggblade et al., 2010). Whereas the farm sector clearly represents all the pure agricultural activities like crop production, livestock rearing and other allied activities.

There could be bidirectional association between the farm and off-farm sectors with competing and/or complementary effects. In the literature, these linkages are identified as the direct production linkages and the indirect expenditure linkages. The direct production linkages are the backward (downward) and forward (upward) interactions between the two sectors. Backward linkage is created when the non-farm sector supplied inputs that can be used for agricultural production such as agrochemicals or fertilizers, composts, water pumps, farming tools and technologies. Non-farm sectors engaging in agro-processing and distribution services are important sources of backward linkages. Promoting non-farm sector will help to provide the farming sector with necessary inputs and technologies through backward production linkage. Forward linkage is created when the farm sector becomes the supplier of inputs to the non-farm sector.

When the linkage in between these sectors is expressed in terms of monetary relationship, rather than the direct material transfer, the indirect expenditure linkage is established. The expenditure linkage between the farm and off-farm sector refers financing expenses of the former using the income from the latter and vice versa. Rural households consume non-farm goods and services using their farm income. On the other hand, off-farm diversified rural households also purchase farm outputs using their off-farm income. It is one way of adapting the adverse effects of climate shocks (Kilica *et al.*, 2009). The expenditure linkage might be either for consumption (consumption linkage) or for investment (investment linkage) or both. Investment linkages occur when returns from one sector can be used to make investments in the other sector. For instance, in the traditional rural economies in which formal insurance and credit services are non-existent, income from off-farm employment is a last resort to finance agricultural production-liquidity linkage (Pfeiffera *et al.*, 2009).

The structure and performance of each sector governs the linkages that will occur. When the farming sector is more external input intensive the backward production linkages will expected to occur. If rural households are motivated and enable to process raw agricultural outputs, forward production linkages will be induced. If the growth in both sectors induces rural income growth and rural development at large, consumption and investment linkages are enhanced. However, if the income in these sectors is not reinvested in the rural economy due to the weak consumption and investment linkages rural development cannot be further inevitable. The strong consumption and investment linkages and thus a virtuous circle of rural development could be achieved if the two sectors are reinforcing each other instead of competing for labour and capital (Nasir and Hundie, 2014). If they compete, farm labour transfer to off-farm activities reduces farm production. However, Lewis (1954) reasoned that farm production do not decline as farm labour is transferred to off-farm employment, because of the availability of excess farm labour relative to farm landholdings. This argument is a baseline for the complementary linkage than the competing effect between the two sectors. Some recent empirical works such as Gebregziabher *et al.* (2012) in Tigray regional state of Ethiopia, Ercolani and Wei (2010) in China and Babatunde (2015) in Nigeria also support this argument.

In rural areas of most developing countries including Ethiopia, where farm holdings are small, farm labour is relatively abundant and rural labour markets are imperfect; the rural off-farm sector will have multifaceted interactions with the farm sector. This multifaceted interaction is amenable for empirical investigation as it is important to be distinguished. Therefore, this study investigates whether the two sectors are associated with competing or complementary effects by looking the effect of off-farm diversification and the resulting income on farm income.

Several studies have implied the emerging income and employment contribution of the off-farm sector to the rural economy (Haggblade *et al.*, 2007, 2010; Winters *et al.*, 2009; Davis *et al.*, 2010). Others examined the welfare, poverty and inequality impacts of off-farm diversification by rural households (De Janvry *et al.*, 2005; Babatunde and Qaim, 2010; Owusu *et al.*, 2011; Scharf and Rahut, 2014; Shehu and Sidique, 2014; Akaakohol and Aye, 2014; Seng, 2015; Kowalski *et al.*, 2016).

Babatunde and Qaim (2010) in Nigeria, Owusu *et al.* (2011) in Ghana and Seng (2015) in rural Cambodie found the positive food security effect of off-farm participation by rural households Shehu and Sidique (2014) in rural Nigeria and Akaakohol and Aye (2014) in Benue also found similar results and suggests off-farm diversification to improve rural households wellbeing in developing countries in general.

The study by De Janvry *et al.* (2005) in Hubie province of China and Scharf and Rahut (2014) in Himalaya looks the inequality effect of non-farm diversification and found the positive role of non-farm participation in reducing income inequality. According to the later study 'high return off-farm activities' have a dis-equalizing effect on rural households' income distribution; while, 'low-return off-farm activities' are important for income equality among rural households by helping the poor to survive and adapt adverse effects of climate shocks. In contrast, Kowalski *et al.* (2016) highlights the role of off-farm diversification as it is insignificant in rural Ethiopia.

However, only few studies were examined the farm and off-farm economic linkages and found conflicting results. Gebregziabher *et al*., (2012) found the complementarities between off-farm and farm sectors as off-farm income is invested on productivity enhancing agricultural inputs in Tigray, Northern Ethiopia. Likewise Babatunde (2015) founds that off-farm income affects farm output and demand for purchased inputs positively and significantly and thus confirms a complementarity effect between these sectors in Nigeria. Ercolani and Wei (2010) also found a positive GDP growth effect of farm labour participation into non-farm activities in China. A study by Nguyen (2019) also found a positive significant effect of non-farm income on farm input expenditure, agricultural value added and productivity in Vietnam.

On the other hand, Kilica *et al*. (2009) in Albania, Pfeiffer *et al*. (2009) in Mexico, Egyei and Adzovor (2013) in Ghana and Nasir and Hundie (2014) in Southern Ethiopia found competing effects of off-farm income on farm production. Kilica *et al*. (2009) found a competing effect between the two sectors as off-farm diversified rural households in Albania are not actually invest the resulting off-farm income in their farm activities. Similarly, Pfeiffer *et al*. (2009) in Mexico, Egyei and Adzovor (2013) in rural Ghana and Nasir and Hundie (2014) in Ethiopia highlight the possible competing effect of off-farm diversification by rural households upon their farm production A study by Kassie (2018) investigates the situation in which farm households in Mecha rural district tends to convert into agroforestry from crop production and its synergy with other non-farm activities. The study explores the important role of the agroforestry production in the area. According to this study the joint adoption of forestry and other non-farm activities by rural households is depends on economic return, land property right issues, experience and land location.

Chapter 3

Re-examining the Economic Impacts of Climate Change: A Study of Ethiopia

3.1. Introduction

The negative impacts of climate change on selected African economies have been widely documented (Yalew, 2020; Tol, 2018; Arndt *et al.*, 2014; Simbanegavi and Arndt, 2014; Asafu-Adjaye, 2014; Mekonnen, 2014; Hassan, 2010 to mention few). This study extends the existing literature by a systematic empirical re-examination of the impacts of the changes in selected climatic variables, in particular temperature, rainfall and CO_2 emission, on the Ethiopian economy. The climatic variables incorporated into the growth model as variables of interest and the model estimated using the Autoregressive Distributed Lag (ARDL) technique. According to the Climate Change Vulnerability Index (CCVI) released by Maplecroft[21] in 2015 and 2017, Ethiopia has significant exposure to climatic risks. The economy is heavily reliant on rain-fed agriculture, which contributed around 38.5 percent of Gross Domestic Product (GDP) by the end of the first Growth and Transformation Plan (GTP) of Ethiopia (National Planning Commission (NPC) of Ethiopia, 2016). Further, the agriculture sector growth helped partial eradication of poverty (World Bank, 2015) and therefore is the backbone of the economy constrained by climatic shocks among other socio-economic, geographic and political factors affecting economic growth. Studies have reported that like neighbouring African countries, the situation is no different in Ethiopia, climate change impact affecting food security and rendering rural livelihoods to be unreliable.

In Ethiopia, the frequency of climate change events have increased and the area affected by climate shocks such as droughts have spatially expanded. The decline in rainfall during the major crop-growing period (mid-June to mid-September) led to significant economic shocks. For instance, in the 2015 recent El Niño inflicted damages more than 10 million people were

[21] Maplecroft is a global risks advisory that released the Climate Change Vulnerability Index (CCVI) of countries across the world. CCVI integrates information about projected temperature and moisture changes, landscape context, natural history traits related to climate sensitivity and adaptive capacity, and documented and modeled responses to climate change

exposed to the perils of famine, diseases and deficiency of water (UNICEF, 2016). As a result, the demand for humanitarian support more than tripled. The country witnessed drought like conditions up to 2017 and the National Disaster Risk Management Commission (NDRMC) warned that 5.6 million pastoralists and agro-pastoralists in Afar, Somali, Oromia and Southern Nation Nationalities and People (SNNP) regions needed emergency food assistance (European Commission, 2017).

Ethiopia spends significant financial resources towards humanitarian responses by diverting its public budget from mega development projects. Such strategy may delay the structural transformation and could potentially deter long-term climate change mitigation. In general, severe and frequent climatic shocks may significantly determine the dynamics in the Ethiopian economy. But, there is an ongoing controversy that the negative impacts of climate change are often over estimated on the one side (Rosen, 2019; Fyfe *et al.*, 2013; Mendelsohn, 2009). Therefore, significant intervention in the form of investments in CCA and mitigation may be unsuccessful because such would limit productive investments (Milliner and Dietz, 2015). Financing climate change remains a major challenge for government departments at different levels (Musah-Surugu *et al.*, 2019). Others opine that development efforts would fail to yield better outcomes unless CCA are prioritized (Nordhaus, 2006; Dell *et al.*, 2012; Burke *et al.*, 2015; Alagidede *et al.*, 2016 and Diffenbaugh and Burke, 2019 to mention few).

Previous studies on the economic impact of climate change in Ethiopia (Deressa and Hassan, 2009; Evangelista *et al.*, 2013; Aragie, 2013) focused on the agricultural sector. However, climate change directly and/or indirectly affects all sectors in the economy. Agriculture has strong backward and forward linkages with the secondary and tertiary sectors of the economy and negative impact of climate change on agriculture create indirect effects on other sectors. Beyond the indirect effect, climate change directly affects directly non-agricultural sectors. For example, energy, an important input for all sectors, is dependent on rainfall and affected during droughts. The major source of the country's energy is hydroelectric power generation[22]. The

[22] Based on the WDI-World Bank data set in between the years 1991 to 2014 on average about 95 percent of the country's energy source is hydroelectric power that significantly relies on rainfall. Erratic and low rainfall had lead the country to energy shortage and power rationing which in turn affects all economic sectors in Ethiopia.

conventional view that non-agricultural sectors are not climate sensitive lacks scientific support (Burke *et al.*, 2015).

Therefore, while examining the impact of climate change on Ethiopian economy and measuring the associated economic costs, it is equally important to capture all the direct and indirect impacts. This helps to answer the following important policy questions. First, what is the effect of climate change on the aggregate Ethiopian economy, both in the short-run and long-run? Second, how much does climate change costs Ethiopian economy in terms of GDP lost? Thus, aggregate indicators are needed to measure the net economic impact of climate change. Research on these measurement tasks is still in its infancy. In this study, GDP is considered as a dependent variable to examines the aggregate economic impacts of climate change and estimates its potential costs on the Ethiopian economy for the last five and half decades. Assuming the effects of climate change is hypothetically different across sectors, the study also looks into the heterogeneous effects by disaggregating the dependent variable into the major sectors of the economy. Such examinations would supplement estimation of the pure impacts on the agricultural sector. This re-examination contributes to the existing debate in the empirical literature cantered on the climate change impact considering Ethiopia. This study uses the level and variations in the mean annual temperature and annual rainfall to represent climate change. The study shows that climate change, captured by increase in temperature and rainfall deviation (including high probability of decrease in rainfall), would jeopardize growth in the long-run. The results may aid national CCA plans and strategies. Moreover, it is important to understand the climate change related problems and situate those in the present and future development plans of the country.

The remaining parts of this chapter are organized as follows. The following section elaborates the research methodology including a discussion on the econometric specification adopted to fulfill the study objectives. The third section presents a discussion of the results obtained from the empirical exercises. The final section summarizes the key results and policy implications.

3.2 Methodology

3.2.1 Data

The study is a time series analysis using annual secondary data for the Ethiopian economy over the period 1960 to 2015. Table 3.1 describes the variables used in the analysis along with their sources. Appendix 3A shows the time series plot of the variables of the model. The descriptive statistics of the data analysed is given in Appendix 3B.

Table 3.1: Data description

S. No.	Name and symbol of variable	Data source	Description
1	GDP (Y_t)	Penn World Table[1]	Real GDP at constant 2011 national prices (in million 2011US$)
2	Capital (k_t)	-do-	Capital stock at constant 2011 national prices (in million 2011US$)
3	Labour (l_t)	-do-	Human capital index, based on years of schooling and returns to education
4	Annual rainfall (r_t)	World Bank[2]	Annual rainfall in millimetres
5	Mean annual temperature (τ_t)	-do-	Mean annual temperature in degree Celsius
6.	Broad Money to GDP ($m2\_gdp_t$)	IMF[3]	Broad Money to GDP (Liquid liabilities to GDP in percentage)
7.	CO_2 Emissions ($CO_2\_emm_t$)	World Bank[4]	co_2 Emissions

Note:

1. Data is available at https://febpwt.webhosting.rug.nl/Home
2. World Bank Climate Change Knowledge Portal: https://climateknowledgeportal.worldbank.org
3. International Monetary Fund (IMF)
4. Data from World Development Indicators available at https:// https://databank.worldbank.org/source/world-development-indicators

Source: Author's representation

3.2.2 Theoretical Model

3.2.2.1 A Simple Model of Climate Dependent Economy

The Solow (1956) neo-classical growth model considered exogenous technology as a source of long-run economic growth. Mankiw *et al.* (1992) put-forth an augmented Solow model for examining whether the Solow growth model is consistent with the international variation in per-capita income. In this study, further modification to model proposed by Mankiw *et al.* (1992) is made and selected climatic variables are included. This inclusion is based on the justification available in Alagidede *et al.* (2016), Ali (2012) and Fankhauser and Tol (2005). Fankhauser and Tol (2005) incorporated temperature in a standard economic growth model to examine the impact of climate change on economic growth. Ali (2012) modified the standard neoclassical growth model by introducing rainfall variability as a factor that incapacitates productivity. Alagidede *et al.* (2016) uses an empirical model developed from an augmented neoclassical growth model with a Cobb-Douglas structure that incorporates climatic variables. It is important to mention studies by Burke *et al.* (2015) and Diffenbaugh and Burke (2019) have related temperature to economic production and inequality, without referring to any specific growth models. Theoretically important economic variables that would explain most of the changes in economic production are not considered by these studies. The methodology in this study is therefore based on sufficient theoretical arguments for the choice of the modified growth model. This allows including economically based independent variables in addition to, climatic variables, the variable of interest.

The augmented neo-classical growth model consider the production function to combine labour and capital to produce output Y in period t:

$$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.1$$

This is a typical Cobb-Douglas form of the output function where, A_t represents technology which is assumed to grow at a constant rate g; thus $A_t = A_0 e^{gt}$. This study attempts to incorporate climatic variable(s) (D_t) as some form of shift factor(s). Given this line of argument and Harrod-neutral technology that assumes A_t augments labour, the production function is modified as:

$$Y_t = \frac{A_t K_t^{\alpha} L_t^{1-\alpha}}{D_t^{\theta}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.2$$

where, the deviation in climatic variable(s) from the optimal level is different from zero, (implying $D_t \neq 0$) and θ depicts the degree of dependence of the economy on climatic variable(s). If $\theta = 0$, the economy is not significantly dependent on climatic variable(s). In terms of effective labour, the theoretical model is further modified as:

$$\tilde{Y}_t = D_t^{-\theta}\, \tilde{K}_t^{\alpha} \text{ ……………………………………………………………………………… } 3.3$$

From this model, the path of income per effective labour ($\tilde{Y}_t$) is determined by the path of capital per effective worker ($\tilde{K}_t$). Assuming instantaneous growth of technology and labour; $A_t = A_0 e^{gt}$ and $L_t = L_0 e^{nt}$ respectively, the path of capital per effective worker is:

$$\frac{d\tilde{K}_t}{dt} = f(\tilde{K}_t^{\alpha}) - \tilde{C}_t - (\delta + n + g)\tilde{K}_t \text{ …………………………………………………… } 3.4$$

The term $\{f(\tilde{K}_t^{\alpha}) - \tilde{C}_t\}$ which is output as a function of capital per effective worker less consumption per effective worker ($\tilde{C}_t$) represents investment per effective worker ($\tilde{I}_t = s\tilde{Y}_t$) where s is savings rate. Therefore, the path of capital per effective worker is further expressed as:

$$\frac{d\tilde{K}_t}{dt} = \tilde{I}_t - (n + \delta + g)\tilde{K}_t$$

$$\frac{d\tilde{K}_t}{dt} = s\tilde{Y}_t - (n + \delta + g)\tilde{K}_t$$

$$\frac{d\tilde{K}_t}{dt} = sD_t^{-\theta}\, \tilde{K}_t^{\alpha} - (n + \delta + g)\tilde{K}_t$$

Finally, the steady state capital per effective worker is derived as:

$$\tilde{K}_t^{*} = D_t^{-\theta/1-\alpha}(s/(n + \delta + g))^{1/1-\alpha} \text{ ……………………………… } 3.5$$

Substituting Equation 3.5 into Equation 3.3 and since per-capita income (y_t) is the product of income per effective labour ($\tilde{Y}_t$) and technology A_t; that is ($y_t = \frac{Y_t}{L_t} = A_t\tilde{Y}_t = A_t \frac{Y_t}{A_t L_t}$), per-capita income at the steady state (y_t^{*}) is simplified as:

$$y_t^{*} = A_t D_t^{-\theta/1-\alpha}(s/(n + \delta + g))^{\alpha/1-\alpha} \text{ ……………………………… } 3.6$$

Equation 3.6 shows that technological change and rate of variability in the selected climatic variables determine long-run per-capita income growth. Here, in the theoretical model, to show how the variable of interest (climatic variables) affects the economic performance of a country per-capita income is used as dependent variable. The theoretical model begins with the assumption that the effect of climate change on the economy is realized through affecting factor accumulation. To show this factor accumulation up to the steady state the process requires simplifying the initial augmented neo-classical growth model in per-capita terms. This is why per-capita income became a dependent variable in the theoretical model. Having seen how climatic variables affect the economy and how they are incorporated in economic model; however, the study prefers GDP (Y_t) instead of per-capita GDP as a dependent variable for the econometric model. This is because for a country specific study to look the economic impact of climate change GDP is preferable than per-capita GDP. For a cross-country study using per-capita GDP as a dependent variable might be meaning full.

3.2.3 Econometric model

Considering log on both side of equation 3.6 above, the following transformed model is obtained:

$$logY_t = \beta_0 + \beta_1 logD_t + \beta_2 logs + \beta_3 log(n + \delta + g) \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots 3.7$$

Where $\beta_0 = logA_t$, $\beta_1 = \frac{-\theta}{1-\alpha}$, $\beta_2 = \frac{\alpha}{1-\alpha}$, $\beta_3 = -\frac{\alpha}{1-\alpha}$, s, saving rate representing contribution of capital, α.

Let $D^j{}_t$ represents a vector of climatic variables and $x^i{}_t$ represents the vector of other explanatory variables that explain s and $(n + \delta + g)$ components jointly. Equation 3.7 is now rewritten as:

$$logY_t = \beta_0 + \beta_j logD^j{}_t + \gamma_i logx^i{}_t \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots 3.8$$

After showing how climatic variables are incorporated in the growth model, due to climatic variables as the variable of interest, for brevity the non-log-log model is preferable. Therefore, the following model is employed for analysis.

$$Y_t = \beta_0 + \beta_1 r_t + \beta_2 \tau_t + \gamma_1 k_t + \gamma_2 l_t + \gamma_3 m2\_gdp_t + \beta_3 co2\_emm_t + \varepsilon_t \ldots\ldots\ldots 3.9$$

Since climate change is a dynamic phenomenon, time series data analysis assures a meaningful approach to investigate the economic impact of climate change over a specified period of time. The dependent variable is Real GDP at constant 2011 national prices (in mil. 2011US$) denoted by ($Y_t$). The model consists the variables of interest, such as annual rainfall (r_t),mean annual temperature (τ_t), and Co_2 emission ($co2\_emm_t$).Theoretically important economic variables such as capital (k_t), labour (l_t), and Broad Money to GDP ($m2\_gdp_t$) are used.

3.2.3.1 Steps in estimation

The study follows a cointegration test using ARDL bounds testing approach and error correction mechanisms to examine both the long-run and short-run relationships. After examining the long-run and short-run relationships, a separate Toda-Yamamoto causality test is conducted to determine direction of causality between the variable of interest (climatic variables) and the Ethiopian Economy. The Nonlinear Autoregressive Distributed Lag (NARDL) version is also used as a robustness check. The details of these analysis and estimation techniques are presented in the subsequent paragraphs.

The analysis begins with the unit root test, since in the ARDL bounds testing no variable should be integrated of order 2, $I(2)$ or above that invalidate the methodology though enables to analyse $I(0)$ and/or $I(1)$ variables (Pesaran *et al.*, 2001). Generally, time series analysis requires stationary data. If the variables are non- stationary, the data are not mean reverting, rendering them redundant for prediction purposes. On the other hand, regression on non-stationary variables results spurious relationship between completely unrelated variables since the shock in the system have cumulative effect unlike regression on stationary time series data in which the shock in the system die out. As a consequence, the usual t, F and R^2, statistical test results from non-stationery time series regression are not reliable and their asymptotic behavior is not hold true. Thus, unit root tests are used to see whether the series is stationary or non-stationary particularly to justify that no variable is I(2) or above in this case. In this study, the Augmented Dicky-Fuller (ADF) (1979) and the Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) (1992) unit root tests are employed.

The ARDL technique has the following advantages over the conventional cointegration methods. First, it estimates the long-run relationships using only a single reduced form equation (Pesaran et al., 2001). Second, it addresses endogeneity problems. Third, it allows analysis of variables regardless of whether they are stationary (I(0)), non-stationary (I(1)), or a combination of I(0) and I(1) but not I(2) or above (Pesaran et al., 2001). Finally, it provides unbiased and consistent estimation irrespective of sample size (Rahman and Kashem, 2017 citing Harris and Sollis, 2005; Jalil and Ma, 2008).

The basic ARDL (p, q, q,…, q) model is written as:

$$\Delta Y_t = B_0 + \sum_{i=1}^{p} B_i \Delta Y_{t-i} + \sum_{i=0}^{q} \alpha_i \Delta r_{t-i} + \sum_{i=0}^{q} \theta_i \Delta \tau_{t-i} + \sum_{i=0}^{q} \delta_i \Delta k_{t-i} + \sum_{i=0}^{q} \gamma_i \Delta l_{t-i} + \sum_{i=0}^{q} v_i \Delta m2\_gdp_{t-i} + \sum_{i=0}^{q} m_i \Delta co2\_emm_{t-i} + \lambda_{1i} Y_{t-i} + \lambda_{2i} r_{t-i} + \lambda_{3i} \tau_{t-i} + \lambda_{4i} k_{t-i} + \lambda_{5i} l_{t-i} + \lambda_{6i} m2\_gdp_{t-i} + \lambda_{7i} co2\_gdp_{t-i} + \varepsilon_t \quad \ldots\ldots 3.10$$

where, p and q are the optimal lag length of the dependent variable and independent variables respectively. Unlike the VAR model which has equal number of lags for all variables in the model, in this case the lag lengths may not necessarily be the same. Optimal lag length should be determined before the estimation of the ARDL model.

The ARDL Model bound testing requires the estimation of the ARDL model using the determined optimal lag length (Pesaran *et al.*, 2001). After estimation of the model, conducting the Wald's coefficient restriction test on the coefficients of unrestricted Error Correction Term (ECT) variables give F-statistics. Comparing this F-statistics with the Pesaran critical values helps to determine the presence of long-run cointegration among variables of the model. The ARDL cointegration procedure begins with conducting the bound test for the null hypothesis of no Cointegration that is,

$$H_0 = \lambda_{1i} = \lambda_{2i} = \lambda_{3i} = \lambda_{4i} = \lambda_{5i} = \lambda_{6i} = \lambda_{7i} = 0$$

Against the alternative hypothesis of

$H_1 \neq \lambda_{1i} \neq \lambda_{2i} \neq \lambda_{3i} \neq \lambda_{4i} \neq \lambda_{5i} \neq \lambda_{6i} \neq \lambda_{7i} \neq 0$. This is the Wald's coefficient restriction test.

The short-run parameters are estimated using the regular Error Correction Model (ECM) as shown in equation 3.11 (assuming the optimal lag is 1):

$$\Delta Y_t = \beta_0 + \beta_1 \Delta Y_{t-1} + \beta_2 \Delta r_{t-1} + \beta_3 \Delta \tau_{t-1} + \beta_4 \Delta k_{t-1} + \beta_5 \Delta l_{t-1} + \beta_6 \Delta m2\_gdp_{t-1} + \beta_7 \Delta co2\_emm_{t-1} + \alpha ECT_{t-1} + \varepsilon_t \quad \ldots 3.11$$

The ECM results indicate the speed of adjustment back to the long-run equilibrium after short-run shocks. The ECM integrates the short-run coefficient with the long-run coefficient without losing long-run information. Under ECM technique, the long-run causality is depicted by the negative and significant value of the lagged error correction term (ECT_{t-1}) coefficient α and the short-run causality is shown by the significant value of coefficients of other explanatory variables.

In the ARDL Bounds Testing technique, checking the absence of serial correlation among the errors of the ARDL model (Equation 3.10) and the stability of the ARDL model are important assumptions. Breusch-Godfrey Serial Correlation LM Test and the cumulative sum (CUSUM) tests are used to check the absence of serial correlation among the errors of the ARDL model and the stability of the ARDL model respectively. Following Toda and Yamamoto (1995), after examining the long-run cointegration between variables, the causality test was conducted to determine the direction of causality between the variables of interest and the dependent variable of the study. Lastly, the Nonlinear Autoregressive Distributed Lag (NARDL) version is also employed as robustness check and to further investigate hidden long-run cointegrations and whether the positive and negative changes of explanatory variables have asymmetry or symmetry effects on the dependent variable. This version of the ARDL approach was introduced by Shin *et al.* (2014) as an extension of the method introduced by Pesaran *et al.* (2001). This method isolates positive changes from negative changes in a series; therefore, it is important for analysis of the series that are naturally prone to fluctuations.

3.3. Results and Discussion

3.3.1 Unit Root test

The detailed result of the ADF and KPSS unit root tests are presented in Appendix 3B along with the graphs of variables used in the model (Appendix 3A). The result shows that the variables are mixture of I(0) and I(1) this therefore necessitated the need for the ARDL bound testing technique proposed by Pesaran *et al.* (2001).

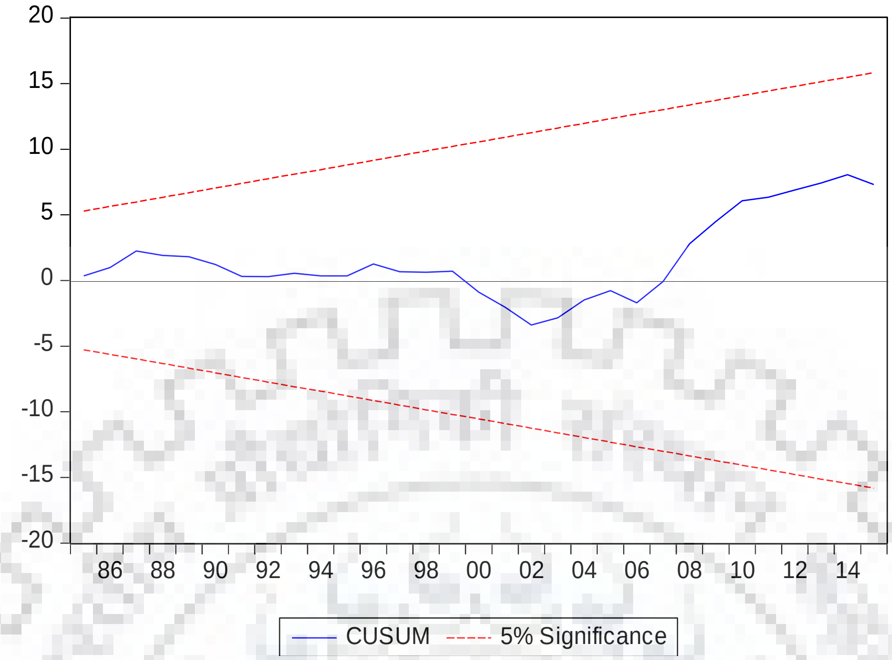
3.3.2 The ARDL model estimation

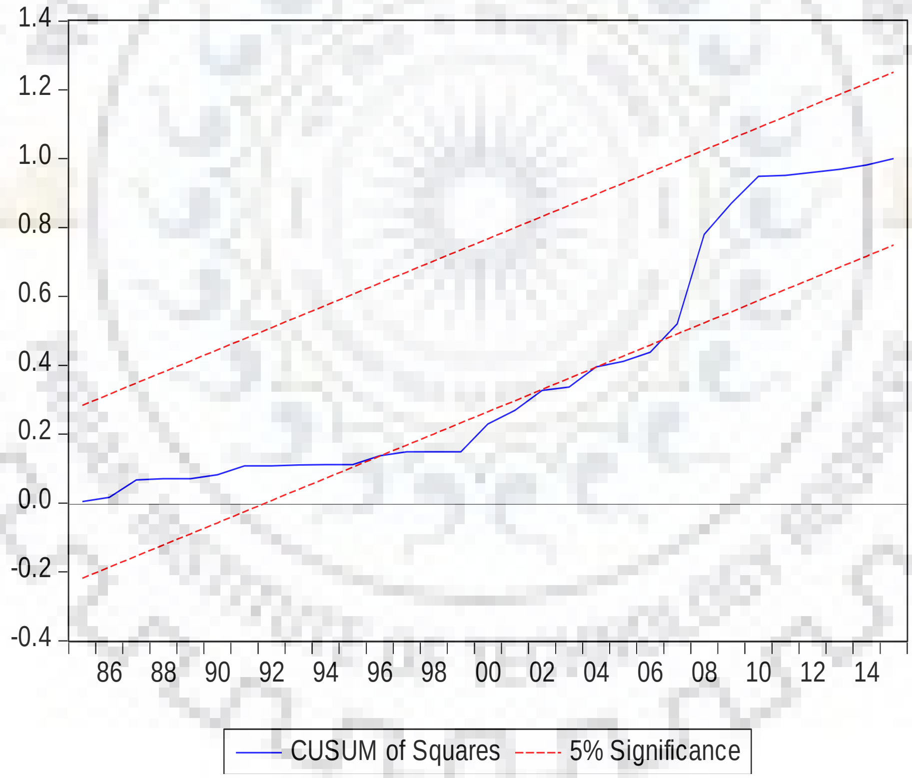
The ARDL model estimation requires the determination of optimal lag length for the basic ARDL model ($\boldsymbol{Y_t} = \boldsymbol{f}(\mathrm{r_t}, \tau_\mathrm{t}, k_\mathrm{t}, l_\mathrm{t}, m2\_gdp_t, co2\_emm_t)$) (Pesaran *et al.*, 2001). The optimal lag length according to all criteria is determined to be (1,3,3,3,2,2,2) for each variable respectively.

3.3.3 Diagnostic tests

Following the standard practice of validating the results obtained from the earlier estimation, diagnostic and stability tests are conducted to check for the robustness. The ARDL model is seemingly a good fit and it passes all the diagnostic tests. To start with, the R-square is 0.966 (Adj-R^2: 0.942) implying that almost 97 percent variations in the dependent variable are explained jointly by the variables in the model. The Durbin Watson (DW) statistics is 2.292, which confirms that the model is not spurious. Moreover, the computed F-statistic is 2628.670, large enough and statistically significant rejecting the null hypothesis that the coefficients of the regressors are zero. As presented in Table 3.2, the model fulfils the conditions for the Jarque-Bera (JB) normality test, Ramsey's Reset stability test, Breusch-Godfrey test for serial correlation (also known as the LM test) and Breusch-Pagan-Godfrey (BPG) test for heteroskedasticity. Following Pesaran *et al.* (2001), who suggested the need to analyse the stability of the long-run coefficients in conjunction with the short-run dynamic model, the cumulative sum of the recursive residuals (CUSUM) as well as the cumulative sum of squares of recursive residual (CUSUM of squares) were investigated. This is graphically represented in Figures 3.1, which portray the plots of CUSUM and CUSUM of squares test statistics as resting neatly within the boundaries at 5 percent significant level, the ARDL model is stable.

Figure 3.1: CUSUM and CUSUMSQ test results from basic ARDL model





Source: Author's calculations

3.3.4 ARDL Bound Test

The next level of analysis is conducting the Cointegration testing using ARDL bounds testing approach (Pesaran *et al.*, 2001). The result is presented in Table 3.2.

Table 3.2: ARDL Bound test

Model	Optimal lag length	F-Stat	Result
$\boldsymbol{Y_t} = \boldsymbol{f}(r_t, \tau_t, k_t, l_t, m2\_gdp_t, co2\_emm_t)$	(1,3,3,3,2,2,2)	10.788***	Cointegrated
Critical values (1%) – Lower 3.150 – upper 4.430			
R^2 = 0.966; adj. R^2 = 0.942			
Normality = 0.124		RESET=	1.075
CUSUM: Stable		CUSMSQ =	Stable
LM(1) = 0.183		BPG (1) =	0.0474

Notes: *** denotes significance at the 1% level. The optimal lag is determined by AIC. The LM, BPG, Normality, and RESET tests symbolize Breusch-Godfrey Serial Correlation LM Test, the Breusch-Pagan-Godfrey heteroscedasticity Test, Jarque-Bera normality and the Ramsey Regression specification error Test respectively. Numbers in parentheses indicate the order of the diagnostic test.

Source: Author's calculations

From Pesaran table, the upper bond at 1 percent for 6 explanatory variables with unrestricted intercept and no trend specification is 4.430 and here the associated F statistics of the ARDL bounds testing is 10.788. The result revealed that the F-statistic is greater than the upper bound critical values. It shows the existence of a cointegrating relationship among the variables. Once cointegration among the variables was checked, the next task in the ARDL approach is to estimate the long-run and short-run relationship.

3.3.5 Long-run and short run relationships

The results show that annual rainfall (r_t) through its deviations from long-term average and its variability including high probability of decrease in rainfall, mean annual temperature (τ_t) and co_2 emission ($co_2\_emm_t$) would jeopardize growth in the long-run, while effects in the short run are not adverse. In addition variables in the model like capital (k_t) and labour (l_t) have positive significant effect on GDP (Y_t) in the long run. However, labour (l_t) as represented by human capital index has a negative significant effect in short-run, it might be due to the cost incurred for human capital development. Broad money to GDP ($m_2\_GDP_t$) has a negative significant effect in the long-run and a positive significant effect in the short-run which might indicate the effect of inflation. Having co-integration among variables error correction will also happen in the short-run. The associated significant and negative error correction term (the speed of adjustment) in the estimated error correction model further confirms the existence of a stable long-run relationship among the variables. About 32 percent of a deviation from long-run equilibrium following a short-run shock that arises in the system is restored (adjusted) towards the long-run equilibrium within a year.

Table 3.3: Long-run (LR) and Short-run (SR) coefficients

Variables	LR coefficients Y_t	t-stat	Variables	SR coefficients Y_t	t-stat
r_t	-59.096***	-2.970	Δr_t	15.183***	3.650
τ_t	-6669.417*	-1.500	$\Delta \tau_t$	281.070	0.250
k_t	0.446***	3.800	Δk_t	0.105	0.960
l_t	351935.600***	6.590	Δl_t	-755820.50***	-5.240
$m2\_gdp_t$	-1254.530***	-6.420	$\Delta m2\_gdp_t$	300.219***	3.430
$co2\_emm_t$	-5.339**	-2.040	$\Delta co2\_emm_t$	2.351***	3.680
			C	-42206.650	-1.360
			ECT(-1)	-0.316***	-4.110
R^2	0.966		Adj-R^2	0.942	
F-statistic	2628.670***		JB	035(0.219)	
LM	1.773(0.183)		DW	2.292	
R/ Reset	2.358(0.132)		BPG	53.000(0.474)	

*, ** and *** denote statistical significance at the 10%, 5% and 1% levels respectively. Values in parentheses are probabilities of accepting the null hypothesis of the respective diagnostic test.
Source: Author’s calculations

3.3.6 Toda Yamamoto causality test

The ARDL Bounds (cointegration) test indicates only the presence of causality of some direction, however, it does not reveal to which direction that causality goes. Therefore, the chapter attempts to investigate the direction of causality using the Toda and Yamamoto (1995) causality test. Toda and Yamamoto (1995) in order to investigate Granger causality (1969), they developed a method based on the estimation of augmented VAR model $(k + dmax)$ where k is the optimal lag on the VAR model and $dmax$ is the maximum integrated order on system’s variables (VAR model). The results, reported in Table 3.4, shows a strong unidirectional causality from climatic variables to Ethiopian economic performance measured in GDP(y_t) while Ethiopian economic performance, GDP(y_t), does not significantly Granger cause climate change. The causality test supports the results from ARDL estimation that climatic variables have a significant adverse effect on Ethiopian economy in the long-run. This indicates that climate change and the subsequent shocks in Ethiopia might be due to the externality from the global warming, which is mainly caused by developed economies, rather than from the Ethiopian economic activities.

Table 3.4: Toda-Yamamoto causality test

Dependent variable	Y_t	r_t	τ_t	k_t	l_t	$m2\_gdp_t$	$co2\_emm_t$
Y_t	-	0.043	2.169	5.281*	1.993	0.352	1.780
r_t	5.093*	-	1.049	0.890	1.560	1.201	1.339
τ_t	1.201	0.444	-	1.642	0.080	1.474	0.923
k_t	8.098**	2.263	1.280	-	1.214	1.179	10.324***
l_t	6.308**	1.458	4.723*	5.114*	-	7.374**	0.073
$m2\_gdp_t$	37.226***	1.414	1.060	2.427	11.958***	-	1.564
$co2\_emm_t$	12.176***	1.254	0.381	1.607	6.043**	1.057	-

*, ** and *** denote statistical significance at the 10%, 5% and 1% levels respectively. dmax = 1 based on the results of the unit root tests.
Source: Author's calculations

That is, developing countries including Ethiopia are suffering most disproportionately from global climate change and variability though they contribute the least to the problem. Thus, the country should priorities CCA that enables the economy to minimize the adverse externalities of climate change. As a result domestic policy responses for climate change that significantly hinders domestic economic progress may not be effective. Climate change adaptation policies that help economic progress in parallel are advisable to build effective CCA capacity.

3.3.4 The NARDL analysis results

The presence of long-run cointegration among model variables is further confirmed following the bounds test proposed by Pesaran et al. (2001) and Shin et al. (2014) applied on the estimated NARDL model. The calculated f statistic value of bound test is 24.688 and it is greater than the upper bound critical value of 3.860, as given from the Table of Pesaran et al. (2001) at 1 percent level of significance, hence the null hypothesis of no cointegration was rejected and say there is cointegration. The primary purpose of employing NARDL here is to check whether the positive changes and negative changes of the variable of interest, climatic variables, have same effect on the dependent variable. The NARDL symmetry test was employed using Wald test under the null hypothesis of no asymmetry on the estimated NARDL model that consists the positive change and the negative change of each climatic variable as a series. As the result shows, the probability value on the Wald test for each variable is significant suggesting rejection of the null hypothesis of no asymmetry and implying that there is statistical inequality or asymmetry between the effect of the positive change and negative change of each climatic variable (as a series) on the dependent variable. As confirmed from the ARDL estimation annual rainfall (r_t) may be through its deviations from long-term average and its variability, mean annual temperature (τ_t) and Co_2 emission ($co2\_emm_t$) have significant negative effect on the dependent variable GDP (Y_t).

Table 3.5: The NARDL regression coefficients

Dependent variable Variables	ΔY_t Coefficient	Std. Error	t-Statistic
C	-200418.800***	21024.570	-9.532
Y_t(-1)	-0.924***	0.108	-8.582
r_tPOSITVE	2.157	1.888	1.143
r_tNEGATIVE	-5.551**	2.250	-2.467
τ_tPOSITVE	-8326.642***	1433.780	-5.807
τ_tNEGATIVE	-5169.229***	716.807	-7.211
k_t(-1)	0.184***	0.055	3.370
l_t(-1)	208625.600***	19907.670	10.479
M2_GDP(-1)	-470.786***	54.748	-8.599
CO2_EMMPOSITVE	-2.843**	1.305	-2.179
CO2_EMMNEGATIVE	-10.221***	1.411	-7.242
R^2 0.998		F-stat	195.082***
Durbin-Watson stat 2.230			
NARDL Bound test: **c(2)=c(3)=c(4)=c(5)=c(6)=c(7)=c(8)=c(9)=c(10)=c(11)=0** Critical values (1%) Lower bound =2.540 & upper bound= 3.860		F-Stat 24.688***	Result: Cointegration re-confirmed

NARDL symmetry test	F-Statistic	Result
1. H_0 =-c(3)/c(2)=-c(4)/c(2)= no asymmetry	10.016***	Asymmetry found
2. H_0 = -c(5)/c(2)=-c(6)/c(2)= no asymmetry	4.497**	Asymmetry found
3. H_0=-c(10)/c(2)=-c(11)/c(2)=no asymmetry	11.794***	Asymmetry found

** and *** denote statistical significance at the 5% and 1% levels respectively
Source: Author's calculations

The significant negative effect of these climatic variables on GDP is further confirmed by the NARDL estimation. In addition the NARDL estimation shows that the positive change of annual rainfall (r_t) has insignificant positive effect while the negative change has significant negative effect on the GDP. This clearly shows that the rainfall deviations from long-term average and its variability including high probability of decrease in rainfall[23] have caused annual rainfall (r_t) to have a statistically significant negative effect on Ethiopian economic performance. The positive changes in rainfall implying increase in rainfall, has a positive effect on GDP as confirmed by the NARDL estimation. To be noted, high levels of rainfall beyond a threshold contribute negatively through floods. Even though, both the ARDL and NARDL estimations confirm the significant negative effects of mean annual temperature (τ_t) and CO_2 emission ($CO_2\_emm_t$) on GDP; the NARDL estimation highlight different effects from the positive and negative changes of these variables on GDP. The theoretically expected effect of economically meaningful variables of the model such as capital (k_t), labour (l_t) and the ratio of Broad money to GDP ($m_2\_GDP_t$) is also realized in the NARDL estimation.

3.4. Chapter summary

The result from the empirical exercise asserts the need for efficient and effective adaptation strategy because if climate change is not contained, economic growth may remain lower than a priori expectation. Increase in temperature, rainfall variability (including high probability of decrease in rainfall) and CO_2 emissions would jeopardize growth in the long-run. As confirmed from the ARDL estimation, annual rainfall, mean annual temperature and CO_2 emission have significant negative effect on the dependent variable GDP. The significant negative effects of these climatic variables on GDP are further confirmed by the NARDL estimation. Therefore, the seasonal availability and optimal conditions of climatic variables, rainfall and temperature, as well as emission reduction are among the most vital factors for improving performance of Ethiopia's economy. The observed changes in the climatic variables negatively affect the Ethiopian economic performance. Therefore, managing climate related problems is indispensable. Adverse economic impacts of climate change in Ethiopia are becoming visible and lead development efforts unsuccessful. Development efforts that are environmentally unsustainable and incapable to adapt and minimize the adverse externality of climate change are not successful. The current scenario has however improved and changed. The economy could not achieve economic advancement at the cost of the environment. Therefore, CCA and mitigation strategies should get priority and attention. The Climate-Resilient Green Economy

[23] Such variables are not explicitly included in the model to avoid collinearity and other statistical problems

(CRGE) strategy may be mainstreaming in every aspects of the economy and every stakeholder should implement it in detail. Having the evidence of unidirectional causality flows from climatic variables to Ethiopian economic performance; however, domestic policy responses for climate change that directly hinders domestic economic progress may not be effective. CCA policies that help economic progress in parallel are more advisable. Since climate change is a natural phenomenon, not only human induced, the most effective measure to manage the adverse impacts is improving the climate change adaptive capacity. Improving the overall CCA capacity of the national economy requires understanding the local level climate change vulnerabilities and effects. In addition, active participation in climate change negotiations at the global level should be adopted.

Chapter 4 [24]

Effects of climate shock on Ethiopian rural households: An integrated livelihood vulnerability assessment approach

4.1. Introduction

Climate change is a persistent long-term shift in the state of the climate beyond the average atmospheric condition. Climate variability in the context of climate change refers to transitory instabilities in the weather patterns based on the temporal and spatial scales beyond the usual weather events (IPCC, 2014; Kolawole *et al*., 2016). Climate change induced climate variability could ultimately lead to climatic shocks that directly results in environmental degradation. The environmental limits have many indirect impacts on the livelihood, health, agricultural production, labour productivity and socio-economic welfare of systems (Masuda *et al*., 2019; Thakur and Bajagain, 2019; Nastis *et al*., 2012). Climatic shocks are huge, exogenous and irregular externalities (for example,., drought, epidemics, flood), having irreversible adverse impact on the microeconomic systems (Martin and Bargawi, 2005). The intensity of the adverse impact from climate shocks depends on the extent of systems' vulnerability to climate change and variability. According to the IPCC (2007), vulnerability in the context of climate change is "the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity".

Earlier studies (Burke *et al*., 2015; Dell *et al*., 2012) have provided statistical evidence that the developing economies are mostly affected by climate shocks as they are predominantly agrarian in nature. Limited adaptation strategies, lack of initiative and poor governance increases uncertainties in economies where the contribution of the agricultural sector is highly significant (Diao *et al*., 2010; Alston and Paradey, 2014). For instance, rain-fed agriculture in Ethiopia accounts for 38.5 percent of GDP, 80 percent of all national employment and up to 90 percent of export earnings (National Planning Commission (NPC) of Ethiopia, 2016). An

[24] A slightly different version of the analysis presented in this chapter is published as Haron & Sen (2021).

earlier report from World Bank (2015) shows the large contribution of agriculture to the fall in poverty rates from 44 percent in 2000 to 30 percent in 2011. However, the sector is highly constrained by climate shocks among other challenges and might contribute to keep Ethiopia, in what Nelson (1956) called, the 'low-level equilibrium trap'[25]. Further, the agrarian communities are adversely affected (IPCC, 2012), consequently, they remain in the vicious circle of poverty in which rural livelihoods become unreliable and vulnerable.

Vulnerability assessments have shown that rural households in the developing economies including households in Ethiopia are vulnerable to climate shocks. Studies are mostly national and sub-national level assessments emphasizing vulnerabilities of sectors like agriculture, or natural resources such as water, fishery, health, forestry among others (for example,., Brooks *et al*., 2005; Deressa, 2007; Deressa *et al.*, 2008, 2009; Fussel, 2010; Islam *et al.*, 2014; Pandey *et al*., 2015; Byers *et al*. 2018). Few studies focused on the climate change and vulnerability to poverty (for example, Deressa, 2013; Demissie *et al*., 2017; Gallardo, 2018).

Vulnerability and adaptation are locale specific dynamic characteristics that vary across space and in terms of temporal scales. National and sectoral level vulnerability assessments do not emphasize local vulnerability, while they are important to understand development priorities (Narayanan *et al*. 2016). According to Fussel (2010), national and sectoral level vulnerability indices could not adequately consider circumstances that make a system particularly vulnerable to climate shocks. Downscaling provides more concrete information on local impacts (Jacques, 2006). Effective adaptation measures would require a thorough understanding of the local community characteristics and evaluation of interests of those likely to be affected. The national adaptation policy does not sufficiently address this. In this backdrop, local specific rural household level vulnerability assessments may enable us to examine some practical policy specific questions. First, who are the local vulnerable groups? Second, are groups of rural households considered in the study, equally vulnerable? Third, to what an extent the households and communities at large are vulnerable and affected? Fourth, what is their ability (preparedness) to withstand shocks and their sensitivity and exposure to climate shocks? Fifth, what factors would determine their vulnerability? Further, it is necessary to identify the

[25] 'Low-level equilibrium trap' is a situation in which poor economies are unable to save and invest much, and this in turn results in very low or stagnant rate of growth in national income.

efficient and inclusive coping strategies that could be implemented to sustain rural livelihoods and help achieve selected Sustainable Development Goals (SDGs). It is important to note that, improving the climate change adaptive capacity of vulnerable people is one of the SDG target (UNDP, 2015).

The country level studies as well as local vulnerability assessments (for example, Senbata, 2009; Demeke *et al*., 2011; Tesso *et al*., 2012; Gebrehiwot *et al*., 2013) have their own limitation in addressing local household level heterogeneities and vulnerability differences. The studies are inadequate in providing guidance for inclusive adaptation measures at the local level (Ludena and Yoon, 2015). In this regard, Simane *et al*. (2016) and Amare and Simane (2017) considered the agro-ecological heterogeneity in their vulnerability assessment studies. In local vulnerability assessments, however, heterogeneities across units of analysis are better explained with their adaptive capacity that is an important source of vulnerability differences and intervention areas. Agro-ecological differences are less at the local level. A given agro-ecology may comprise of heterogeneous groups of rural households with varying degree of vulnerability to climate change. This necessitates a household level vulnerability assessment that would consider the endogenous adaptive capacity differences instead of the exogenous ecological differences. This study, by hypothesizing exogenous agro-ecological and climate shock situations as covariate shocks (exposure) that are common for all local rural households, investigates other policy endogenous variables that determine vulnerability differences. This is one of the major contributions of this study.

Heterogeneity in CCA capacity of rural households is due to the differences in the socio-economic and demographic status, livelihoods and that of the existing social networks (Hahn *et al*., 2009). For simplicity, since all these differences contribute to the status of households' rural off-farm diversification, which is an adaptation effort, this study considers rural off- farm diversification[26] to account for heterogeneity across the units under analysis. Therefore, vulnerability differences and corresponding factors are assessed across off-farm diversified

[26] The study looks rural off-farm diversification in a wider context that consist all rural non-farm employments and agricultural wage employment on other people's farm which broadly categorized into wage employment and self-employment activities.

and non-off-farm diversified rural households. Moreover, off-farm diversified rural households are further categorized as low wage and/or self-employment (low return) off-farm activity participants[27], and high wage and /or self-employment (high return) off-farm activity participants[28].

The primary objective of the study is to estimate the Livelihood Vulnerability Indices (LVI) of the three heterogeneous groups of rural households in South Gondar, Ethiopia by examining major factors increasing households' vulnerability. The secondary objective is to assess the effect of climate shock on the rural household income. The estimation of potential income losses of the selected sample households accomplished the later objective. The study also identifies factors responsible for variation in households' vulnerability to climate shock; particularly, the impact of rural off-farm diversification is assessed in this regard. The results may help policy-makers realise the need for inclusive adaptation measures for enhancing resilience and thereby reducing the existing vulnerability of the rural households. The study reveals that rural households are adversely affected by climate shock; in particular, poor non-off-farm diversified rural households were found to be highly vulnerable. Therefore, immediate attention and emphasis should be towards off-farm diversification for reducing vulnerability and lower the adverse impacts of climate change at the household level. The remaining parts of this chapter are organized as follows. The next section presents a discussion on the vulnerability assessment framework. Section three provides details on the study

[27] Agricultural wage employment on other people's farm, unskilled daily labourers, domestic servants and migrants for work, food-for-work participants are typical examples of low paying wage employment off-farm activities. While collecting and selling firewood, carpentry, basketry, Handcrafts or pottery, blacksmith or metal works, repair services, weaving, spinning, leather tanning, local food and drink preparation and petty trade are categorized as low return self- employment activities.

[28] High paying wage employment includes skilled labourers (wood house construction, builders/masons and painting, cobblestone construction) and formal international migration for work, while activities like crop and livestock trading, stone and sand mining and transport services (using small automobile and pack animals), afforestation, grinding mill are high return self-employment activities in the study area. Low wage and/or self-employment versus high wage and /or self-employment categories are mutually exclusive based on the existing nature of rural households in the study area but no exclusivity with in each category.

methodology. Results are discussed in section four and the last section summarizes major findings and highlights few policy implications.

4.2. Vulnerability Assessment Framework

There are many methods for analysing and quantifying vulnerability to climate change. They are based on varying approaches such as biophysical (top-down), socio-economic (bottom-up) and the integrated vulnerability assessment approaches. The most widely adopted methods are the indicator (index) method[29] and the econometric methods[30]. There are further three different composite indices namely, the Livelihood Vulnerability Index (LVI), the LVI-IPCC and the Livelihood Effect Index (LEI). The LVI uses a balanced weighted average approach where each sub-component contributes equally to the overall index although each component is comprised of different number of sub-components. The LEI is derived from the Sustainable Livelihood Framework (SLF) that identifies five different types of vulnerability indicators: natural, human, physical, social and financial capital. The LVI-IPCC method developed by Hahn *et al*. (2009) is adapted in this study because of its distinguishing features. The method groups many major vulnerability indicators under few but meaningful vulnerability contributing factors such as exposure, adaptive capacity, and sensitivity. Subjectivity in the selection of indicators and their relative weights as well as the difficulty in testing or validating the different metrics of data having various scales is the main limitation of the indicator (index) method. The econometric method, particularly Vulnerability as Uninsured Exposure to Risk (VER) method is also used in this study for substantiating the results from the former exercise. In the next few paragraphs, the biophysical (top-down), socio-economic (bottom-up), the integrated vulnerability assessment approaches and the LVI-IPCC methods of quantifying vulnerability are discussed.

The conceptual vulnerability assessment framework for this study, the LVI-IPCC, emerges from the IPCC (2001). IPCC (2014) provides a comprehensive definition of vulnerability to climate change and it refers to the susceptibility to harm, rather than the measure of harm itself.

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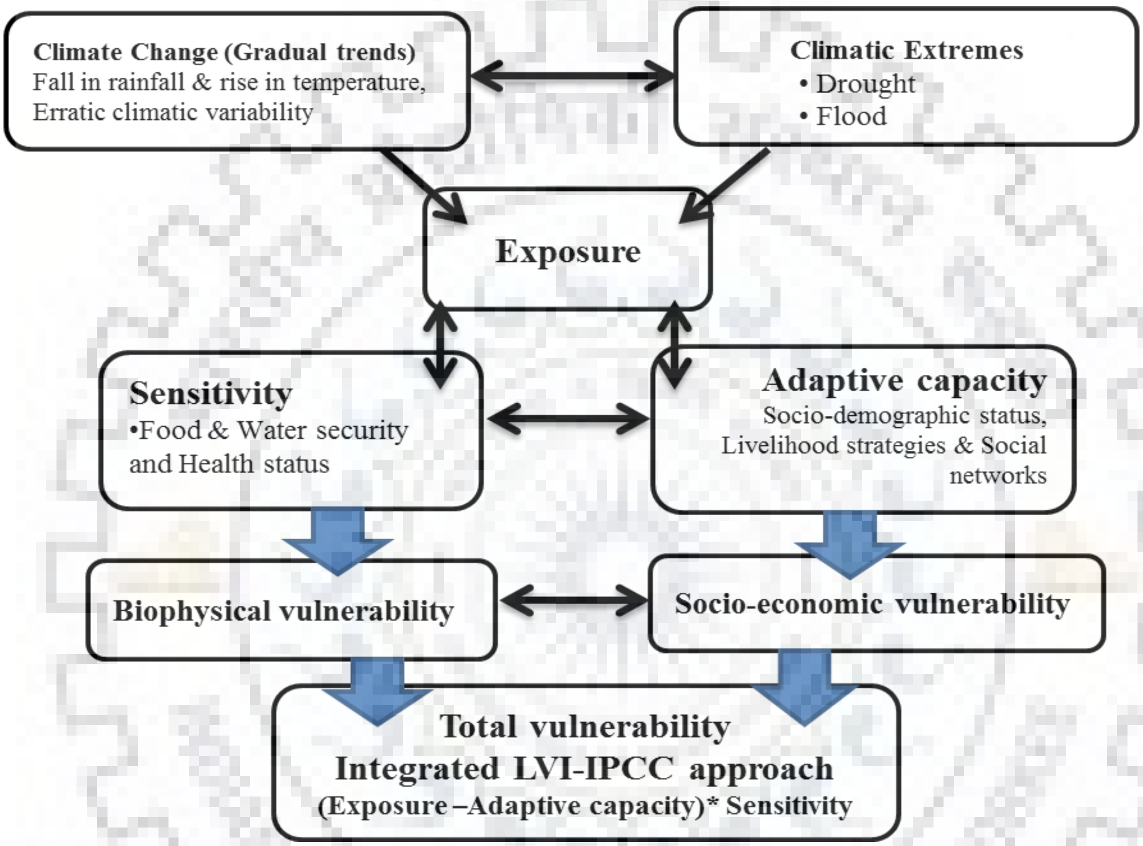
[29] The indicator method is based on selecting some indicators from the whole set of potential indicators and then systematically combining the selected indicators either by giving equal weights or different weights for each indicator to indicate the levels of vulnerability (Deressa *et al*., 2008).

[30] Discussed in the methodology section

The extent of vulnerability of a system depends on the overall nature of climate shocks (exposure) and characteristics of the systems (sensitivity and adaptive capacity). An integrated vulnerability approach that accounts for the overall nature of climate shocks and characteristics of systems (groups of rural households) is used in this study.

Figure 4.1: Vulnerability Assessment Framework



Source: Authors' representation based on review of literature

For instance, the agricultural system exposed to climate shocks in the biophysical domain (Amare and Simane, 2017). Climate shocks, expressed through climatic extremes like droughts, floods and epidemics, are result of gradual changes in the trends and variability of rainfall and temperature. The exposure of the agricultural system to climate change is mostly dependent on these risks. The sensitivity of the agricultural system depends on the types of economic activities that the households practices. Households with rain-fed farming as the only source of income and living in areas where health and water services are inaccessible and insufficient are more sensitive. The two measures of exposure and sensitivity correlate with the biophysical domain and highlight the vulnerability of agricultural system, as shown in

Figure 4.1. The biophysical vulnerability does not give much emphasis to the socio-economic characteristics of agents in the system. However, the existing socio-economic backgrounds of the agrarian communities in the agricultural system have its own role in affecting the system's sensitivity and vulnerability to climate shocks.

The integrated vulnerability assessment approach includes socio-economic vulnerability in addition to the biophysical vulnerability. The adaptive capacity measures such as climate risk pooling, risk distribution and buffer schemes of rural households exhibits the socio-economic vulnerability (Lemos *et al*., 2016). Households with a better socio-economic and demographic status, livelihood strategies and social networks have better adaptive capacity and therefore, would be capable in reducing the adverse effects of climate change. According to Lemos *et al*. (2016) such adaptive capacity measures include interventions that aimed to address climate-related risks directly (specific capacity measures) and structural deficits (for example,., lack of income, education, health, political power) (generic capacity measures) that shape vulnerability. All these interactions reveal how and by how much, the agricultural system is vulnerable to climate shocks. However, there are number of ways to analyse these interactions, ways integrating the biophysical and socio-economic vulnerabilities of a system. This study employs the LVI-IPCC procedure of such integration.

Vulnerability is a comprehensive theoretical concept and so a practical measurement is difficult (Hinkel, 2011; Patt *et al*., 2012). An acceptable, easy and unique method for vulnerability measurement is nonexistent (Satapathy *et al*., 2014 citing Hinkel *et al*., 2010). Hence, it would be meaningful operationalizing vulnerability rather than measuring it (Hinkel, 2011). The literature refers operationalizing vulnerability as vulnerability assessment (Hinkel, 2011; Satapathy *et al*., 2014). There are top-down and/or bottom-up vulnerability assessment approaches (Dessai and Hulme, 2004; Ludena and Yoon, 2015). Top-down approaches are biophysical vulnerability assessments that analyse climate change and its impacts on biophysical systems but fail to consider human interactions and the adaptive capacity component. On the other hand, bottom-up approaches are participatory socio-economic vulnerability assessments that investigate vulnerable people to identify driving factors and solutions that are endogenous to policy decisions (Van Aalst *et al*., 2008).

Vulnerability assessment approaches are effective and may adequately capture all possible dimensions of vulnerability when one integrates both the biophysical (sensitivity and exposure) and the socio-economic (adaptive capacity) aspects of vulnerability. In economic analysis of climate shocks, integrated local level vulnerability assessments that account for socio-economic variables are considered to analyse build adaptive capacities of local communities to understand and find their own solutions to their problems (Yoo *et al.*, 2011). Few studies, such as, those by Deressa *et al*. (2008), Senbata (2009), Demeke *et al*. (2011), Tesso *et al*. (2012), Gebrehiwot *et al*. (2013), Simane *et al*. (2016), and Amare *et al*. (2017) (Ethiopia); Hahn *et al*. (2009) (Mozambique); Mohan and Sinha (2010), Narayanan *et al*. (2016) (India) and Etwire *et al*. (2013) (Ghana) applied the integrated approach to reveal the vulnerability of rural households. Although the integrated approach corrects the weaknesses of other approaches, it has its own set of limitations because there is no standard method for combining biophysical and socio-economic vulnerabilities to know the net total vulnerability of a given system. For instance, Gebrehiwot *et al*. (2013) investigated district level vulnerability to climate change and variability in Tigray, northern Ethiopia. Using factor analysis, an overall vulnerability index was constructed, for the 34 rural districts by combining exposure and sensitivity. The index was compared with the adaptive capacity, unlike the IPCC framework. The study finds that vulnerability to climate change is linked to social and economic development.

The LVI-IPCC framework that first compare exposure with adaptive capacity and then sensitivity (that is, (Exposure –Adaptive capacity) * Sensitivity) have been applied for vulnerability assessments following Hahn *et al*. (2009) application to assess the vulnerability differences between two villages in Mozambique. Mohan and Sinha (2010), for example, applied the LVI-IPCC across districts in the Ganges river basin and found significant district level differences in vulnerability. Differences between districts were attributed to a number of factors, including relative degree of urbanization. More highly urbanized districts had greater adaptive capacity and therefore lower climate vulnerability. Narayanan *et al*. (2016) investigate the effects of climate change on the households and of the adaptation responses in rural India. The study found a direct adverse impact of climate change on the households' total income. However, they do not measure the extent of vulnerability. In a study of climate vulnerability in northern Ghana, Etwire *et al*. (2013) applied the LVI-IPCC and found regional differences in vulnerability. Following the foregoing review, the current study adopts the integrated vulnerability assessment approach and using the LVI-IPCC framework in conjunction with the econometric techniques to determine the vulnerability differences, corresponding factors and adaptation efforts among rural households in South Gondar zone in the Amhara region, Ethiopia. The LVI-IPCC and the econometric methods are discussed in the methodology section.

4.3. Methodology

4.3.1 LVI-IPCC and Econometric methods of vulnerability assessment

4. 3.1.1 Choosing the vulnerability indicators

Vulnerability to climate change is determined by a complex interrelationship between multiple factors where few factors are not often directly quantifiable. Vulnerability assessment requires a detailed contextual understanding of the relevant systems and how they are impacted by structural changes. As already highlighted in the above sections, a practical approach towards vulnerability assessment involves estimation of vulnerability level of a community and its contributing factors through the development of indices following three steps (Hinkel, 2011). The first step identifies what to be indicated. In this case it is climate change vulnerability of the three heterogeneous groups of rural households. Following IPCC (2001), this study defines vulnerability through three contributing factors and those are exposure, sensitivity and adaptive capacity. The second step is the selection of indicator variables under each vulnerability components (exposure, adaptive capacity and sensitivity based on LVI-IPCC frame work) (Hahn *et al.,* 2009; Hinkel, 2011). Using the actual, minimum and maximum values of sub-component indicators, the standardized index value for the sub-component indicators are calculated. Next, the standardized major component indices are calculated and aggregated to form an overall index. This process of choosing indicators is crucial and a difficult task since vulnerability itself has no tangible elements. The theory motivates choice of indicators and previous literature validates their representativeness using insights gained from observation and survey conducted at the local level.

I) Exposure

For this study, the indicators used for exposure is detailed in Table 4.1. It is hypothesized that higher the climatic variability and frequency of natural disasters, the higher is the exposure of the rural households.

Table 4.1**:** Indicators for exposure

IPCC contributing factors	**Major indicators of vulnerability**	**Sub- indicators of vulnerability**
Exposure	Natural disasters caused by climate change and variability	Number of climate shocks (Droughts, epidemics, floods etc) households faced for the last 20 years
		Percent of households that did not get warnings before climate shocks
		Households faced an injury/death due to climate hazards for the last 20 years (in percent)
		Mean SD of maximum temperature by month for last 20 years
		Mean SD of minimum temperature by month for last 20 years
		Mean SD of average rainfall by month for last 20 years

Source: Author's representation

II) Adaptive capacity

Adaptive capacity includes a vector of resources and assets that represent the means through which adaptation actions come into existence. According to Hahn *et al*. (2009), the major indicators of vulnerability based on the adaptive capacity are socio-economic and demographic status, livelihood strategies and social networks. These indicators have sub-indicators as shown in Table 4.2. Their relevance in building household adaptive capacity to climate change is discussed briefly in the next paragraph.

The better these major indicators are, the better is the climate change adaptive capacity. For instance, households with access to irrigation may face lesser risk of crop damage during droughts in comparison to households depending entirely on rain-fed agriculture. Similarly, households with relatively better rural infrastructure like all-weather roads, electricity, telecommunication networks, access to media, and proximity to markets improve their adaptive capacity through easy access to weather related information, inputs and market information and agricultural extension services. The availability of these facilities are important for early warning and for making communities resilient, thereby making them responsive (Gawith *et al*. 2016). Rural infrastructures enable households to plan proactive adaptation measures against climate risks. Diversification and focus on non-farm activities provide households security during periods of food shortage or crop failure. Similarly, households with savings experience including participation in the informal institutions like *Equb* provide greater capability to minimize livelihood risks. Other socio-demographic variables like household head's literacy rate, number of economically active household members, age of the household head (farming experience), among others are also helpful in improving households' adaptive capacity.

Table 4.2: Indicators for adaptive capacity

IPCC contributing factors	Major indicators of vulnerability	Sub-indicators of vulnerability
Adaptive capacity	Socio-demographic Status	Inverse of dependency ratio (ratio of economically active population to dependents including orphans)
		Percentage of household with literate head (at least able to read and write)
		Average age of the household head
		Percentage of household with irrigation practice
		Percentage of household lived with relatively better rural-infrastructure
	Livelihood strategies	Percent of households having abroad and/or domestic migrant member for work
		Off-farm income share from the total household income
		Average number of off-farm rural livelihood activities diversified by a household
	Social networks	Average give : receive ratio (Ratio of help given by a household to other households in the past month +1 to the help received by a household +1(ratio ranges from low adaptive capacity 0.5 to high adaptive capacity 2) for example, if a household gives help to other household but not received help from others the ratio becomes 1+1/0+1=2)
		Average lend: borrow money ratio (Ratio of households lends money to others in the past month +1 to a household borrowing money +1 in the past month. (ratio ranges from low adaptive capacity 0.5 to high adaptive capacity 2) for example, if a household lends to other household but not borrow from others the ratio becomes1+1/0+1= 2)
		Percent of households that have a saving experience in informal (Equb) and formal institutions

Source: Author's representation

Finally, rural livelihood diversification is an important variable that enhances adaptive capacity. Higher number of diversified activities in a household helps to enhance the household's adaptive capacity through distributing the risks among diversified income sources. Social capital is also an important instrument. Identifying the extent of community resilience would provide decision makers directions for improving local communities' climate change adaptive capacity (Yoon *et al.*, 2016).

Table 4.3: Indicators for sensitivity

IPCC contributing factor	Major indicators of vulnerability	Sub-indicators of vulnerability
Sensitivity	Food	Percent of households that significantly depends on rain-fed farm income.
		Household food deficit period of time (range 0-12 months)
		Average crop diversity index (inverse of number of crop types cultivated by a household +1)
		Percent of households that do not save crops
		Percent of households that do not save seeds
	Water	Percent of households encounter water conflicts
		Percent of households that use a natural water source instead of potable water
		Average time to water source (minutes)
		Percent of households that were not consistently access water from the source every day
		Inverse of the average number of liters of water used per household member
	Health	Average time to health facility (minutes)
		Percentage of households that face chronic illness on at least 1 family member
		Average Malaria sensitivity *Prevention Index (range: 0-12) (Months reported exposure to malaria*owning at least one Mosquito net indicator (have Mosquito net=0.5, no Mosquito net =1) (for example,. respondent reported malaria is a problem 3 months a year and they do not own a Mosquito net =3*1=3).

Source: Author's representation

III) Sensitivity

Sensitivity depends on the nature of economic activities that the households are engaged in. Households with traditional farming as the only source of income, and living in areas where health and water services are inaccessible and insufficient are naturally more sensitive. In general, the current state of the community's food and water security and health status are considered indicators of the community's sensitivity to climate change in the study area. Table 4.3 presents sub-vulnerability indicators that determine rural households' sensitivity.

4.3.1.2 Calculating the LVI–IPCC

The LVI-IPCC framework adapted in this study follows the methodology developed by Hahn *et al*. (2009), with the adjustment of indicators to suit the local context considering the selected households in the South Gondar zone of Amhara region in Ethiopia. The LVI-IPCC framework uses seven major indicators and several sub-indicators as detailed in Table 4.1 through Table 4.3.

The sub-component indicators are first standardized because they were in different scale of measurement, using the following normalization formula:

$$\mathbf{S_{sd}} = \frac{\mathbf{S_{actual} - S_{min}}}{\mathbf{S_{max} - S_{min}}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{4.1}$$

where, S_{sd} is the standardized index for each sub- indicator; S_{actual} denotes the actual average value of each sub-component in each sample category; S_{max} and S_{min} represents the extreme values for each sub-component in the sample. The average value of the standardized indices of the sub-indicators under each major indicator gives the standardized index for each corresponding major indicators.

Unlike the composite index approach that merges all the standardized indices of major indicators into an overall vulnerability index in a single step, the LVI-IPCC framework first combine them according to their corresponding contributing factor category, to calculate the standardized index for each contributing factors or components of vulnerability via a weighted average formula. The weighted average formula is:

$$\mathbf{CF_{sdi}} = \frac{\sum_{i=1}^{n} \mathbf{W_{Mi} M_{sdi}}}{\sum_{i=1}^{n} \mathbf{W_{Mi}}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{4.2}$$

where, CF_{sdi} is the standardized index value for each contributing factor; M_{sdi} is the standardized index value for each major component indicator; W_{Mi} is the weight given for each major component indicator based on the number of sub-component indicators in each major component indicator and n is the number of major component indicators in each contributing factor.

After computing the standardized index value for each contributing factor (exposure, sensitivity and adaptive capacity), the final task is integrating these three indices using the following formula:

$$\mathbf{LVI_{IPCC}} = (\mathbf{Exposure_{sdi}} - \mathbf{Adaptive\ Capacity_{sdi}}) * \mathbf{Sensitivity}_{\mathbf{sdi}} \ldots\ldots\ldots\ldots\ldots\ldots \mathbf{4.3}$$

where, LVI_IPCC denotes the total average Livelihood vulnerability index for each sample category. LVI-IPCC ranges from value -1 to 1(Hahn *et al*. 2009) in which, the range from -1 to -0.4 implies not vulnerable, -0.41 to 0.3 suggest moderately vulnerable while 0.31 to 1 shows high vulnerability (Gravitiani and Fitriana, 2018).

4.3.2 Econometric method to vulnerability assessment

The other common method employed in vulnerability assessment is the econometric method. There are three econometric methods sharing a common feature. They construct a measure of welfare loss attributed to shocks (Deressa et al., 2008). The three methods are namely vulnerability as expected poverty (VEP), vulnerability as low expected utility (VEU) and vulnerability as uninsured exposure to risk (VER) (Moret, 2014; Hoddinott and Quisumbing, 2003).

In the VEP method, vulnerability is treated as expected poverty due to shocks and estimated by the probability in which shocks move consumption (income) of households below a given minimum level or forces to stay below the given minimum requirement if it is already below that level (Deressa *et al*., 2008; Chaudhuri *et al*., 2002).

In the VEU method, vulnerability is treated as the expected low utility due to shocks and estimated by the difference between the utility derived from some level of certainty-equivalent consumption at and above which the household would not be considered vulnerable and the expected utility of consumption (Deressa *et al*., 2008 citing Ligon and Schechter 2002, 2003).

The VER method is based on ex-post facto assessment of the extent to which a negative shock causes welfare loss. The theoretical model for the econometric method used in this study follows the VER method with a significant improvement as explained in this section. Let us assume that, the rural households' estimated total income loss $\mathrm{E(Hloss)} \geq 0$ is a function of climate shock ($CS \geq 0$). During the survey, households are requested to estimate income loss at the household level by assuming it as a difference between the households' expected yearly income and their actual yearly income plus their exogenous expenditure as a result of climate related problems including direct adaptation expenditures, if at all any. Rural households' estimated total income loss due to climatic and non-climatic shocks may consist of both agricultural losses (Aloss) and non-agricultural losses (NAloss). The probability with which climate shocks would contribute for this estimated household total income losses is an increasing function of climatic shocks ($\mathrm{P} = \mathrm{P}(\mathrm{cs}),\ 0 \leq \mathrm{p} \leq 1$ and hence $\frac{\partial \mathrm{P}_{(\mathrm{cs})}}{\partial(\mathrm{cs})} \geq 0$. It is further assumed that the household's estimated total income loss $E(Hloss)$ is a linear function of climatic shocks and linear for both agricultural losses (Aloss) and non-agricultural losses (NAloss) and that (Aloss) ≥ (NAloss) for any types of climatic shock due to the nature of the agrarian community. Therefore, $\frac{\partial \mathrm{Aloss}_{(\mathrm{cs})}}{\partial(\mathrm{cs})} \geq \frac{\partial \mathrm{NAloss}_{(\mathrm{cs})}}{\partial(\mathrm{cs})}$, and $\frac{\partial^2 \mathrm{Aloss}_{(\mathrm{cs})}}{\partial(\mathrm{cs})^2} = \frac{\partial^2 \mathrm{NAloss}_{(\mathrm{cs})}}{\partial(\mathrm{cs})^2} = 0$, as they are a linear function of climate and related shocks.

Therefore, the contribution of climate shocks to estimated household total income losses is given by:

$$\mathrm{E}(\mathrm{Hloss}) = \mathrm{P} * \mathrm{Aloss}(\mathrm{cs}) + (1 - \mathrm{P}) * \mathrm{NAloss}(\mathrm{cs}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .4.4$$

Differentiating Equation (4) with respect to climate shock gives us an expression for the change in the estimated household income losses due to a climate shock.

$$\frac{\partial \mathrm{E}(\mathrm{Hloss})}{\partial(\mathrm{cs})} = \frac{\partial \mathrm{Aloss}_{(\mathrm{cs})}}{\partial(\mathrm{cs})} * \mathrm{P} + \frac{\partial \mathrm{NAloss}_{(\mathrm{cs})}}{\partial(\mathrm{cs})} * (1 - \mathrm{P}) + \frac{\partial \mathrm{P}_{(\mathrm{cs})}}{\partial(\mathrm{cs})} \left(\mathrm{Aloss}_{(\mathrm{cs})} - \mathrm{NAloss}_{(\mathrm{cs})}\right) \ldots 4.5$$

It is important to note that, the probability with which climatic shocks would contribute to the estimated household total income losses depends on the nature of the covariate shocks (referring to exposures), idiosyncratic shocks (sensitivity) and socio-demographic variables (adaptive capacity) of the sample rural households.

The following estimable econometric model for vulnerability and /or micro-level climate change impact assessment is adapted from Narayanan *et al*. (2016) based on the above theoretical underpinnings and in line with the integrated vulnerability approach.

$$E(\mathrm{Hloss}) = \alpha + \sum \beta i\,(\mathrm{Expo})_i + \sum \gamma i\,(\mathrm{Sens})_i - \sum \lambda i\, x_h + \varepsilon \ldots\ldots\ldots\ldots\ldots\ldots 4.6$$

where, $E(Hloss)$ stands for the household estimated total income loss as a measure of household hazard loss or vulnerability to climate change, $(\mathrm{Expo})_i$ and $(\mathrm{Sens})_i$ denotes exposure represented by the covariate shocks and sensitivity represented by the idiosyncratic shocks of sampled rural households respectively. While, x_h refers socio-demographic characteristics of sampled rural households that represent their adaptive capacity to climate change. Idiosyncratic shocks are more or less individual household specific while covariate shocks are common to the majority of households in the study area.

More specifically, the estimable econometric model for this study is estimated using the Ordinary Least Square (OLS) procedure, thereby identifying determinants of vulnerabilities. The final model is:

$$\begin{aligned}\mathrm{Hloss} = {} & \alpha + \beta_1 \mathrm{Drought} + \beta_2 \mathrm{climate\_variability} + \gamma_1 \mathrm{Water} + \gamma_2 \mathrm{Health} + \gamma_3 \mathrm{Livestock} \\ & - \lambda_1 \mathrm{diversification1} - \lambda_2 \mathrm{diversification2} - \lambda_3 \mathrm{Head\_literacy} \\ & - \lambda_4 \mathrm{age\_head} - \lambda_5 \mathrm{irrigation} - \lambda_6 \mathrm{rural\_infrastructure} + \varepsilon \ldots\ldots\ldots\ldots\ldots 4.7\end{aligned}$$

A detailed description of the data used in the econometric method is presented in Table 4.4.

Table 4.4: Data and Definition of variables

Variable type	Variable	Definition	Conceptual basis	Shock categorization
Dependent variable	Household estimated total Income loss (Hloss)	Estimated as the difference between the households expected yearly income and their actual yearly income plus household exogenous climate related expenditure	Vulnerability	Hazard loss
Independent variable	Drought	1 if a household reports a decreasing trend in rainfall and/or an increasing trend in temperature for the last 20 years and 0 otherwise (no change and opposite change)	Exposure	Covariate shock
	Climatic_variability	1 if a household suffered pre and post-harvest damage caused by excessive rainfall and/ or flood , epidemics and any short term climatic abnormality and 0 otherwise	Sensitivity	Idiosyncratic shock
	Water	Average time a household spent to access water from the source once (minutes)		
	Health	Average time to health facility (minutes)		
	Livestock	1 if a household engages in livestock production otherwise 0		
	Head_ literacy	1 if the head able to read and write at least, 0 otherwise	Adaptive capacity	Not shock type
	Diversification1	1 if a rural household participated in low wage and/or self-employment off-arm activities, 0 otherwise		
	Diversification2	1 if a rural household participated in high wage and/or self-employment off-arm activities, 0 otherwise		
	Gender_head	1 if household head is male, 0 if female		
	Age_head	Years of household head		
	Irrigation	1 if the household engaged in irrigation, 0 otherwise		
	Rural_ infrastructure	1 if a household has access to relatively better rural infrastructures on average , 0 otherwise		

4. 4. Results and Discussion

The actual value of sub indicators for each sample category and the minimum and maximum values of sub indicators for the whole sample are presented in Table 4.5. The indexed sub indicators, LVI-IPCC contributing factors, and the overall LVI-IPCC for each sample category are presented in Table 4.6.

The IPCC framework for vulnerability assessment in the study area yielded that (LVI-IPCC$_{non-diversified}$ = 0.44; LVI-IPCC $_{Low\ wage\ \&/or\ self-employment}$ = 0.29 and LVI-IPCC $_{High\ wage\ \&/or\ self-employment}$= 0.2) which clearly indicates that rural households that do not diversified into any rural off-farm activities are highly vulnerable than the diversified one.

In the case of the major indicator of vulnerability - natural disaster due to climate change and variability that determines the exposure component of vulnerability the three sample rural household groups are not much different. The sub-indicator values under this major indicator are more or less the same across the three sample rural household groups. This is very much consistent with the hypothesis set by the study that climate shocks at a local level are more or less common to all local rural households (covariate shock); therefore, cannot be the main source of vulnerability differences.

While the adaptive capacity of each category of sampled rural households is very much different (adaptive capacity $_{non-diversified}$ = 0.08; adaptive capacity $_{Low\ wage\ \&/or\ self-employment}$ = 0.17 and adaptive capacity $_{High\ wage\ \&/or\ self-employment}$ = 0.27) and highly contributed for the observed extent of vulnerability differences among the categories of sampled rural households. Rural households' climate change adaptive capacity is dependent on their socio-demographic status, livelihood strategies and social networks. A huge difference in the index value of socio-demographic status across the three sample rural household groups is revealed. Off-farm diversified rural households are better in their socio-demographic status. Sub-indicators like inverse of dependency ratio, percentage of household with literate head, average age of the household head (farming experience) and percentage of household with relatively better rural infrastructure, etc., are in favour of the off-farm diversified rural households and therefore responsible for the difference in the adaptive capacity and the extent of vulnerability to climate change across groups of sampled rural households. The other source of difference in the adaptive capacity and then the extent of vulnerability to climate change is explained by the difference in the major vulnerability indicator of livelihood strategy. Major difference in the index value of livelihood strategy across groups of sampled rural households was found. Sub-indicators like percentage of households having abroad or domestic migrant for work, off-farm income share from the total household income and average number of rural livelihood diversified are more likely favour to the off-farm diversified rural household groups.

The index value of sensitivity, IPCC contributing factor to vulnerability, of each category of sampled rural household is also different ($sensitivity_{non\text{-}diversified} = 0.81$; $sensitivity_{Low\ wage\ \&/or\ self\text{-}employment} = 0.70$ and $sensitivity_{High\ wage\ \&/or\ self\text{-}employment} = 0.57$) and highly contributed for the observed extent of vulnerability differences across the groups of sampled rural households. Rural households that are diversified into rural off-farm economy have relatively higher adaptive capacity than the non-diversified rural households. Therefore, they have the ability to integrate their adaptation capacity to lessen their extent of sensitivity and then their vulnerability to climate change.

Table 4.5: Actual sub indicator values for each sample category, minimum and maximum sub indicator values for the whole sample

IPCC contributing factors	Major indicators	Sub indicators	Non-diversified n=156	Low wage &/or self-employment n=106	High wage &/or self-employment n=61	Max.	Min.	Units
Exposure	Natural disasters caused by climate change and variability	Average number of climate shocks for the last 20 years	20	19	18	26	3	count
		Percent of households that did not get a warning for climate shocks	100	95	91	100	0	percent
		Households faced an injury/death due to climate hazards for the last 20 years (in percent)	97	87	80	100	0	percent
		Mean SD of maximum temperature by month for last 20 years	0.91	0.84	0.80	1.90	0.40	Celsius
		Mean SD of minimum temperature by month for last 20 years	0.89	0.99	0.82	3.50	0.20	Celsius
		Mean SD of average rainfall by month for last 20 years	149	149	148	213	95	mm
Adaptive capacity	Socio-demographic Status	Inverse of dependency ratio	0.18	0.21	0.29	0.71	0.10	ratio
		Percentage of household with literate head	16.10	27.55	28.53	100	0	percent
		Average age of the household head	43.50	48.20	60.87	74	28	years
		Percentage of household with irrigation practice	12.38	2.79	18.58	100	0	percent
		Percentage of household with relatively better rural-infrastructure	12.38	20.12	36.36	100	0	percent
	Livelihood strategies	Percent of households having abroad and/or domestic migrant member for work	0	17	23	100	0	percent
		Off-farm income share from the total household income	0	11	28	100	0	percent
		Average number of rural livelihood diversified	0	1.12	1.33	6	0	count
	Social networks	Average give : receive ratio	0.5	0.55	0.65	2	0.5	ratio
		Average lend: borrow money ratio	0.5	0.5	0.60	2	0.5	ratio

		Percent of households that have a saving experience at least in informal (Equb)	1	6	14	100	0	percent
Sensitivity	Food	Percent of households that significantly depends on rain-fed farm income.	100	97	91	100	0	percent
		Average number of months that the household is food deficit (range 0-12)	4	3	1	4	0	count
		Average crop diversity index	0.48	0.31	0.29	1	0.13	ratio
		Percent of households that unable to save crops	100	98	87.5	100	0	percent
		Percent of households that unable to save seeds	91	87	74	100	0	percent
	Water	Percent of households encounter water conflicts	87.5	91	99	100	0	percent
		Percent of households that use a natural water source instead of potable water	90	81	76	100	0	percent
		Average time to water source (minutes)	100	90	85	120	10	minutes
		Percent of households that were not consistently access water from the source every day	96.5	96	95	100	0	percent
		Inverse of the average number of liters of water used per household member	0.2	0.14	0.1	0.2	0.01	1/litres
	Health	Average time to health facility (minutes)	150	120	90	180	60	minutes
		Percentage of households that face chronic illness on at least 1 family member	38	30	11	100	0	percent
		Average Malaria sensitivity *Prevention Index (range: 0-12)	6	4	3	12	0	Months *bed nets indicator

Source: Authors calculation

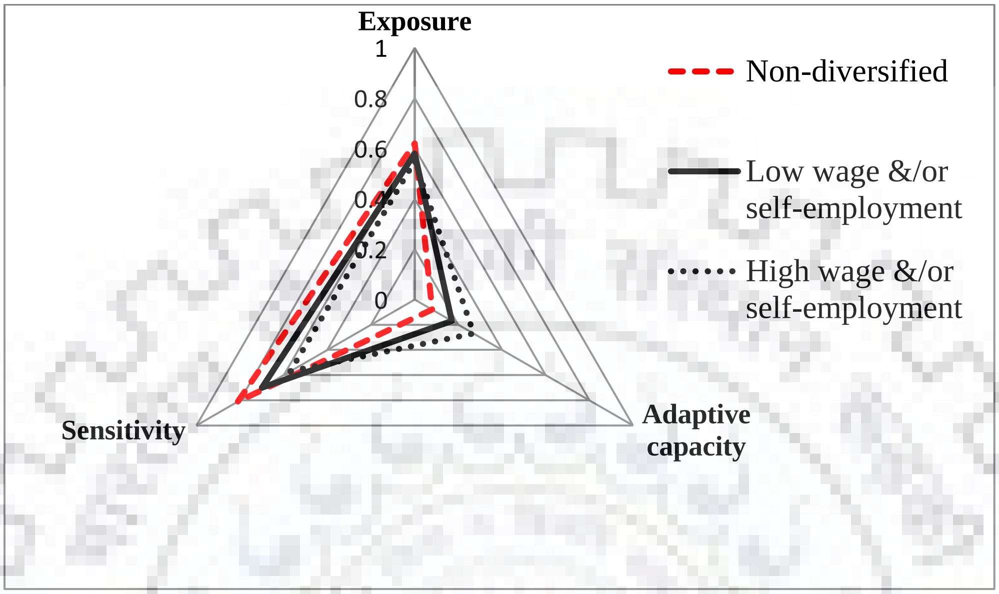
Table 4.6: Indexed sub-indicators, LVI-IPCC contributing factors and overall LVI-IPCC for each sample category

Sub indicators	Non-diversified n=156	Low wage &/or self-employment n=106	High wage &/or self-employment n=61	Major indicators	Non-diversified n=156	Low wage &/or self-employment n=106	High wage &/or self-employment n=61
Average number of climate shocks for the last 20 years	0.74	0.70	0.65	Natural disasters caused by climate change and variability	0.62	0.58	0.55
Percent of households that did not get a warning for climate shocks	1	0.95	0.91				
Households faced an injury/death due to climate hazards for the last 20 years (in percent)	0.97	0.84	0.80				
Mean SD of maximum temperature by month for last 20 years	0.34	0.29	0.27				
Mean SD of minimum temperature by month for last 20 years	0.21	0.24	0.19				
Mean SD of average rainfall by month for last 20 years	0.46	0.46	0.45				
Total Exposure index					0.62	0.58	0.55
Inverse of dependency ratio	0.13	0.18	0.31	Socio-demographic Status	0.18	0.23	0.37
Percentage of household with literate head	0.16	0.28	0.29				
Average age of the household head	0.37	0.44	0.71				
Percentage of household with irrigation practice	0.12	0.03	0.19				
Percentage of household with relatively better rural-infrastructure	0.12	0.2	0.36				
Percent of households having abroad and/or domestic migrant member for work	0	0.31	0.34	Livelihood strategies	0	0.20	0.28
Off-farm income share from the total household income	0	0.11	0.28				
Average number of rural livelihood diversified	0	0.19	0.22				
Average give : receive ratio	0	0.03	0.10	Social	0	0.03	0.1

Average lend: borrow money ratio	0	0	0.06	networks			
Percent of households that have a saving experience at least in informal (Equb)	0.01	0.06	0.14				
Total adaptive capacity					0.08	0.17	0.27
Percent of households that significantly depends on rain-fed farm income.	1	0.97	0.91	Food	0.86	0.76	0.59
Average number of months that the household is food deficit (range 0-12)	1	0.75	0.25				
Average crop diversity index	0.40	0.21	0.18				
Percent of households that unable to save crops	1	0.98	0.88				
Percent of households that unable to save seeds	0.91	0.87	0.74				
Percent of households encounter water conflicts	0.88	0.91	0.99	Water	0.92	0.82	0.77
Percent of households that use a natural water source instead of potable water	0.90	0.81	0.76				
Average time to water source (minutes)	0.82	0.73	0.68				
Percent of households that were not consistently access water from the source every day	0.97	0.96	0.95				
Inverse of the average number of liters of water used per household member	1	0.68	0.47				
Average time to health facility (minutes)	0.75	0.50	0.25	Health	0.54	0.38	0.20
Percent of households with family member with chronic illness	0.38	0.30	0.11				
Average Malaria sensitivity *Prevention Index (range: 0-12)	0.50	0.33	0.25				
Total sensitivity					0.81	0.70	0.57
LVI-IPCC					0.44	0.29	0.20
Average vulnerability to the study area							0.31

Source: Authors calculation

Figure 4.2: Vulnerability Triangle of LVI IPCC contributing factors for the three categories of sampled rural households



Source: Authors calculation from survey data

In all the indicator based approaches of vulnerability assessment including the LVI-IPCC framework, there is subjectivity in the selection of sub-indicators and no straightforward validation method for the indices themselves (Vincent, 2007; Hahn *et al*., 2009). In fact, LVI-IPCC framework utilizes household level primary data in which the researcher organizes the survey instruments, carries out the sampling procedures, trained the survey field team and conduct physical observation on the phenomena, sources of potential measurement errors are reduced.

The econometric method of vulnerability assessment, VER, was employed to support the LVI-IPCC framework. As the dependent variable, household estimated total income loss (Hloss) is continuous variable measured in Ethiopian Birr, OLS estimation is appropriate to estimate the econometric model. The estimated model was tested and satisfies all the least square assumptions but heteroscedasticity is suspected because the data contains information on 3 heterogeneous groups of rural households. Therefore, OLS regression considering White's correction for heteroscedasticity was followed to generate consistent standard errors. The OLS results are presented in Table 4.7.

Table 4.7: Determinants of rural households' vulnerability to climate change related shocks

	Coefficient	Robust standard errors	t-statistics	Standardized Coefficient
Dependent variable: vulnerability: Hloss				
Independent variables				
Exposure				
Drought	893.286***	283.899	3.150	0.094
Climatic_variability	247.244**	235.169	1.050	0.029
Adaptive capacity				
Diversification1	-3242.821***	318.101	-10.190	-0.365
Diversification2	-2891.519***	495.657	-5.830	-0.271
Gender_head	-399.755	289.711	-1.380	-0.041
Age_head	-14.792	11.657	-1.270	-0.039
Head_literacy	-641.225**	309.945	-2.070	-0.075
Rural_infrastructure	-966.321***	329.687	-2.930	-0.116
Irrigation	-3432.639***	340.070	-10.090	-0.389
Sensitivity				
Water	25.821**	11.289	2.290	0.170
Health	26.685***	8.352	3.200	0.243
Livestock	1269.359***	247.131	5.140	0.141
Constant	5703.124***	731.295	7.800	
Number of observations	323		F(12,310)	232.180***
Variance inflation factor (VIF)	3.520		R^2	0.831
			Adj R^2	0.825

Source: Authors calculation using survey data; *, ** and *** imply that the coefficients are statistically significant at 10%, 5% and 1% respectively.

The R^2 of the model is 0.831 and the adjusted R^2 is 0.825. The statistically significant F-test at 1 percent confirms that the model is overall significant and fits the data well. To make this econometric approach consistent with the LVI-IPCC framework and as both are integrated livelihood vulnerability approaches the variables in the model are classified into the three IPCC vulnerability contributing factors of adaptive capacity, exposure and sensitivity.

Consistent with the findings of LVI-IPCC framework the econometric analysis also found that being diversified in both groups of rural off-farm activities decreases rural households' vulnerability to climate shocks compared to the non-diversified rural households. Other adaptive capacity variables like irrigation, rural-infrastructure and head literacy also have significant effect in reducing the rural household vulnerability to climate change related shocks. Rural households having irrigation experience, living in rural villages having relatively easy access for infrastructures like all-weather roads, market, transportation, electricity, mobile networks, radio and television are less vulnerable.

On the other hand, being less secured in water and health facilities and a significant engagement in the usual rain-fed mixed farming that includes livestock production alone have a tendency to increase vulnerability indicated by their positive coefficient. Livestock production in the study area does not help to reduce vulnerability rather; it increases as it was climate sensitive like farming. Loss of livestock and associated losses in income during climate shock is very common in the study area. For instance, the significant livestock death due to significant water and livestock feed stress in the 2015 El Niño induced drought is a good example. Though, livestock production is an important source of income for rural households, its capacity to resist the negative impacts of climate shocks is very low due to the traditional practices. This do not imply a need to decrease livestock production, rather it urges to improvements the management of livestock. Livestock production in the study area should be supported by scientific research, new technology and training.

Whereas, with regard to drought and climatic variability, taken as the exposure component of vulnerability in the LVI-IPCC framework have positive and significant coefficient. These variables are more or less common to all local rural households and so considered as covariate shocks. Rural households repeatedly experiencing temperature increase, rainfall decrease, and pre and post-harvest damages due to climatic fluctuations are expected to be highly vulnerable. Therefore, the study reveals that the rural household economy is significantly and adversely affected by climate shocks in the study area.

Standardized beta coefficients that help us to prioritize proper intervention strategies to reduce the rural household vulnerability and then the adverse impact of climate change are presented in Table 4.7. As indicated by the standardized beta coefficients diversification of rural households into rural off-farm activities is the best intervention strategy to reduce vulnerability next to irrigation. Therefore enabling rural households to participate in rural off-farm activities and irrigation should be prioritize and recognize as best intervention strategy to reduce vulnerability. Improvements in the access of water, health and other rural-infrastructure are also indispensable. Modernizing the traditional livestock production practices is also important. The included climatic variables drought and climatic variability significantly explained the rural household vulnerability captured by the annual estimated household total income loss and thus had an adverse effect on the household level economy.

4.5. Chapter summary

This study concludes that the traditional rain-fed agriculture in the study area leaves rural households highly vulnerable to climate change due to their disadvantaged socio-economic and demographic conditions and poor adaptive capacities. In short, the rural household's livelihood in the study area was found to be significantly and adversely influenced by climate shock. Moreover, the study shows that vulnerability differences among the rural off-farm diversified and non-diversified rural households are also notable. Rural households that do not diversify into any rural off-farm activity are highly vulnerable to climate shock. Rural off-farm activities help the participants to develop and/or enhance climate resilience that would lessen their sensitivity and vulnerability to the exogenous covariate climate shocks. Therefore, the study recommends rural off-farm diversification as one possible CCA option in the study area. Rural households should utilize the capacities and opportunities of rural off-farm diversification to adapt the adverse climate change impacts and sustain their rural livelihood and contribute for the achievement of the related targets in the SDGs at large. However, the findings also suggest that the overall rural off-farm participation rate, rural off-farm diversification index and rural off-farm economic efficiency were low in the study area.

The study highlights the vulnerability differences within the rural off-farm diversified households. Rural households engaged in high wage and/or self-employment activities were found to be less moderately vulnerable compared to those diversified households engaging in the low wage and/or self-employment activities. This implies that the return from rural off-farm activities significantly contribute in reducing vulnerability. Here, natural difference in the expected return from rural off-farm activities is minimal but the differences are due to the existing socio-economic, demographic and varying technical abilities across rural households. Therefore, policy interventions should emphasize on the overall growth of the rural off-farm economy with the aim of increasing the rural off-farm participation rate, rural off-farm diversification index and enhancing rural off-farm economic efficiency and the return from each activity.

Promoting the growth of rural off-farm activities, better irrigation facilities, improvements in access to water, health and other rural-infrastructure should be prioritized and recognized as best intervention strategy to reduce rural households' vulnerability to climate shocks in the study area. Priority should be to improve rural households' climate change adaptive capacity as an effective pro-active strategy in place of the usual reactive relief oriented strategy. Policy interventions should be based on socio-economic and demographic characteristics and inclusive for relatively marginalized groups.

Policy, financial and promotional supports should be given for the rural off-farm economy from national and local level governments and development institutions. Considering the heterogeneity of the rural off-farm economy it should be integrated and mainstreamed into various concerned economic sectors. Having national strategic plan on the off-farm economy should be the first step for this. Learnings from the selected region in Ethiopia may be useful for other African and least developed and developing economies.

Chapter 5

Climate Change and Off-Farm Diversification as an Adaptation Option in Rural Ethiopia

5.1. Introduction

As already discussed before, the developing and less developed economies are more affected by climate change (Dell *et al.*, 2012; Burke *et al.*, 2015) though they contribute the least to the problem (Kolawole *et al.*, 2016). This is because such economies are dependent on the traditional climate sensitive agriculture and agricultural practices transferred over generations. Further they have limited or no adaptation capacities (Collier *et al.*, 2008). Limited utilization of the existing adaptation options makes the economy vulnerable to and affected by various climatic shocks such as droughts, floods and other extreme weather events. In the absence of any effort to implement corrective measures, the future impact of such shocks becomes worse (Lanzafame, 2014). Frequent climatic shocks have increased the risks and uncertainties associated with the farm sector that urgently calls for measures to strengthen the adaptive capacity of the rural households through diversification. Diversification, especially into off-farm activities, could be among the possible CCA options (Yaro, 2013; IPCC, 2014). Rural off-farm diversification and the related indigenous knowledge in the face of CCA are not yet well investigated (Anik and Khan, 2012) though they may help in climate adaptation (Lebel, 2013). In this backdrop, this thesis also examines how does the rural off-farm sector would grow and could be used as relevant option for adapting to climate change? In this chapter the plausible answer to this question is presented.

During the review of the existing CCA efforts in Ethiopia, it was found that the approach is similar in many ways to relief oriented disaster management. Its contribution to climate shock vulnerability reduction efforts has been rather poor and almost negligible. From 1974 to 1989, reactive emergency response disaster management has been emphasized. Before 1974, the disaster management issue was relatively unrecognized. From 1990 to 1994, efforts were made to shift the focus from the reactive to the strategically preferable proactive way of disaster management prioritizing prevention and preparedness. From 1995 onwards, transformation began through policy acceptance and institutional commitments (Abebe, 2010). However, the implementation of effective prevention and preparedness based pre-disaster management strategies in Ethiopia is yet practically intangible. The recent 2015 El Niño induced drought was a good example in which the government spent huge budget for direct relief transfer from the mega development projects. But, enhancing CCA capacities of rural households was overlooked. Large proportion of rural households in Ethiopia has no access to non-farm income (Deressa *et al.,* 2008). Income diversification is not commonly used as CCA option in rural Ethiopia (World Bank, 2010). Rural households that participated into non-farm activities in Ethiopia were not more than 25 percent, of them very negligible amount about 2 percent were exclusively engaged in non-farm activities (Rijkers *et al.,* 2008 cited in Asfaw *et al.,* 2017). Off-farm participation rate was among the lowest in Amhara regional state of Ethiopia which encompasses the geographical area of this study (Bazezew *et al.,* 2013).

Moreover, the government did not create conducive working environment for rural households. In recent times, large numbers of rural households are internally displaced due to political instability. Therefore, engaging in regular farming activities and following climate adaptation options are difficult. Formal reactive mechanisms of insurance and credit markets are almost nonexistence in rural Ethiopia (Sisay, 2010). In the absence of strong pro-active risk reduction strategies and formal reactive mechanisms, insuring majority of climate shock impacts using relief is found to be inefficient.

The study looks rural off-farm economy (diversification) in a wider context that consists all ‘off the owners’ own farm activities including agricultural wage employment on other people’s farm and all non-farm activities by rural households regardless of location (Babatunde, 2013). Rural non-farm activities are non-agricultural wage and self-employment income generating activities by rural households (Haggblade *et al.,* 2010).

Unlike other CCA measures rural off-farm diversification is not well investigated (Anik and Khan, 2012). Moreover, studies on the determinants of households’ rural off-farm diversification decision (for example, Dessalegn and Ashagrie, 2016; Asfaw *et al.,* 2017) did not explicitly account climate shock variables as determining factors. Only scant studies like Demeke and Zeller (2012) analyse the issue in relation with weather changes. They also analysis off-farm activities in aggregate terms; however, a disaggregated look on the rural off-farm economy into mutually exclusive categories of high and low return off-farm activities is employed in this study. Having these gaps, this study specifically examine the effects of climate shock and other potential factors on rural households' diversification decision into disaggregated off-farm activities and on the return from such rural off-farm activities in South Gondar, Ethiopia. The study finds that; though, climate change increases the likelihood of rural households' off-farm diversification, the current status of off-farm economy is very low in the study area due to lack of capacity and other constraints. Rural households' capacity development in rural infrastructure, irrigation, awareness creation, education and training on off-farm skills promote the overall growth of off-farm economy so as to serve as an effective CCA option. The remaining parts of this chapter are organized as follows. Section two presents a theoretical off-farm labour supply model. Section three provides data and econometric model specification. Results are presented and discussed in section four. Lastly it ends with chapter summary.

5.2 Off-farm labour supply model

Specifically to examine the effect of climate change on rural households' off-farm diversification decision and to identify other potential determinants of rural off-farm diversification decision and their earnings a theoretical off-farm labour supply model based on Huffman (1980, 1991) and Singh et al. (1986) is adapted. The model uses rural household's off-farm diversification status as dependent variable instead of off-farm labour hours spent as it was difficult to collect off-farm labour hours.

$$\pi_{ij} = \pi_{ij}\,(W_0, F, W, H, L) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 5.1$$

where, π_{ij} represents the probability of the ith household 'to diversify in the jth rural off-farm diversification category[31]; W_0 is off-farm wage or earnings; F is farm characteristics such as farm size and irrigation that determines farm income; W is for household wealth status to account other household assets; H is household characteristics, and L is for local characteristics that shows the market and other rural infrastructure situations. Off-farm wage or off-farm earnings for rural household again depend on household characteristics (H), local characteristics (L), rural labour supply (S_L) and the derived demand for off-farm labour

[31] Discussed in the empirical model

(D_L) from off-farm goods and services demand (D_G). The off-farm wage or earnings function thus will be:

$$W_0 = f(H, L,\ D_L(D_G),\ S_L) \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots 5.2$$

The demand for off-farm goods and services may depend on the status of rural economy. Rural labour supply to the off-farm sector is also affected by the labour absorption capacity of the farming sector. Both the status of rural economy and particularly farming sector labour absorption capacity are related with the well-functioning of climatic conditions. This study denotes climatic conditions using drought (D) as a proxy for decreasing trend in the mean annual rainfall and/or increasing trend in the mean annual temperature and climatic variability (V) as a proxy for climatic fluctuation mainly erratic rainfall variability that causes yield damages, both evidenced from sampled rural households. Note that the demand for off-farm goods and services are not only from rural economy, instead there is untapped urban demand for off-farm goods and services denotes by (U_D). It is also important to consider the availability of the untapped self-employment off-farm opportunities (NW_0) for rural labour besides to the labour absorption capacity of the farming sector. Substituting all these variables into the initial household rural off-farm diversification (off-farm labour supply) equation gives:

$$\pi_{ij} = \pi_{ij}\ \left(W_0\left(H, L, D_L\big(D_G(D, V, U_D)\big), S_L(D, V, NW_0)\right), F, W, H, L\right) \dots \dots \dots 5.3$$

Finally, climate shock effects on rural households' off-farm diversification are shown by differentiating the expanded off-farm labour supply function with respect to D and V which gives:

$$\frac{d\,\pi_{ij}}{dD} = \frac{d\,\pi_{ij}}{dW_O}\left(\frac{dW_O}{dD_L}\frac{dD_L}{dD_G}\frac{dD_G}{dD} + \frac{dW_O}{dS_L}\frac{dS_L}{dD}\right) \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots 5.4$$

$$\frac{d\,\pi_{ij}}{dV} = \frac{d\,\pi_{ij}}{dW_O}\left(\frac{dW_O}{dD_L}\frac{dD_L}{dD_G}\frac{dD_G}{dV} + \frac{dW_O}{dS_L}\frac{dS_L}{dV}\right) \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots 5.5$$

From these two equations both direct and indirect effects of climate shock on the likelihood of rural households' off-farm diversification status are implied. On the first hand, rural households' may be more likely to diversify into off-farm activities as climate shock coping strategy due to shock; on the other hand rural households' may be less likely to diversify as climate shock damages rural economy and in turn decreases demand for off-farm goods and services, demand for off-farm labour, off-farm wage and availability of starting capital for rural households to start off-farm activities. The direct off-farm labour supply increasing effect of climate shock will also nullify due to the decrease in off-farm wage as off-farm labour supply increases. Therefore, the negative or decrease effect of climate shock on rural households' off-farm diversification is understood based on the literal off-farm labour market theory.

However, the practical effect of climate shock on rural households' off-farm diversification depend on the relative strength of these two opposite forces which is explained by the relative elasticity of supply of and demand for off-farm labour for climate shock, which in turn depends on the existing nature of the rural off-farm economy in the study area. Considering the market demand for rural off-farm goods and services from the urban side, their demand and in turn the derived demand for rural off-farm labour may not be decrease as a result of climate shock. This is due to the presence of untapped urban demand for rural off-farm goods and services (U_D). The question is how rural households are enabling to utilize this opportunities.

On the other hand; even though, the rural economy is affected from climate shock the possibility of rural households' off-farm engagement may not be decreased since the sector (mainly the low resource & low return off-farm activities) does not need significant starting capital. Instead rural households' are forced to diversify at least into these low wage and/or self-employment rural off-farm activities as climate shock coping strategies even in the absence of starting capital.

The other fact is the infancy of the off-farm economy. As the off-farm economy is at its infant stage there are huge untapped wage and non-wage (self-employment) income generating off-farm activities (NW_0) that still calls rural households to diversify into off-farm economy, therefore off-farm wage or earnings may not be decrease as participation increases.

All the above facts strengthen the direct increasing effects of climate shock on off-farm labour supply as a coping strategy. But, it is also very important to examine other potential factors that determine rural households' off-farm diversification decision and their earnings from the sector along with climate shock effects. Investigating how rural households utilize the available opportunities in the off-farm economy and how they make it as one effective CCA option for sustaining their livelihood is indispensable.

The important assumption of this study is that rural off-farm activities are different in terms of their resource requirement and earnings generated. These variations are caused and further aggravated due to the socio-economic, demographic, capacity and technical differences among rural households. Therefore, the important hypothesis that this chapter want to test is that potential determinant factors are different across different categories of off-farm activities and have different levels of significance effect on both rural households off-farm participation decision into a particular category of off-farm activity and earnings from that off-farm activity. Having this assumption and hypothesis, the study contributes the analysis of the effects of climate change and other potential determinants on rural households' participation into disaggregated categories of off-farm activities and the returns from such activities using the empirical models discussed in the methodology section. Disclosing the existing variations among rural off-farm activities and rural households and analysing the rural households off-farm participation decision and earnings across the disaggregated categories of off-farm activities namely high wage and/or self-employment (high return) off-farm activities and low wage and/or self-employment (low return) off-farm activities yield a better result than the aggregated analysis one.

5.3. Data and econometric model specification

5. 3.1 Data

The primary aim of this study is testing the hypothesis that climate shocks captured by drought and climatic variability have an effect on rural households' off-farm diversification decision. Simultaneously the study also tries to identify other potential factors determining rural households' off-farm diversification decision and off-farm earnings. Therefore, the probability of a given rural household diversification into a particular group of off-farm activities is modelled as a function of the variable of interest climate shock and other potential factors. The study captures climate shock by drought and climatic variability. Drought is taken as a proxy for decreasing trend in the mean annual rainfall and/or an increasing trend in the mean annual temperature. While, climatic variability is a proxy for pre and post-harvest damages caused by abnormal and erratic rainfall variability, flood and epidemics as evidenced from rural households in the study area.

Table 5.1: Definition and measurement of variables

Variable specification	Symbol	Measurement
Dependent variable for each model		
Off farm diversification decision	π_{ij}	π_{ij} represents the probability that the individual i chooses alternative j $(j = 0, 1, and\ 2)$; i.e, $\sum_{j=0}^{2} \pi_{ij} = 1$; for every individual i due to the mutually exclusive choices $(j = 0, 1, and\ 2)$
Share of off-farm income	Y_i	The share of off-farm income from the total household income given off-farm diversification
Explanatory variables		
Climatic variable		
Drought	D	1 if a household experiences a decreasing trend in the mean annual rainfall and/or an increasing trend in the mean annual temperature and 0 otherwise
Climatic variability	V	1 if the farm household suffered from pre and post-harvest damages caused by abnormal and erratic rainfall variability, flood, and epidemics 0 otherwise
Household characteristics	H	
Gender of the household head	Gender_head	1 for male headed household and 0 otherwise.
Age of the household head	Age_head	Age of the household head in years
Age square of the household head	Agesq_head	The square value of years of household head
Literacy of household head	Head_literacy	1 if the head able to read and write, 0 if otherwise
Household size	HH_size	Total number of people in the household
off-farm skill	Off-farm_skill	1 for those with transferable off-farm skill, 0 otherwise
Farm characteristics	F	
Farm Size	Farm_size	Size of farm land owned by household (in hectares)
Irrigation	Irrigation	1 if the household has access to irrigated land, 0 otherwise
Local or community characteristics	L	
Rural infrastructure	Rural_infrastructure	1 if a household has access to relatively better rural infrastructures on average , 0 otherwise

Based on literature, gender dummy for household head, age of household head and its square value as a proxy for experience and to control life cycle effects respectively, household head literacy and possession of special off-farm skill, household family and farm size, irrigation experience and rural infrastructure accessibility were potential determinants of off-farm diversification and off-farm earnings supposed by the study. Rural infrastructure accessibility indicates the average status of the household in accessing market, all-weather roads, town proximity, electricity, financial services and other infrastructure facilities. The definition and measurement of variables in the model is presented in Table 5.1.

5.3.2 Econometric model specification

5.3.2.1 Modelling effects of climate shocks and other potential determinants on rural off-farm diversification decision

For a dependent variable having more than two naturally unordered alternatives among which the decision maker (chooser) has to choose based on chooser specific characteristics (regressors), multinomial regression models are preferable. Such models are appropriate to examine how the chooser's characteristics do affect his/her choosing a particular alternative among a set of alternatives (Green, 2003, p. 721).

The dependent variable rural households' off-farm diversification has three naturally unordered alternatives: first, households with no diversification; second, diversified into low wage and/or self-employment and third, diversified into high wage and/or self-employment off-farm activities. Based on the existing nature of rural households in the study area as the survey information showed the three alternatives are mutually exclusive. They are dissimilar and not just substitutes for one another. Therefore, these outcome categories of the model have the property of independence of irrelevant alternatives (IIA)[32]. This situation and its mathematical simplicity necessitates to prefer Multinomial Logit model than Multinomial Probit model to specifically examine climate shock effects on the probability of rural household's off-farm diversification choices and to identify other potential determining factors. Some previous studies like Demeke and Zeller (2012), Demie and Zeray (2016) and Dessalegn and Ashagrie (2016) employed Multinomial Logit model. The specified Multinomial Logit model that helps to examine the effects of individual or chooser specific

[32] Multinomial Logit model must satisfy the IIA assumptions. IIA assumption states that the ratio of probabilities of any two choices of outcome categories (alternatives) of an individual (chooser) will be indifferent regardless of what the other alternatives are. Stated differently, the ratio of probabilities of any two choices for an individual chooser should not be influenced by any other alternatives. In short, IIA requires an individual chooser when comparing two alternatives, other alternatives are irrelevant.

but not choice specific explanatory variables on the probability of a particular outcome category is:

$$\pi_{ij} = \frac{e^{\alpha_{j+\beta_j X_i}}}{\sum_{j=0}^{2} e^{\alpha_{j+\beta_j X_i}}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots 5.6$$

Where, α is intercept, β is vector of slope coefficients, X is vector of regressors including climatic variables and e is the base of natural logarithm.

The probabilities π_{ij} represents the probability that the individual i chooses alternatives $(j = 0, 1, and\ 2)$; that is, $\sum_{j=0}^{2} \pi_{ij} = 1$; for every individual i due to the mutually exclusive choices. Note that the subscript j on the intercept and slope coefficients indicates as these coefficients are different from choice to choice; that is, the three probability regressions have different coefficients for the regressors. Of course, it is practically impossible to estimate the three probability regressions independently. What practiced in multinomial logit model is taking one category as comparison (base) category and set its coefficients to zero. In this case, the non-off-farm diversified (or farm only) category has taken as a base and $\alpha_0 = \beta_0 = 0$; therefore, the given multinomial logit model is written separately for each choices as:

$$\pi_{i0} = \frac{1}{1 + e^{\alpha_{1+\beta_1 X_i}} + e^{\alpha_{2+\beta_2 X_i}}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots .5.7$$

$$\pi_{i1} = \frac{e^{\alpha_{1+\beta_1 X_i}}}{1 + e^{\alpha_{1+\beta_1 X_i}} + e^{\alpha_{2+\beta_2 X_i}}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots .5.8$$

$$\pi_{i2} = \frac{e^{\alpha_{2+\beta_2 X_i}}}{1 + e^{\alpha_{1+\beta_1 X_i}} + e^{\alpha_{2+\beta_2 X_i}}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots 5.9$$

5.3.2.2 Modelling determinants of off-farm earnings

To investigate determinants of off-farm earnings by taking the share of off-farm income from the total household income as a dependent variable, limited dependent variable regression models are preferable. This is because the nature of the sample in which information on off-farm earnings is not available or zero for some observations; though, the information on the regressors for all observations in the sample are available. The share of off-farm income is meaningful only for off-farm diversified rural households. Non-off-farm diversified rural households have no value for this dependent variable or they may take it as zero as they are not diversified. When all the information on all regressors, including the one that the associated regressand value is not available, are used the sample size would not decrease and both the diversified and non-diversified samples are included. Such samples are commonly called censored sample. Ignoring information on the regressors that their associated regressand values are not available, the sample is said to be truncated. In this case the sample size will decrease as it only considers off-farm diversified rural households.

OLS estimation using such data, whether include the whole sample or the off-farm diversified sample only, provides biased and inconsistent estimates. The intercept and slope coefficients from the two samples are different. This is due to the fact that, the conditional mean of the error term in such data is non-zero and the error is correlated with the regressors. Therefore, maximum likelihood estimation of the limited dependent variable regression model particularly the Tobit censored sample regression model has used in this study as this model uses more information than the truncated regression model; estimates are expected to be more efficient. The Tobit censored sample regression model is specified as:

$$Y_i^* = \beta_i X_i + u_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 5.10$$

$$Y_i = \begin{cases} Y_i^* \text{ if } Y_i^* > 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 5.11 \\ 0 \text{ if } Y_i^* \leq 0 \end{cases}$$

where, Y_i is the observed dependent variable (off- farm income share), Y_i^* is the latent or desired variable (desired off- farm income share), X_i is vector of regressors affecting the probability of off-farm earnings, β_i is vector of parameters to be estimated and the error term is assumed $u_i \sim N(0, \delta^2)$. The slope coefficients however indicates the marginal impact of a unit change in regressors on the mean value of the latent variable (desired off- farm income share) Y_i^* not on the mean value of the observed dependent variable (off- farm income share) Y_i. This is due to the two simultaneous effects of a change in the value of regressors on the mean value of the observed dependent variable and on the probability that the latent variable is actually observed, in a Tobit censored regression. Unless the probability is known, it is difficult to know the marginal impact of a unit change in regressors on the mean value of the observed dependent variable. The probability calculation depends on all the regressors and their coefficients in the model. However, statistical packages easily provide marginal impacts of each regressor.

5.4 Results and discussion

5.4.1 Descriptive statistics

5.4.1.1 Household characteristics and incidence of rural off-farm diversification

According to the survey data most rural households are reported as they were suffered from climate shock problems namely drought and climatic variability. Almost 73.7 per cent of rural households are reported as they perceive decreasing trend in rainfall and /or increasing trend in temperature as well as 54.5 per cent of rural households are evidenced for pre and post-harvest damages from abnormal and erratic rainfall variability, flood and epidemics in the study area. Furthermore, the data shows that only 23.5 percent of rural households are female headed while the majorities are male headed. The average age of household head is 48.3, and only 31.3 percent of the heads are able to read and write at least. In the study area, 34.7 percent of rural households have special off-farm skill mainly handcrafts (pottery), blacksmith (metal work), weaving, leather tanning, carpentry, and masons. The average household level dependency ratio in the study area is estimated to be 0.69 with an average family size of 6.6 persons from which 3.9 persons are adults and 2.7 persons are dependents.

Table 5.2: Basic Household Characteristics

Variables	Frequency	Percent	Mean	SD	Min.	Max.
D	238	73.68	0.74	0.44	0	1
V	176	54.50	0.55	0.49	0	1
Gender	247	76.50	0.77	0.42	0	1
Age	-	-	48.3	10.99	28	74
HH_size	-	-	6.6	1.51	3	11
Adult labour	-	-	3.9	1.7	1	9
Dependents	-	-	2.7	0.78	0	5
Dependency ratio	-	-	0.69	-	-	-
Farm_size	-	-	5.07	1.97	2	12
Head_literacy	101	31.27	0.31	0.48	0	1
Off-farm_skill	112	34.67	0.35	0.47	0	1
Rural_infrastructure	82	25.5	0.26	0.50	0	1
Irrigation	55	17.03	0.17	0.47	0	1

Source: Authors calculation using survey data (2018)

The majorities, 83.3 percent, of rural households are cultivating land of 1.5 hectare and less and 58.5 percent of them are cultivating one hectare or less. Only 17 percent of the total rural households in the study area are practicing irrigation at least to some extent. Regarding to rural infrastructure, only 25.5 percent of rural households in the study area are reported as they have on average relatively easy access to rural infrastructures; the majority of them are living in the urban (town) adjacent rural districts. Basic rural household characteristics in the study area are summarized in Table 5.2.

Almost all rural households in the study area are engaged in mixed traditional agriculture. The rural off-farm participation rate in the study area is low. Almost 50 percent of the sampled rural households are not diversified into any rural off-farm activity. Even, from the participants almost 33 percent are participated into low wage &/or self-employment rural off-farm activities including food for work program designed by the government. It is only 19 percent of sampled rural households are engaged into high wage &/or self-employment rural off-farm activities that generates relatively better amount of household income. Moreover, rural off-farm diversification index in the study area is very low. On average an off-farm participant household is engaged in only one off-farm activity in the study area. For the off-farm diversified rural households in the study area the average share of off-farm income from the total household income is only about 15 percent. Separately for rural households those diversified into low return off-farm activities and high return off-farm activities the share of off-farm income from the total household income is only about 10 percent and 24 percent respectively.

Table 5.3: Incidence of rural off-farm diversification by sampled rural households

Diversification	Frequency	Percent	Off-farm income share for diversified rural households (in percent)
Farm only (non-diversified)	156	48.30	-
Low wage and/or self-employment	106	32.82	10
High wage and/or self-employment	61	18.89	24
Total	323	100	15

Source: Authors calculation using survey data (2018)

5. 4. 2 Econometric results

5. 4. 2.1 Climate shock effects and other determinants of off-farm diversification: multinomial logit model

The multinomial logit regression results are shown in Table 5.4. The likelihood ratio test, under the null hypothesis that none of slope coefficients are statistically significant, is used as a measure of goodness of fit of the chosen model. The computed LR, which follows the chi-square distribution with the degree of freedom equal to the total number of slope coefficients estimated, is highly statistically significant as its p value being practically zero. This suggests that the model has a good fit, although not every slope coefficient is statistically significant. The multinomial logit model works under the assumption of IIA. The Hausman-McFadden test of IIA assumption and the Wald test for combining alternatives (presented in the Appendix 4A and 4B respectively) are checked and confirmed that the assumption of IIA is not violated and outcome categories or alternatives cannot be collapsed or combined.

Table 5.4: Estimation results of the multinomial logistic regression model

Variables	Low wage and/or self-employment			High wage and/or self-employment		
	Coefficient	Standard error	Z	Coefficient	Standard error	Z
D	1.094**	0.452	2.420	4.793	5.511	0.870
V	1.339***	0.395	3.380	2.962*	1.604	1.847
Gender	1.041**	0.427	2.440	12.849	1633.130	0.008
Age_head	0.334*	0.205	1.620	1.955	1.855	1.054
Agesq_head	-0.003	0.002	-1.550	-0.016	0.016	-1.000
HH_size	-0.548***	0.183	-2.990	-1.108	0.988	-1.121
Farm_size	0.141	0.219	0.650	1.729*	1.085	1.594
Head_literacy	1.363***	0.478	2.850	6.534	1477.891	0.004
Off-farm_skill	1.618***	0.392	4.120	1.483	1.707	0.870
Rural_infrastructure	0.238	0.386	0.620	6.132**	3.315	1.850
Irrigation	-0.623	0.553	-1.130	6.511***	1.977	3.290
Constant	-9.487**	4.722	-2.010	-94.359	2202.907	-0.040
No. of observations	323	LR $\chi2$ (22)	425.94	Pseudo-R^2	0.6389	
		Prob > $\chi2$	0.0000			

Note: sample category of non-diversified or farm only is used as a base. *, **, and *** shows the statistical significance of coefficients at 10%, 5% and 1% respectively.
Source: Authors calculation using survey data (2018)

The results from the multinomial logit model further confirmed that climate shocks, drought and climatic variability, have significant effects on rural households off-farm diversification decision. Specifically, the more likely and more significant effects of such variables to low wage and/or self-employment off-farm diversification indicate as the climate shock adaptation role of the sector. This empirical result of the multinomial logit model supports the theoretical hypothesis derived from the theoretical model that states strong direct impact of climate shock increases supply of off-farm labour by rural households as climate shock coping mechanism.

The other finding is that rural households that have relatively easy access for rural infrastructure and practiced irrigation are more likely and significantly diversified into high wage and/or self-employment off-farm activities than only farm engagement. The reason is that high wage and/or self-employment off-farm activities practiced in the study area such as crop and livestock trading, stone and sand mining, masons, afforestation, grinding mill and formal international migration for work requires some starting capital and location and market advantages; rural households having such accesses are more likely to diversify into high wage and/or self-employment off-farm activities. In this regard, Demeke and Zeller (2012) only accounts town proximity and found that more proximity to the town increases the likelihood of participating in high return off-farm activities. A study by Deichmann et al. (2009) in Bangladesh indicates that improved rural-urban connectivity through accessing infrastructures increase the likelihood of off-farm diversification by rural households. Dessalegn and Ashagrie (2016) also found a negative effect of irrigation due to an aggregated view on off-farm activates. However, this study by accounting all the rural infrastructures on average found the positive influence of rural infrastructures on the likelihood of participation in both high and low wage and/or self-employment off-farm activities though the effect is stronger for the high wage and/or self-employment off-farm activities.

Being male headed household more likely to participate in both mutually exclusive alternatives of off-farm activities, but the result is significant only for diversification into low wage and/or self-employment. Similarly as the age of the household head increases it is more likely that a household will diversify into off-farm activities than farming alone specifically the result was significant for low wage and/or self-employment off-farm diversification. The square value of age of household head is explicitly considered in the model to account the life cycle effects and confirmed that it was only up to a certain age limit that the increase in age of the household head positively contributes to the likelihood of rural households’ off-farm diversification. Studies in rural Ethiopia by Bezu and Barettet (2010) and Demie and Zeray (2016) have found opposite result that the increase in age of household head is more likely to prevent households from off-farm diversification.

Household size negatively affects the likelihood of rural households’ off-farm diversification in both alternatives compared to only farm engagement. This is due to the high family level dependency ratio resulted from high household size. On the other hand, increases in the farm size of a household, more likely the household to diversify into high wage and/or self-employment off-farm activities. It was insignificant for low wage and/or self-employment off-farm diversification. The result indicates the possibilities that the larger the farm size, the larger the farm income which helps rural households to diversify into the high wage and/or self-employment off-farm activities. Demeke and Zeller (2012) had found some what the opposite effect of farm size in rural Ethiopia.

The result also revealed that a household with literate head (at least read and write) is more likely to participate in low wage and/or self-employment off-farm activities. Similarly households that possess special off-farm skill are more likely to diversify into low wage and/or self-employment off-farm activities than remain in only farm engagement. This is due to the reason that most low wage and/or self-employment off-farm activities require some special off-farm skills such as carpentry, basketry, handcrafts or pottery, blacksmith or metal works, repair services, weaving and leather tanning. This finding indicates the importance of skill training, awareness creation and technology transfer to enhance off-farm participation and earnings as well. Financial services along with other rural infrastructure services should be provide to make them high return off-farm activities. A study by Mezgebo and Porter (2020) indicates that local governments in Ethiopia takeover the farm lands of nearby urban farm households for urban use by compensating with cash so as to diversify into non-farm activities. However, these rural households are less likely to diversify into non-farm activities due to the absence of prior experience and awareness. Therefore, policy recognition and promotion of the off-farm sector in general and enhancing the off-farm skills and awareness of rural households is important.

All the above findings from the multinomial logit model showed that given their household and farm characteristics, climate shock influences positively and significantly the likelihood of most rural households diversification decision into low wage and/or self-employment off-farm activities as coping strategies in the study area; while for some socio-economically advantageous rural households that have an access for rural infrastructure and irrigation, climate shock influences positively and significantly their likelihood of diversification into high wage and/or self-employment off-farm activities compared to only farm engagement. In other words, determinants of diversification into low wage and/or self-employment off-farm activities are dominated by climate shock while wealth or capacity related variables are more responsible for high wage and/or self-employment off-farm diversification. This finding indicates the importance of working on providing financial services for rural households which was missed in rural Ethiopia. It is consistent with the findings of Bezu and Barret (2010) and to some extent with Demie and Zeray (2016) that identified only some capacity variables like education, land, irrigation and adult household members as important factors affecting the likelihood of non-farm diversification.

5.4.2.2 Determinants of off-farm earnings: The Tobit model

From the results of the multinomial logit model, the effects of climate shock on rural households' off-farm diversification decision and in addition, other potential determinants of off-farm diversification were identified. Now let us examine the effects of all these explanatory variables on off-farm earnings for participant rural households' using the Tobit model.

Censored type of data causes OLS estimators of linear models to be biased and inconsistent. The maximum likelihood estimation of the Tobit model yields consistent estimators in the presence of data censoring if the errors are normally distributed. However, non-normality and heteroscedasticity results in the Tobit estimators being inconsistent (McDonald and Nguyan 2015). Therefore, normal distribution and homoscedasticity assumptions are important assumptions that need to be checked and satisfied in the Tobit model. For this sake the White's heteroscedasticity-consistent standard errors or robust estimation of the Tobit model is used. In addition, normal distribution of the error term in the model was checked and satisfied as presented in the appendix.

The likelihood ratio chi-square of 264.88 (df=11) with a p-value of 0.000 (in the non-robust Tobit estimation case, not presented in the chapter) and the overall F-test, F (11,312) with a p-value of 0.000 in the robust Tobit estimation case shown in Table 5.5 tells us that our model is overall significant. Moreover, the correlation between the predicted and observed values of the dependent variable off-farm income share is 0.739. Squaring this value gives the multiple squared correlation that indicate predicted values share about 55 percent of their variance with the observed off-farm income share. All these shows the goodness of fit of the Tobit model employed here.

Table 5.5: Estimation from a Tobit model

Variables	Coefficient	Robust Standard error	Marginal effect (d_y/d_x)	t- value
D	0.090***	0.021	0.052	4.350
V	0.086***	0.017	0.049	5.110
Gender_head	0.014	0.020	0.008	0.690
Age_head	0.004	0.007	0.002	0.540
Agesq_head	-0.00004	0.00006	-0.00002	-0.620
Litracy	0.047**	0.025	0.027	1.870
HH_size	-0.004	0.006	-0.002	-0.670
Farm_size	0.021***	0.006	0.012	3.54
Off-farm_skill	0.022	0.016	0.012	1.380
Rural_infrastructure	0.063***	0.016	0.036	3.840
Irrigation	0.060***	0.017	0.034	3.580
Constant	-0.355**	0.173		-2.050
No. of observations	323	Left –censored observations at off-farm income share ≤ 0		156
		Uncensored observations		167
F(11,312)	34.38	Prob > F		0.000
PseduR^2	2.4636	Log pseudo likelihood		78.68
Dependent variable	*Off-farm income share*			

*, **, and *** shows the statistical significance of coefficients at 10%, 5% and 1% respectively.
Source: Authors calculation using survey data (2018)

Based on the robust estimation result of the Tobit model presented in Table 5.5, climate shock variables, head literacy, farm size, rural infrastructure and irrigation were positively and significantly influences off-farm earnings. While age and gender of household head, special off-farm skill possessed by a household positively but insignificantly affects the share of off-farm income. In this study, it is only household size that negatively but insignificantly affects the dependent variable of the model off-farm income share. The square value of household head age that accounts the life cycle effects indicates that it is only up to a certain age limit that the age of the household is positively influences off-farm income share of rural households in the study area.

The positive and significant effects of climate shock variables on off-farm earnings indicate the less climate sensitivity of the off-farm economy compared to the farming economy; but, it does not mean that climate shock variables were positively contribute for off-farm earnings. Though, it is expected that climate shocks may have direct adverse effect on off-farm earnings its indirect implication on the share of off-farm earnings of rural households in the study area is positive and significant. This is due to the strong direct adverse impact of climate shock on farm income. As farm income decreases due to climate shock, rural households are motivated to diversify into off-farm activities as a copying mechanism and this increases off-farm income and share of off-farm income from the total household income.

Each slope coefficient of the Tobit model indicates the marginal impacts of the corresponding explanatory variable on the latent (desired) off-farm income share of rural households. However, the practical interest is to know the marginal impacts on the actual observed dependent variable of the model off-farm income share of rural households. The marginal impact of explanatory variable on the actual observed off-farm income share is indicated through the marginal effect coefficients of the Tobit model.

Using these marginal effect coefficients, rural households who had anticipated or perceived the occurrence of climate shock earned off-farm income 5 times larger than those who did not anticipated the occurrence of climate shock. Rural households with literate head who enables at least read and write have off-farm income share 3 times higher than rural households with illiterate head. This indicates the importance of awareness creation and education in enhancing off-farm earnings.

A unit (1 tsimad or 0.25 hectare) increase in farm size raises the share of off-farm income by 1.2 percent. Likewise, rural households who practiced irrigation have off-farm income share 3.4 times higher than those who did not have practiced irrigation. Rural households who had relatively easy access to rural infrastructures on average have nearly 4 times higher off-farm income share than those who do not have an easy access for rural infrastructures. These important wealth variables seem to have lesser impact on off-farm income share as they also have important impact on the farm income. Due to their positive impact on farm income their contribution to the off-farm income share is lessen though their contribution to the off-farm earnings is good. In this study it is evidenced that small proportion of rural households in the study area having relatively better wealth, mainly captured by irrigation practice, were diversified into high wage and /or self-employment off-farm activities. As a result, in the Tobit model it is checked that such wealth related variables of the model have positive marginal impacts on the off-farm income share. Demie and Zeray (2016) also found that some capacity variables like education, land, irrigation and adult household members as important factors affecting non-farm earnings of rural households in Eastern Ethiopia. The relatively higher marginal effects from climate shock variables than the effects from wealth variables is the implication of the tendency of many rural households off-farm diversification into low return off-farm activities as a climate shock copying mechanism than utilizing off-farm opportunities in enhancing household income.

5.5 Chapter summary

to examine the effect of climate shock and other potential factors on the likelihood of rural households' diversification, multinomial logit model is employed considering different household groups based on the off-farm activities undertaken. Estimation of a Tobit censored model enable the measure of the influence of the selected explanatory variables on off-farm earnings.

Empirical results from the multinomial logit model confirm that rural households that anticipated climate shock are more likely to diversify into both categories of off-farm activities compared to only farm engagement, though the result seems stronger for low wage and/or self-employment off-farm diversification. The distinction in rural households' diversification decision between the two off-farm diversification categories is better explained by other non-climatic variables of the model. Male headed households, an increase in age of the household head up to a certain limit, head literacy and households' possession of special off-farm skill positively and significantly affects the likelihood of rural households' diversification into the low wage and/or self-employment off-farm activities compared to only farm engagement. Household size has the opposite effect. While wealth related variables, farm size, the relative easy access for rural infrastructures and irrigation practices positively and significantly affects the likelihood of rural households' diversification into the high wage and/or self-employment off-farm activities compared to non-off-farm diversification. The Tobit model correspondingly revealed that climate shock variables, head literacy, farm size, rural infrastructure and irrigation were positively and significantly influences off-farm earnings. Though rural households have tendency to off-farm diversification as climate sock copying mechanism; the current status of off-farm economy in the study area is very low with minimum participation rate, diversification index and return.

From the findings, the study concludes that climate shock and other determinants have different effects on rural households' diversification decision and earnings among the identified mutually exclusive categories of off-farm activities. Climate shock is the dominant push factor for rural households' to participate into the low wage and/or self-employment activities; whereas, wealth or capacity related variables are most responsible for rural households diversification into high wage and/or self-employment off-farm activities. Most off-farm participant rural households' in the study area took the sector as climate shock copying mechanism. The sector was also confirmed as less climate sensitive than the farming sector. Considering lack of capacity as important constraint for off-farm participation and earnings; capacity development for rural households in rural infrastructure services like finance, education, training, technology transfer and promoting working culture, road and transport, electricity that enable to solve the supply side constraints of the off-farm economy and benefits the agriculture sector simultaneously should be provide. Working on the demand side constraints through awareness creation on the importance of off-farm goods and services, providing market networks for off-farm goods and services, strengthening rural-urban linkages and establishing rural towns is also indispensable.

Moreover, the growth of off-farm economy is indispensable for achieving current policy targets of overall rural development, reducing the urban-rural income differentials and increasing rural youth job employment creation in Ethiopia. Without promoting off-farm economy such policy targets are unattainable. Policy level recognition should require for the overall growth of off-farm economy and to make it a sustainable means of climate shock adaptation strategy. This study contributes a specific examination of climate shock effects on off-farm diversification and earnings taking a disaggregated look on off-farm economy into mutually exclusive categories of high wage and/or self-employment and low wage and/or self-employment off-farm activities. It is also important to investigate its linkage to the farming sector.

Chapter 6

Farm and off-farm economy linkages in rural Ethiopia: *A synergy or a trade-off?*

6.1 Introduction

Rural dwellers had both farm and off-farm income opportunities. However, there was a strong perception that rural households in developing economies are engaged exclusively on farming. This perception has resulted rural development policy which entirely seems agricultural development policy that concentrates on farming and neglects the relevance of the rural off-farm sector. In fact, the role of pure agriculture was undeniable; it is the source of livelihood for more than three- fourths of the global rural population (Alstou and Paradey, 2014). However, since early 1980's rural development policies are transformed so as to recognize the rise of a differentiated rural economy in which the rural off-farm economy plays an increasingly important role (Udin, 2015). The decline in the overall carrying capacity of the farming sector and the resulting persistent and deepening rural poverty due to climate shock and the related environmental degradations coupled with population growth are some of the reasons that initiated policy transition.

Nowadays, increasing numbers of evidences are showing that the contribution of off-farm economy is not trivial. Off-farm income share was estimated to be about 35 percent in Africa and about 50 percent in Latin America and Asia (Haggblade et al., 2007, 2010). It also accounts for 10 percent of the full time rural employment in Africa and 30 percent in Asia (Haggblade et al., 2007; Davis et al., 2010) and too more part-time rural employment (Winters et al., 2009). Besides to these cross country studies that attempted to show the income and employment contribution of the rural off-farm sector there are several theoretical and empirical literatures that examined the effects of off-farm economy on rural welfare, poverty and inequality (De Janvry et al., 2005; Babatunde and Qaim, 2010; Owusu et al. 2011; Scharf and Rahut, 2014; Shehu and Sidique, 2014; Akaakohol and Aye, 2014; Seng, 2015; Kowalski et al., 2016). They inferred the potential of rural off-farm economy to sustain rural livelihood. However, the sector did not yet get enough policy attention.

Beyond recognizing the relevance of the sector, what matters in CCA is enabling to account its interaction with the farm sector. The ultimate climate change adaptation role of off-farm economy will depend on its effect upon the farming economy. Theoretically there are two possible linkages in between farm and off-farm economies - complementarity and substitutability. If they are complementary each other the CCA role of the off-farm sector is substantial. In this case, rural development policy is recommended to strongly promote the untapped off-farm economy and focus on maximizing the synergy between the sectors. However, if they are competing or substitutable each other the CCA role of the off-farm sector is minimal. Therefore, rural development policy should be designed and implemented in a manner that enables minimizing the trade-offs between the sectors. Moreover, the linkage between these sectors is dynamic over time and across spaces which makes easily adoption of cross country experiences problematic (Nasir and Hundie, 2014).

Only few studies were examined the linkage between off-farm and farm sectors (Kilica et al., 2009; Pfeiffer et al., 2009; Gebregziabher et al., 2012; Egyei and Adzovor, 2013; Babatunde, 2013; Nasir and Hundie, 2014). The available studies found mixed results - some evidenced a complementary linkage while others found competing effects. The possible competing linkage is farm labour transfer to the off-farm sector. However, an ultimate effect of the shift of farm labour to off-farm sector on farm production is governed by the amount of farm land, farm labour and other agricultural employments available in the rural labour market. If there is surplus labour then the loss of labour in the farm as a result of non-farm diversification can be easily substituted and have no negative effect on farm production. Here it is important to note the Lewis (1954) dual sector model which shows the possibility of rural transformation through labour transition from the subsistent farming sector to the off-farm sector (the way to capitalist sector) without any cost in the agricultural sector. Under this circumstance off-farm diversification by some members of the rural household will not reduce agricultural production as the remaining household members will enough to efficiently cultivate the available farm land.

Therefore, the empirical examination of farm and off-farm economy linkages through explicit evaluation of the effect of off-farm diversification and the resulting off-farm income on the farm one is indispensable. This will help to take a side from the available conflicting results. It also enable to confidently suggest a need for policy directions that recognize off-farm diversification as important CCA option and promote rural off-farm economy at large. Having limited related works and their conflicting results, this study aims to examine the effect of off-farm diversification and the resulting off-farm income on the farm sector income in South Gondar zone of Amhara region of Ethiopia using a cross-sectional rural household data collected from 323 farm households. The remaining part of the chapter is structured as follows. Theoretical backgrounds and empirical literatures regarding farm and off-farm economy linkages are presented in the next section. Section three provides study methodology. In section four estimation results are presented and discussed, followed by conclusion and policy implication.

6.2 Data and econometric model specification

6.2.1 Data

The goal of this study is to investigate the linkage between farm and off-farm economy so as to confidently suggest off-farm economy as a CCA option. A detailed description of the data used in the study is presented in Table 6.2. The data is collected through household survey using a structured questionnaire conducted during the period December, 2018 to January, 2019. The sample involves 323 rural households selected from ten villages located in four districts in the zone using multi- stage sampling technique. The survey collects information regarding farm and off-farm activities, farm and off-farm income, demographic and socioeconomic characteristics, farm characteristics, rural infrastructure and climatic conditions.

The majority of rural households in the study area are engaged in subsistence agriculture. Though, Ethiopia follows Agricultural Development Led Industrialization (ADLI) as economic development strategy for a long period, economic transformation is not yet realized. Ethiopia remains least urbanized and least industrialized with more than 80 percent rural population and about three-quarters of agricultural employment (Schmidt and Bekele, 2016). Though, push factors like agro-climatic shocks have lead rural households to diversify in to off-farm activities, very low proportion of the rural households have participated yet. The rural off-farm participation rate in the study area is low. Almost 50 percent of the sampled rural households are not diversified into any rural off-farm activity. Even, from the participants almost 33 percent are participated into low wage &/or self-employment rural off-farm activities including food for work program designed by the government. It is only 19 percent of sampled rural households are engaged into high wage &/or self-employment rural off-farm activities that generates relatively better amount of household income. Moreover, rural off-farm diversification index in the study area is very low. On average an off-farm participant household is engaged in only one off-farm activity in the study area. For off-farm diversified rural households in the study area average share of off-farm income from the total household income is only about 15 percent. When we look it separately for rural households diversified into 'low wage and/or self-employment' and 'high wage and/or self-employment' off-farm activities it was 10 percent and 24 percent respectively.

Table 6.1: Some key characteristics of sample households

Variables	Freq.	Percent	Mean	SD	Min.	Max.
Rural household income (in ETB)	---	----	44058.09	26068.69	12500	169400
Farm income (in ETB)	---	---	38209.30	16243.15	12500	101640
Off-farm income (in ETB)	---	---	5848.80	10449.35	0	67760
Participation in off-farm activities	167	51.70	---	---	---	---
Farm only (non-diversified)	156	48.30	---	---	---	---
Low wage and/or self-employment	106	32.82	---	---	---	---
High wage and/or self-employment	61	18.89	---	---	---	---
Off-farm income share	---	15	---	---	---	---
Farm only (non-diversified)	---	0	---	---	---	---
Low wage and/or self-employment	---	10	---	---	---	---
High wage and/or self-employment	---	24	---	---	---	---
Total sample for the study	323	100	---	---	---	---

Source: Authors calculation based on survey data

Table 6.2: Descriptions of variables used in the analysis

Variable	Description	Mean	SD
Dependent variable			
Lfarm income	Log of the average value of household farm income in Ethiopian Birr (ETB)	10.465	0.416
Independent variables			
Off-farm income	Amount of income that a household derives from off-farm activities in a year in ETB	5848.80	10449.34
Off-farm diversification	Dummy 1 if a household diversifies in to off-farm activities otherwise 0	0.517	0.501
Lnfarm_size	Log value of the farm land holding size of a household in Tsimad (1 Tsimad= ¼ Hactare)	1.536	0.295
Lnfarm_labour	Log value of the amount of labour used in the farm production	1.589	0.167
Lnfarm_expenditure	Log value of the amount of money spent for farm input expenditure in ETB	8.120	0.707
Irrigation	Dummy 1 if the household engaged in irrigation 0 if not	0.170	0.479
Cash_crop	Dummy 1 if the household cultivates cash crop for the market 0 if not	0.331	0.471
Climatic_variability	Dummy 1 if the household suffered from harvest damages due to abnormal and erratic rainfall variability, flood, and epidemics 0 if not	0.550	0.490
Age_head	Years of household head	48.3	10.99
Gender_head	1 for male headed household and 0 female headed	0.77	0.42
Head_literacy	1 if the head can read and write and above, 0 if not or illiterate or cannot read and write at least	0.31	0.48
Instruments			
Electricity	Dummy 1 if the household have access for electricity 0 if not	0.328	0.470
Off-farm_skill	1 for those with transferable skill for off-farm activities, 0 otherwise	0.346	0.476
Town_proximity	The distance from the home of the household to the nearest market town in kilometre	15.149	5.591
Adult_schooling	Average years of schooling of other adult household members in the household excluding the head of the household	3.520	2.526

Source: Authors calculation based on survey data

6.2.2 Econometric model specification and estimation techniques

To assess the effects of off-farm engagement and the resulting off-farm income on the households' farm income, the following farm production model is specified:

$$Y_i = \alpha_0 + \beta_i X_i + \delta_i H_i + \mu \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots 6.1$$

Where Y_i is farm income of the ith household, X_i is the variable of interest off-farm income of the ith household or a dummy for off-farm participation of the ith household representing one, if the household participates in off-farm activity and zero otherwise (in separate models), δ_i is the parameter of the ith explanatory variable H_i and μ is a random error term. β_i is the key parameter of interest that captures the effects of off-farm income and off-farm participation on farm income (in separate models). A significant positive value of β_i indicates the complementarity between the two sectors and thus a need to promote off-farm economy and maximizing its positive synergy with farming sector and vice versa. H_i includes observable farm and household characteristics those are expected to affect household farm income. The inclusion of these observable farm and household characteristics is helpful to control the systematic differences between off-farm participated and non-participated households. To estimate Equation (6.1) the explanatory variables should be exogenous. However, the bidirectional relationships between the two sectors lead the variable of interest, off-farm income or off-farm diversification, endogenous to the model. The household farm income depends on household's off-farm participation, and on the other hand access to off-farm income depends on the level of farm income. This makes X_i endogenous and the OLS estimate of coefficient β_i biased and inconsistent (Kilic et al., 2009; Babatunde, 2013). In order to tackle this endogeneity bias, the study uses an instrumental variable (IV) approach. This approach helps to isolate exogenous variation in off-farm income.

The IV approach is implemented using a two stage least squares (2SLS) estimation technique. 2SLS – IV requires appropriate instrumental variables (Z_i) that are uncorrelated with the error term or have no partial effect on farm income and uncorrelated with factors affecting farm income but very much correlated with the endogenous explanatory variable off-farm income. In the first stage, X_i is written as a linear function of the instruments and control variables.

$$X_i = \beta_0 + \beta_i Z_i + \delta_i H_i + \nu \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots 6.2$$

Estimating Equation (6.2) gives the fitted value $\hat{X}_i$:

$$\hat{X}_i = \hat{\beta}_0 + \hat{\beta}_i Z_i + \hat{\delta}_i H_i \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots 6.3$$

This isolates the exogenous component of off-farm income to be used in the second stage regression as regressor to estimate the parameter of interest shown as in Equation (6.4).

$$Y_i = \lambda_0 + \lambda_1 \hat{X}_i + \delta_i H_i + \mu + v \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots 6.4$$

The second stage OLS regression gives unbiased estimates since the composite error term $\boldsymbol{\mu} + \boldsymbol{v}$ has zero mean and is uncorrelated with $\boldsymbol{\hat{X}_i}$ and $\boldsymbol{H_i}$. Therefore, the quality of 2SLS estimation depends on instruments. Finding appropriate instruments is not easy. The best instruments are selected based on strong theoretical grounds. In this case, important factors that determine rural households' off-farm diversification but have no direct impact on their farm are considered. Accordingly, access for electricity, possession of special off-farm skill, town proximity and adult years of schooling are taken as instruments. Good instruments should be both valid (uncorrelated with the error or instrumental exogeneity) and relevant (correlated with the endogenous covariate off-farm income). The validity and relevant of instruments are checked using the over identifying restriction test and the significance of the instruments in the first stage IV regression respectively. Taking off-farm diversification as a binary endogenous explanatory variable the treatment effect model is employed as another model to show the effect of off-farm diversification on household farm income. Taking the logarithmic value of variables in the model except dummies and off-farm income due to its zero value for the rural households that are not participated in off-farm activity, Cobb-Douglas production function is employed as it gives elasticity or marginal productivities of farm inputs which are easy for interpretation in economic terms.

6.3 Results and discussion

6.3.1 Descriptive statistics

The mean difference in household and farm characteristics between off-farm diversified and non-diversified rural households is shown in Table 6.3. On average off-farm diversified rural households have significant higher values for most of the household and farm characteristics than non-diversified households. Though, relatively poor rural households have a tendency to engage into low return off-farm activities as a means of survival and better-off households in to high return off-farm activities; it seems that off-farm diversified rural households on average are significantly better endowed in household income, farm income, farm size, family farm labour, irrigation and electricity accesses. This will indicate that better resource endowment by a household may not prevent them from off-farm diversification instead helps them to participate into high return off-farm activities. Off-farm diversified rural households on average tend to be male headed and have about 14 years older household head than the non-off-farm diversified rural households. This indicates that age of the household head may serve as an experience that helps them to participate in to off-farm activities. Older rural households have relatively larger number of adult household members that will participate in to off-farm activities. Moreover, the mean difference test also indicates that off-farm diversification requires households to have a literate head, a better in adult years of schooling and special off-farm skill. Off-farm diversified rural households also have larger farm input expenditure and practiced cash crop production than the non-diversified households. Differences in climatic variability that shows the pre and post-harvest damages caused by abnormal and erratic rainfall variability, flood, and epidemics is not significant indicates that climate shock is a covariate risk which is common for all rural households. Likewise, mean difference in town proximity between two groups is insignificant though the less in the town proximity the household seems non-diversified in to off-farm activities. Therefore, this descriptive statistics suggests the positive association between off-farm and farm sectors of the rural economy. This positive association between the two sectors will be further examined in detail using empirical analysis.

6.3.2 Econometric results

The endogeneity of off-farm income and off-farm diversification was checked using the Durbin Wu-Hausman test. The Durbin Wu-Hausman test clearly rejected (p=0.028) and (p=0.031) the exogeneity of off-farm income and off-farm diversification; indicating these variables are indeed endogenous, so that the IV approach is appropriate.

The endogenous explanatory variable off-farm income was controlled using four instruments namely, adult years of schooling, possession of special off-farm skill, access to electricity and town proximity. Theoretically, these variables are important for off-farm diversification but very unlikely to affect the farming sector. With respect of these instruments, the off-farm diversified rural households have better value than the non-diversified as shown in the Table 6.3.

Table 6.3: Mean differences of model variables between diversified and non-diversified rural households

Variable	Households not diversified in to off-farm activities (N=156)	Off-farm diversified households N=167	T-test mean difference
Household income	26421.19	60533.29	-15.998***
Farm income	26421.19	49220.95	-18.076***
Farm size	3.862	5.787	-14.773***
family farm labour	4.769	5.150	-4.443***
farm input expenditure	2206.09	6090.12	-18.228***
Irrigation	0.064	0.623	-13.159***
Cash crop production	0.051	0.593	-12.879***
Climatic variability	0.795	0.210	12.927
Agehhh	40.032	54.443	-12.729***
Genderhhh	0.571	0.868	-6.249***
Head literacy	0.327	0.922	-13.831***
Instruments			
Electricity	0.006	0.629	-16.359***
Special off farm skill	0.224	0.461	-4.625***
Town proximity	19.628	10.964	21.986
Adult years of schooling	1.942	4.994	-13.993***

*** Statistical significance at 1 percent

A two stage least square (2SLS) regression using instrumental variable estimator allows for both the first and the second stage results simultaneously. The first stage regression results are necessary to check instrumental exogeneity and the relevance of instruments. Our main interest is on the second stage regression results which consists the significance level and sign of the coefficient of the variable of interest off-farm income.

The first stage regression result is shown in the second result column of Table 6.4. It shows that instruments are very relevant as all the instruments except town proximity are statistically significant. Instruments are correlated with the endogenous explanatory variable off-farm income. As expected, adult years of schooling, possession of special off-farm skill and access to electricity affects off-farm income positively and significantly. Similarly, town proximity which creates market opportunity and reduces transaction costs plays an important but insignificant role in off-farm diversification. The nearest the distance to town, it is the higher the possibility to diversify into off-farm activities and the better the off-farm income. These results are consists with some previous studies that focus on the determinants of rural households' off-farm participation decisions (for example,., Bezu and Barret, 2010; Demeke and Zeller, 2012; Babatunde, 2013; Demie and Zeray, 2016). Other coefficients of the first stage regression will show the determinants of off-farm income. However, these coefficients are less important as OLS is not an appropriate estimation technique for the determinants of off-farm income. This is due to the censored nature of the sample in which information on off-farm income is not available or zero for non-off-farm diversified rural households. Moreover, the Hansen's J chi-squared over identification test is used to look at the validity of instruments. The null of this test is that instruments are jointly valid. As shown in Table 6.4, the Hansen's J chi-squared is insignificant (P = 0.246), indicates that instruments are valid. The Weak instrument-robust inference test was also highly significant revealing the strength of the instruments used in the model and the strong correlation between the instruments and the endogenous explanatory variable off-farm income.

The result of second stage IV regression is shown in column (3) of Table 6.4. The simple OLS regression result is also available for comparison in column (1) of the same Table. The coefficient of off-farm income from the second stage regression that we are interested on is significant and positive. It shows that off-farm income affects the farm income positively and significantly. As per the finding each additional 10,000 ETB of off-farm income increases the farm income of the rural household by about 7 percent; while, in the OLS estimation, the effect is only 5 percent which is a downward biased. The result revealed that off-diversification by rural households and then generating off-farm income complements with their farm income rather than competing. It is consistent with the findings of Gebregziabher et al. (2012) in Tigray regional state of Ethiopia, Ercolani and Wei (2010) in China and Babatunde (2013) in Nigeria. This empirical finding also reinforces the descriptive statistics presented in Table 6.3 that indicates the higher mean value of farm income for off-farm diversified rural households than the non-off-farm diversified rural households. Though positive and significant, the magnitude seems lesser as the off-farm sector is at its infant stage with low participation rate, low diversification index and low return. This may also due to some rural households that did not reinvest their off-farm income in their agricultural activities instead leave out from agriculture. Big investment to widen further the scope and scale of agriculture is not common in rural households having capacities. The lowest but positive and significant impact will indicate more efforts are required to promote the growth of off-farm sector and the positive linkage between these sectors. Efforts are also required to aware rural households to invest their income to widen the scope and scale of their agriculture and not to leave out from the agriculture sector without having better alternative. When we look the effects of other control variables farm size, family farm labour, farm input expenditure, irrigation, and head literacy have significant positive effect on farm income. While, cash crop production, gender and age of the household head have insignificant positive effects on farm income, it is only climatic variability that affects rural households' farm income negatively and significantly.

Farm size has the highest farm income elasticity followed by farm input expenditure. A 10 percent increase in farm size, leads to a 3.8 percent rise in farm income. The elasticity of farm income with respect to farm input expenditure is 0.28. Though, farm income elasticity with respect to family farm labour is not negative or zero unlike the Lewis (1954) argument of surplus farm labour, it is relatively smaller compared to other elasticity in the model. A 10 percent increase in family farm labour brings only 1.4 percent increment in farm income, ceteris paribus. The complementary linkage between farm and off-farm sector due to the significant positive effect of off-farm income on farm income in the presence of a positive marginal productivity of farm labour shows the existence of surplus farm labour that will further enhance the productivity of both farm and off-farm sectors. Following the Lewis (1954) argument of surplus farm labour, Sen (1966) argues that surplus labour may exist even at positive marginal productivity of labour. This finding clearly indicate the fact that in rural areas, in which land holding is very small and farming is seasonal, there is enough rural farm labour that can participate in both farm and off-farm sectors for the growth of each sectors. Improving the working culture of rural farm labour and providing awareness's and other opportunities will enable to utilize the capacities of the rural farm labour for the growth of both farm and off-farm sectors and their positive linkage and rural development at large.

Table 6.4: 2SLS estimation results

Variables	(1) OLS Lfarmincome	(2) 2SLS: 1st stage Off farm income	(3) 2SLS: 2nd stage Lfarmincome	(4) Treatment effect model Lfarmincome
Off farm income	5.09e^{-06}*** (6.580)	---	6.86e^{-06}*** (6.110)	---
Off-farm diversification	---	---	---	0.047*** (3.190)
LFarm size	0.425*** (10.550)	12535.310*** (6.040)	0.378*** (8.330)	0.565*** (15.720)
Lfamily farm labour	0.123*** (3.970)	-4866.329*** (-2.890)	0.143*** (4.470)	0.069** (2.270)
Lfarm input expenditure	0.281*** (18.810)	-1120.701 (-1.320)	0.284*** (19.090)	0.254*** (15.640)
Irrigation	0.051 (0.340)	560.370 (0.690)	0.013* (0.090)	0.010 (0.640)
Cash crop production	0.026 (1.570)	419.811 (0.460)	0.023 (1.390)	0.036** (2.140)
Climatic variability	-0.039*** (-3.240)	279.396 (0.430)	-0.041*** (-3.420)	-0.026** (-2.110)
Agehhh	0.001** (2.100)	95.429*** (2.970)	0.001 (1.360)	0.003*** (4.260)
Genderhhh	0.006 (0.570)	-562.458 (-0.940)	0.007 (0.700)	0.004 (0.310)
Head literacy	0.026** (2.020)	-1465.259** (-2.050)	0.030*** (2.390)	-0.001 (-0.030)
Instruments				
Electricity	---	51.347* (0.060)	---	---
Special off farm skill	---	1040.563** (1.920)	---	---
Town proximity	---	-23.721 (-0.250)	---	---
Adult years of schooling	---	2500.199*** (14.440)	---	---
Constant	7.235*** (77.950)	-8334.357 (-1.250)	7.259*** (78.330)	7.275*** (72.450)
R^2/ $adj\ R^2$	0.968 / 0.966	0.854 / 0.848	0.967 / ---	--- / ---
No. of obs. 323	F(10,312) =942.690, Prob>F =0.000	F(13,309) =139.450, Prob>F =0.000	Wald $\chi^2(10)$ =9589.71 (0.000)	LogLL= 351.651 Wald $\chi^2(10)$ = 8809.55 (0.0000)
Test of endogeneity (H_0: Variables are exogenous)				
Durbin (score) χ^2(1)	4.781** (p = 0.028)	Wu-Hausman F(1, 311)	4.672** (p = 0.031)	
Test of validity of instruments				
H0: instruments are weak	Robust F(4,309)=20.636, p = 0.000			
Test of over identifying restriction:				
Hansen's J χ^2(3)	4.147, p = 0.246			

Figures in bracket are t- values. *, ** and *** refers coefficient statistical significance at 10%, 5% and 1% respectively.

Rural households who practiced irrigation have farm income 1.3 times higher than those who did not practiced irrigation. Likewise, rural households with literate head who can at least read and write will have farm income 3 times higher than rural households with illiterate head. On the other hand, rural households that seriously suffered from pre and post-harvest damages caused by abnormal and erratic rainfall variability, flood, and epidemics have farm income 4.1 times lower than rural households that control these climatic problems in advance. This indicates that agro-climatic shocks are critical challenges for the farm sector. Improving variables that are in favour of the farming sector like off-farm diversification helps rural households to generate alternative off-farm income and enhancing farm input expenditure which will in turn help to offset the farm income reduction due to agro-climatic shocks. To examine the effect of off-farm diversification on household farm income considering off-farm diversification as a binary endogenous explanatory variable the treatment effect model was employed. The result from this treatment effect model shows that off-farm diversified rural households have farm income 4.7 times higher than those who did not diversified into any off-farm activity.

6.4 Chapter summary

It is evidenced that off-farm diversification by rural households and the resulting income have a significant positive effect on the households' farm income. Therefore, these two sectors are complementary each other. It is possible to confidently suggest off-farm diversification by rural households as an important CCA option and sustainable source of income that enable to sustain rural livelihood. Though, the linkage is positive and significant the magnitude is minimal. This is due to the common trend that the better-off rural households are reinvested their farm and off-farm income out of the rural economy instead of expanding the scale and scope of their farming further. Unless additional effort is not done to invest the bulk of rural income in the rural economy, rural development cannot be easily inevitable. Therefore, much greater efforts are required to make these positive association or complementary linkage strong and sustainable. Though the MPL in the farming sector is positive and significant the complementarity between the two sectors is implied by the study; surplus labour may exist even MPL is positive. Further studies should explicitly examine the channels in which the off-farm economy positively affects the farm economy.

Chapter 7

Conclusion and Policy Implications

7.1 Important findings

The thesis broadly focuses on climate change impact and adaptation considering the Ethiopian economy that is second most populous nation in Africa and one of the fastest growing economy. The thesis aims to fulfil the following:

- Estimate aggregate economic impacts of climate change in Ethiopia over the period 1960-2015
- Investigate the dynamics of household level climate shock vulnerabilities and the role of CCA (vulnerability reduction) in general and the household's off-farm diversification in particular
- Identify factors affecting the growth of rural off-farm sector as a potential CCA strategy
- Examine the rural off-farm and farm economic linkages to support the assumption that rural off-farm diversification is in fact an effective CCA strategy.

These objectives have been achieved as presented in chapters, three, four, five and six of the thesis. The empirical evidences in the Ethiopian case supports the adverse impact of climate change on the economy at the aggregate level. Furthermore, unless the observed climate change induced impacts are adapted and mitigated systematically, the cost to the economy may worsen in the future. The adverse climate change related impacts have rendered development efforts unsuccessful or short of fulfilling the desired goals. Climate change, in the thesis have been considered as the observed changes in *rainfall*, *temperature* and CO_2 *emission (one of the main components of the GHGs)*. These have statistically significant impact on the performance of the Ethiopian economy. A strong causality flows from such observed changes in climatic variables to economic variables. Taking into cognizance the empirical results, the country requires identification and implementation of adaptation strategies for reducing the negative impacts of climate change. However, this thesis do not directly delve into the identification of alternative adaptation strategies those may be suitable for the country.

Aggregate indicators are often helpful in reaching national consensus regarding climate actions. As countries participate in various negotiations to reduce their contribution and in return, exposure to climate change related risks, the earlier step may further strengthen commitments. The challenge is to consider possible circumstances that may make local systems particularly vulnerable to climate shock. Vulnerability and adaptation are local or regional specific dynamic characteristics that vary across space and temporal scales. Effective adaptation measures depends on thorough understanding of the local community characteristics and evaluation of interests of those seemingly vulnerable, apart from a rigorous understanding of the locale environment. In this backdrop, local specific rural household level vulnerability assessment was undertaken to supplement the results from the aggregate economic impact analysis and to make it further practical for policy intervention.

The rural household level assessment examines few practical policy relevant questions such as, who are the local vulnerable groups. Are the groups of rural households equally exposed and vulnerable? The extent the households and communities at large are vulnerable and affected? What is their ability (preparedness) to withstand shocks and their sensitivity and exposure to climate shocks? What factors would determine their vulnerability? In particular, it examines the CCA or vulnerability reduction role of the untapped rural off-farm sector. Economic linkage between the off-farm and farm sectors is also examined for more robust result on the CCA role of off-farm diversification. The final exercise was to identify the factors associated with the overall growth of rural off-farm sector.

The observations from our field survey corroborate largely with the extant literature that the rural farm households that relied on the traditional rain-fed agriculture are highly vulnerable to climate change due to their disadvantaged socio-economic and demographic conditions and poor adaptive capacities. Vulnerability difference among the rural off-farm diversified and non-diversified rural households is also noteworthy. Rural off-farm activities help the participants to develop and/or enhance climate resilience that would lessen their sensitivity and vulnerability to the exogenous covariate climate shocks. Therefore, the study recommends rural off-farm diversification as one of the possible CCA option.

Promoting the growth of rural off-farm activities, better irrigation facilities, improvements in access to water, health and other rural-infrastructure should be prioritized and recognized as best intervention strategy to reduce rural households’ vulnerability to climate shocks in the study area, selected districts of South Gondar Zone in the Amhara region. Priority should be to improve rural households' climate change adaptive capacity as an effective pro-active strategy in place of the usual reactive relief oriented strategy. Policy interventions ideally should be based on the socio-economic and demographic characteristics, more so to make policies inclusive for relatively marginalized groups.

This thesis supports the view that climate shocks increases the likelihood of rural households' off-farm diversification. Further, rural households anticipating climate shock are more likely to diversify into off-farm activities. The distinction in rural households' diversification decision between the two mutually exclusive categories of off-farm activities is explained by other non-climatic variables of the model. Climate shocks is the dominant push factor. Most off-farm participant rural households' took the sector as a copying mechanism. The sector too seems less climate sensitive than the traditional farm sector. The determinants of off-farm diversification consistently affect off-farm earnings. Considering lack of capacity as an important constraint for off-farm participation and related earnings, the rural households' capacity development through enhanced rural infrastructure, irrigation facilities, awareness creation for sustainable and climate smart farming, timely weather information, education and training on off-farm skills, among others; may promote the overall growth of the off-farm economy without hurting the growth and importance of the farm sector seemingly at risk.

The important implication is the presence of significant positive association or complementary linkages between the farm and the off-farm sector. These enable framing suggestions that off-farm diversification by rural households is an important CCA option and a sustainable source of income that could secure rural livelihood. Further, there is a possibility to promote the off-farm sector without any cost on the farm sector. Rural development is inevitable through focusing and working on the positive synergy between the farm and the off-farm sectors, instead of concentrating only on the farm sector. Though the linkage is positive and statistically significant, the magnitude is however small. This is probably due to the common trend that better-off rural households are re-investing their off-farm income out of the rural economy instead of expanding the scale and scope of their farming activities. Unless additional efforts are directed to undo the low investments, large proportion of rural households' incomes may remain low. Therefore, greater efforts are necessary and required to make these positive associations and/or complementary linkage strong and sustainable; at the same time to enhance the CCA capacity of off-farm diversification by rural households.

7.2 Policy recommendations

In general, climate change reportedly intensifies poverty, income or economic inequalities and the adaptive capacity differences across households and regions in a country. The two key macroeconomic policy challenges, namely growth and equality, are complicated by climate change. There must be a practical consensus and commitment from the individual to the global stakeholders on the urgent need for climate action. The strong unidirectional causality flows from the observed changes in climatic variables to Ethiopian economic performance indicates that climate change and the subsequent shocks in Ethiopia might be due to the externality from the global climate change rather than induced within or due to the domestic economic activities. This confirms the argument that developing countries including Ethiopia are suffering disproportionately from climate change though they contribute the least to the problem. Thus, the country should priorities CCA that enables the economy to minimize the adverse externalities of climate change. As a result, domestic policy responses for climate change that significantly hinders domestic economic progress may not be effective. CCA policies that may help economic progress in parallel are desirable to build effective CCA capacity. However, this thesis has not explored the question of most efficient and effective climate adaptation strategy thereby leaving a gap that may be explored by/in future research.

Development efforts that are environmentally and ecologically unfriendly and incapable to adapt and fail to minimize the adverse externalities due to climate change are not successful. The scenario now had changed. For example. Ethiopia could not achieve economic advancement at the cost of the environment. Therefore, CCA and mitigation strategies should get priority and be in place in a better attention than before. Development efforts would fail to yield better outcomes unless CCA is prioritized. The Climate-Resilient Green Economy (CRGE) strategy shall be mainstreaming in every aspects of the economy and relevant stakeholders should implement it in detail. In addition, Ethiopia should continue active participation in climate change negotiations at the global level and imbibe successful policy initiatives. Since climate change is also a natural phenomenon, not only human induced; improving the overall climate change adaptive capacity of the economy is also compulsory to manage the adverse impacts of climate change. Improving the overall CCA capacity of the national economy requires understanding the local level climate change vulnerabilities and effects.

As rainfall variability is the most influential factor, few measures such as encouraging production using rainwater harvesting and improved water use efficiency, enhancing ground water conservation activities are equally important. All other adaptation measures should be identified, and their scientific utility studied; subsequently utilized depending on the locale context. For example, research supports that diversification into a less climate sensitive rural off-farm economy is also advisable. Even though rural off-farm economy has importance in sustaining the rural livelihoods, the sector is not recognized nationally and rural farmers are not adequately informed.

The review of literature and policy papers indicate that climate change adaptive capacity of Ethiopian economy is low. As already highlighted, the dominant economic sector, agriculture, is traditional, subsistent and vulnerable to climate change impacts. If the climate change adaptive capacity of the economy is improved, Ethiopia may have a comparative advantage in the region. Therefore, improving agriculture, policies targeting efficient utilization of indigenous knowledge, exploitation of off-farm skills existing within the indigenous rural farm households for CCA, and in general, promoting the rural off-farm sector assumes importance in managing climate related problems. Scaling up the best practices in few rural households to other marginalized rural households through structured policy attention such as using vital resources, land and labour, and improving awareness, should be prioritised.

Policy, financial and promotional supports should be given for the rural off-farm economy from national and local level governments and development institutions. Considering the heterogeneity in the rural off-farm activities, the sector should be integrated and mainstreamed into other related economic sectors. Having a national strategic plan on the rural off-farm economy should be the first step in this regard.

7.3 Limitation and future research

The study, in its climate change impact analysis, only uses the level and variations in the annual rainfall, mean annual temperature and CO_2 emission as manifestations of climate change.

Other aspects of climate change are not taken into account. Cross sectional data on the sample rural households in the selected rural villages of South Gondar Zone of Amhara region is used to the climate change vulnerability assessment. Therefore, future research may aim at analysing the adverse economic impact of climate change considering all the manifestations of climate change and also all the channels through which climate change may affect the economy. The main challenge was to validate the existing secondary data. Data unavailability was one major reason restricting the analysis undertaken to fulfil the first objective. Further, the channels that possibly link off-farm sector with the farm sector should be explicitly examined, this is a gap in the current thesis. The use of longitudinal and panel data to account the dynamic nature of off-farm economy over time is preferable. Finally, time and resources were constraints restricting the study to consider only one Zone in Ethiopia. I would be interesting to analyse how best the results corroborate and/or extend the results through systematic analysis undertaken in other Zones and agro-ecological zones.

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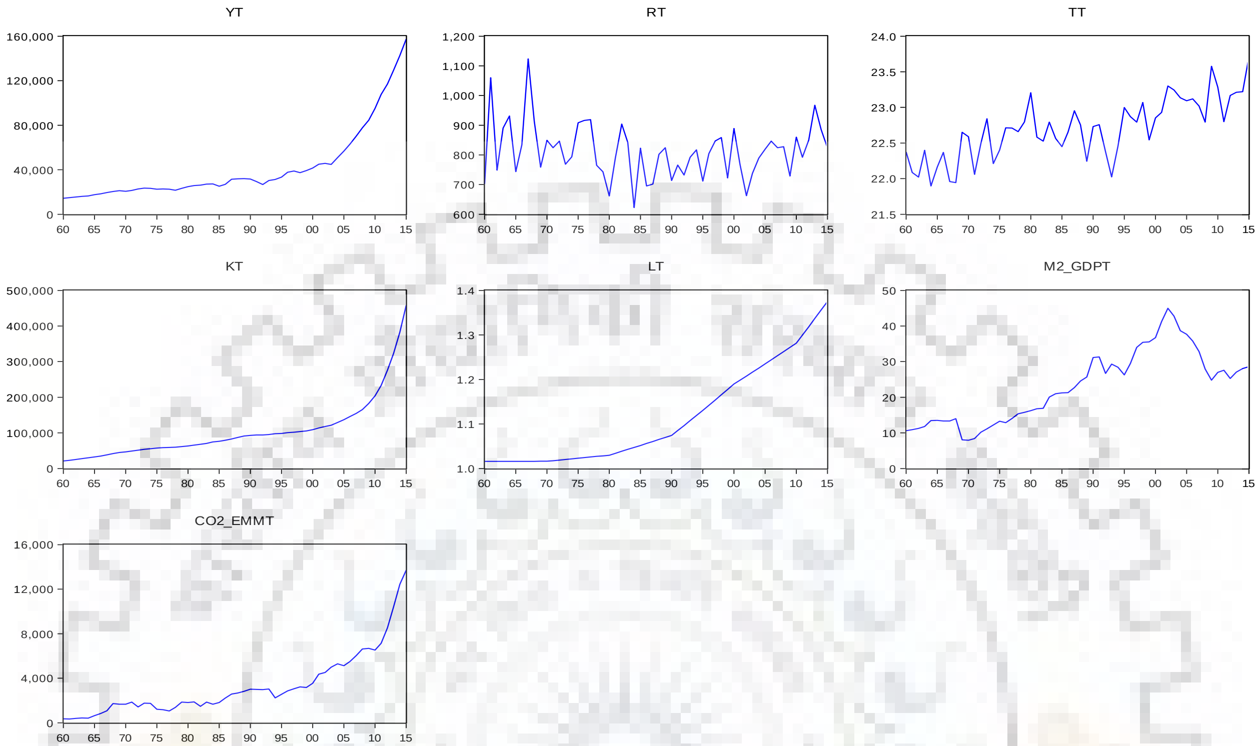
Appendices

Appendix 1A: an overview of selected droughts in Ethiopia for the last 50 years

Drought periods	Seasonal events	Affected areas	Key impacts/effects	Responses
1972-1974	A 30 percent normal rainfall deficit and a 15-30 days delay in the main season rainfall	Tigray, Wollo, north and south eastern areas of the country and pastoralist areas	Water stress, crop damage by pests, a 20 percent reduction in agricultural production, 7.3 million people are affected, 200,000 people died, 30 percent of the livestock perished	Emergency food aid and other humanitarian assistance by the government and aid agencies
1983-1984	A 30 percent normal rainfall deficit in both the short and main rain season and a 15-30 days delay in the main season rainfall	Historic severe drought covering all regions of the country mainly from Tigray and other parts of northern Ethiopia	8 million people affected and 1.2 million dead. GDP falls up to 25 percent (WB, 2006), Water stress, electric rationing, 400,000 refugees outside the country, 2.5 million people internally displaced	Massive emergency food and health assistance, development and rehabilitation work
1991/92	Rainfall failure during the long season	4 million people affected in most parts of the country, Tigray, Afar, Amhara, Somali, Oromia, and SNNP	Food and water shortage, water and electricity rationed for cities and towns, large number of animals died	Food aid from the government and aid agencies
2002/3	Rainfall failure in both seasons	About 14 million people in all regions mainly Tigray, Amhara, Afar, Somali are affected	Large number of animals are died in the pastoralist regions	Food aid from the government and aid agencies

Appendix 3A: graphs of variables used in the model



Appendix 3B Descriptive statistics

Variable	YT	RT	TT	KT	LT	M2_GDPT	CO2_EMMT
Mean	41812.09	813.1744	22.69895	104745.1	1.114329	22.89905	3289.366
Median	28316.55	818.1083	22.72160	84859.75	1.062907	23.63500	2401.885
Maximum	157473.9	1123.617	23.71438	458265.2	1.375276	44.96900	13718.25
Minimum	14281.22	622.5764	21.89627	21027.86	1.015876	7.942000	341.0300
Std. Dev.	33415.94	92.44414	0.423552	86301.87	0.109425	10.08851	2893.254
Skewness	1.969257	0.761366	0.036299	2.269955	0.847313	0.293072	1.788811
Kurtosis	6.112789	4.493812	2.530887	8.514336	2.386781	2.012409	6.203988
Observations	56	56	56	56	56	56	56

Appendix 3C: ADF and KPSS unit root tests

Series	ADF H_0: Variable is Non-stationary H_1: Variable is stationary				KPSS H_0: Variable is stationary H_1: Variable is Non-stationary				Highest Order of Integration
	Test statistic		Critical values		Test statistic		Critical values		
	Level	1st Diff.	1 %	5 %	Level	1st Diff	1 %	5 %	
Y_t	-0.206	-9.342*** (0.0005)	-4.144	-3.498	0.218	0.197***	0.216	0.146	$I(1)$
r_t	-6.677*** (0.000)		-3.555	-2.915	0.214***		0.216	0.146	$I(0)$
τ_t	-2.753	-11.677*** (0.000)	-4.141	-3.497	0.098***		0.216	0.146	$I(1)$
k_t	-3.161	-10.009*** (0.000)	-4.148	-3.501	0.254	0.136***	0.216	0.146	$I(1)$
l_t	-2.300	-7.377*** (0.000)	-4.141	-3.497	0.115***		0.216	0.146	$I(1)$
m2_gdp	-1.375	-3.152** (0.028)	-3.563	-2.919	0.180***		0.216	0.146	$I(1)$
co2_em	-3.898	-3.955** (0.016)	-4.137	-3.495	0.101***		0.216	0.146	$I(1)$

Note: *, **, *** denote statistical significance at the 10%, 5% and 1% levels respectively

Appendix 4A: Mean differences of model variables between off-farm diversified and non-diversified rural households

Variable	households not diversified into off-farm activities N=156	Off-farm diversified households N=167	T-test mean difference
LVI	0.440	0.258	52.576***
Drought	0.583	0.880	-6.412***
Climatic_variability	0.795	0.210	12.927
Age_head	40.032	54.443	-12.729***
Agesq_head	1994.628	2887.353	-7.958***
Head_literacy	0.327	0.922	-13.831***
HH_size	6.122	7.059	-5.866***
Farm_size	4.093	5.988	-9.796***
off-farm_skill	0.224	0.461	-4.625***
Rural_infrastructure	0.256	0.749	-10.123***
Irrigation	0.064	0.623	-13.159***
Water	58.654	35.509	8.316***
Health	87.949	57.425	7.854***
Livestock	0.942	0.455	11.099***

*** Mean differences between off-farm diversified and non-diversified rural households are statistically significant at 1 per cent level.

Appendix 4B: Calculating LVI-IPCC for the group of non-off-farm diversified rural households-example

Vulnerability Contributing factors	Major vulnerability indicators	Indexed value for Major vulnerability indicators	No. of sub vulnerability indicators per major vulnerability indicator	Indexed value for the contributing factor	LVI-IPCC for non-off-farm diversified group of households
Exposure	Natural disaster & climate variability	0.62	6	0.62	0.44
Adaptive capacity	Socio-demographic status	0.18	5	0.08	
	Livelihood strategies	0	3		
	Social networks	0	3		
Sensitivity	Food	0.86	5	0.81	
	Water	0.92	5		
	Health	0.54	3		

Step 1- calculating the indexed value of sub and major vulnerability indicators (repeat for all vulnerability contributing factors and for all sample groups)

Example-the indexed values of socio-demographic status and its sub indicators under the adaptive capacity vulnerability contributing factor for the group of non-off-farm diversified rural households

Sub vulnerability indicators for socio-demographic status	Sub indicator value	Max. indicator value	Min. indicator value	Indexed sub-indicator value	Indexed value for socio-demographic status
Inverse of dependency ratio	0.18	0.71	0.10	0.13	0.18
Percentage of household with literate head	16.10	100	0	0.16	
Average age of the household head	43.50	74	28	0.37	
Percentage of household with irrigation practice	12.38	100	0	0.12	
Percentage of household with relatively better rural-infrastructure	12.38	100	0	0.12	

a) Indexed sub-indicator value (let for Average age of the household head) (repeat for all sub indicators)

$$\mathbf{S_{sd}} = \frac{\mathbf{S_{actual} - S_{min}}}{\mathbf{S_{max} - S_{min}}} = \frac{\mathbf{43.5-28}}{\mathbf{74-28}} = \mathbf{0.37}$$

b) Calculating average gives the Indexed value for socio-demographic status= (0.13+0.16+0.37+0.12+0.12)/5=0.18

Step 2- Indexed value for the contributing factor (repeat for all contributing factors and sampled groups)

Example for adaptive capacity

$$\mathbf{CF_{sdi}} = \frac{\sum_{i=1}^{n} \mathbf{W_{Mi} M_{sdi}}}{\sum_{i=1}^{n} \mathbf{W_{Mi}}} = \frac{\mathbf{0.18*5+0*3+0*3}}{\mathbf{5+3+3}} = \mathbf{0.08}$$

Step 3- final LVI-IPCC calculation (repeat for all sample groups)

$$\mathrm{LVI_{IPCC}} = (\mathrm{Exposure_{sdi}} - \mathrm{adaptive\ capacity_{sdi}}) * \mathrm{sensitivity}_{\mathrm{sdi}} = (0.62 - 0.08)0.81 = 0.44$$

Appendix 5A: The Hausman-McFadden test of IIA assumption (N=323)

H_0: Odds (outcome-J vs outcome- K) are independent of other alternatives

Omitted	**χ2**	**Df**	**P> χ2**	**Evidence**
Farm only	0.000	8	1.000	For H_0
Low wage and/or self-employment	1.284	8	0.864	For H_0
High wage and self-employment	-1.448	8	-	For H_0

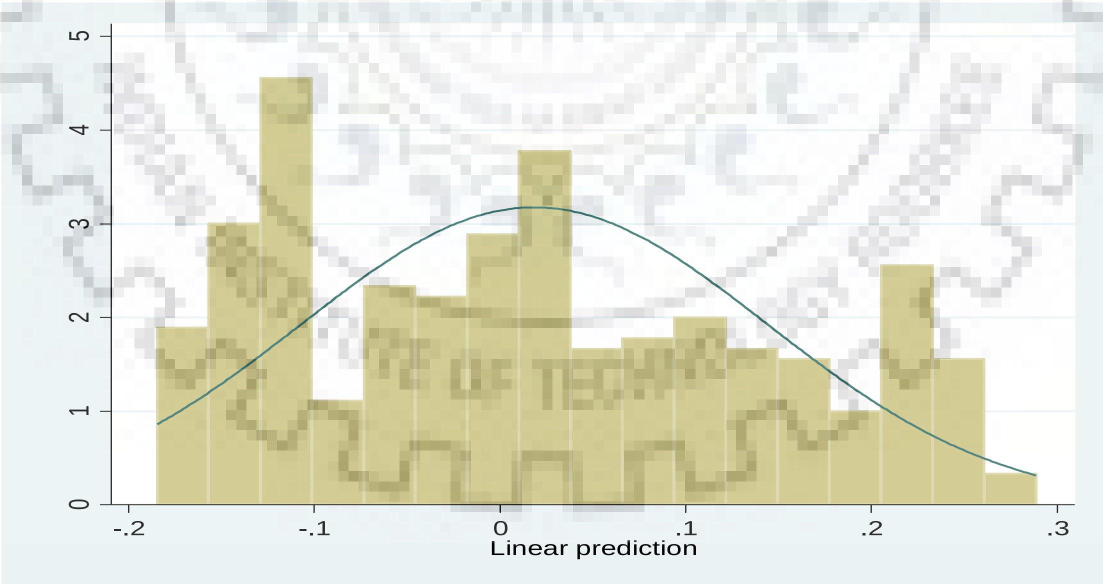
Note: A significant test is evidence against H_0. Hausman and McFadden (1984) concluded that a negative result is evidence that IIA has not been violated.

Appendix 5B: Wald tests for combining outcome categories

H_0: All coefficients except intercepts associated with given pair off outcome categories are 0 (i.e, categories can be collapsed or (combined)

Categories tested	χ2	Df	P > χ2
Farm only and Low wage and/or self-employment	68.156	7	0.000
Farm only and High wage and self-employment	27.411	7	0.000
Low wage and/or self-employment and High wage and self-employment	27.316	7	0.000

Appendix 5C: normal distribution of the error term in the Tobit censored model



Household Survey Questionnaire

Background:

The questionnaire is designed to fulfil the objectives in the thesis titled, "CLIMATE CHANGE IMPACTS, VULNERABILITIES AND OFF-FARM DIVERSIFICATION AS AN ADAPTATION STRATEGY: EVIDENCE FROM ETHIOPIA" for partial fulfilment of the requirements for the award of PhD degree by the researcher. The information collected are purely for academic and research purposes and your responses would remain confidential. I remain thankful to you for your collaboration and participation in the survey.

Part I: Socio-Demographic Characteristics of Sampled Households

1. Name of the district/woreda:______________________
2. Name of the village/kebelle:______________________
3. Age, gender, education and marital status of household members

H/hold members	Age	Gender		Education level		Marital status**	Remarks:
		Male	Female	Level*	Years of schooling		
H/head 1							**Total household size**
Others 2							
3							No. of economically active HH member /adults/
4							
5							
6							No. of dependents
7							
8							Average years of schooling
9							
10							

Key:

***Education Level:** (i) Illiterate (unable to read and write) (ii) Informal education (able to read and write), (iii) Primary education, (iv) Secondary education, (v) Training after primary education, (vi) Training after secondary education, (vii) Higher education (college and/or university).

****Marital Status:** (i) Married (ii) Single (iii) Divorced (iv) Widowed

4. Is there any orphan who depends on your household for living? A. Yes B. No

5. Is any of your household members migrates abroad and/or in the country beyond the household community for work?

6. Does the household own land? A. Yes B. No

7. If the answer for Question number '6' is 'Yes', what is the size of the farm land?

A. in hectare _______ B. or in *timad*____________

8. Do you have irrigated land A. Yes B. No

9. Agro-ecology: A. Highland/Dega B. Midland/Woinadega C. Lowland/kola

10. Relative wealth category of the household A. poor B. Medium (less poor) C. Better-off

Part II: Economic activities of Sampled Households

11. Occupation of the household: A. Farm B. Off-farm C. Both

12. Which one of the following is the farm activity of your household? (You can mention more than one activity)
A. Crop production B. livestock C. Poultry
D. Bee keeping E. Other, specify________________________________

13. How many kinds of crops does your household commonly grow in the last farming year? ___

14. Does your household cultivate cash crop? A. Yes B. No

15. Does your household save some amount of current production for future consumption in another year?

A. Yes B. No

16. Does your household save seeds for next year production? A. Yes B. No

17. Net farm income in the last 12 months of the farming year, that is, the last full Mehere/Kiremt and the last full Belg/Bega (December, 2017- December, 2018).

Farm activity	Farm income /in birr/
Crop production	
Livestock	
Other farm activity	
Total	

18. How many family labour are employed in your household farming (agricultural) activity?

____

19. Do you think that your economically active household members are under employed in your household activity? A. Yes B. No

20. Did you hire farm labour for your household farming activity? A. Yes B. No

21. For what purpose do you use the income you earn from farm activities?
   A. For consumption and essential household expenses   B. To expand farm activity
   C. To invest on farm and farm inputs (to the existing scale and scope of farm activity)
   D. To start/invest in off –farm activities   E. To repay previous credit
   F. For asset building   G. If others, specify_______________

22. How much did you spent on farm inputs in the last farming year? (In Ethiopian Birr) ____________

23. Does your household live significantly depends on farm income?   A. Yes   B. No

Part III: Climate change impact and adaptation options

24. Have your agricultural productions and productivity ever been affected by the change in temperature?
A. Yes   B. No

25. Have your agricultural productions and productivity ever been affected by the change in rainfall
A. Yes   B. No

26. If your answer to Questions 24 and/or 25 is yes, to what extent do you think, as to your evaluation, the change in climate (drought) has affected your farming and production?
   A) Less affected   B) Moderately affected   C) Highly affected

27. Have you noticed any long-term changes in the mean temperature over the last 20 years?
   A) Yes   B) No
   (If yes, is it an increase or decrease or both? Please explain __________________)
   If too difficult: has the number of hot days stayed the same, increased or declined over the last 20 years? Please explain ____

28. Have you noticed any long-term changes in the mean rainfall over the last 20 years?
   A) Yes   B) No
   (If yes, is it an increase or decrease or both? Please explain __________________)
   If too difficult: has the number of hot days stayed the same, increased or declined over the last 20 years? Please explain ____

29. Does your household suffer a pre and/or post-harvest damage caused by abnormal and erratic variability of rainfall?   A. Yes   B. No

30. How many times climate shocks did affect your area for the last 20 years? __________

31. Did you get a warning about the climate hazards before it happened?   A. Yes   B. No

32. Did the climate hazard leads to injury/death in your household?   A. Yes   B. No

33. How much your household loss annually on average due to death of household members, livestock, productivity changes, pre and post-harvest damages and others? (Estimated value in Birr)

____

34. What adaptation measures or adjustments in your farming have you made to the long-term shifts in climate? (Please choose and tick from below as many as you made).

a) Diversifying into off-farm activities
b) Build a water harvesting or conservation scheme
c) Implement soil conservation techniques
d) Change planting dates
e) Irrigate more
f) Change from crop to livestock
g) Buy insurance
h) Put trees for shading
i) Reduce number of livestock
j) Lease your land
k) Migrate to urban area and abroad for work
l) Change crop variety (including new varieties)
M. if others specify, _____________

35. If you are diversifying into off-farm activities; what type of off-farm activities does your household engage in? (Please choose and tick from below as many as you made).

Low paying wage employment	**High paying wage employment**	**Low return self-employment activities**	**High return self-employment activities**
1. Agricultural wage employment on other people's farm	1. skilled labourers (wood house construction, builders/ masons and painting)	1. Collecting and selling firewood	1. Transport services (using small automobile and pack animals)
2. Unskilled daily labour	2. Health workers	2. Weaving (cloths, mats)	2. Livestock, grain and livestock products trading
3. Domestic servants	4. Agricultural experts	3. Spinning of cotton/wool	3. Coble stone preparation
4. Food-for-work programs	4. Teachers	4.Dressmaking/tailoring	4. Stone and sand mining
5. Grinding mill operation	5. Cobblestone construction	5. Handcrafts work/ Pottery	5. Fabrication and selling of farm tools
6. Security work	6. Tractor operation	6. Leather tanning	6. afforestation(planting trees)
7. Retail shop operation	7. Formal international migration	7. Food vending and distilling local brews	7. Grinding mill
8. Waiter	8. Others, please specify ________	8. Blacksmiths/metal works	8. Renting tractor

9. Others, please specify _________		9. Wood work/carving and carpentry	9. Others, please specify ____________________
		10. Repair services	
		11. Petty trade	
		12. Charcoal/fuel wood production	
		13. Traditional medicine	
		14. Others, please specify ______	

36. If you are engaging in off-farm activities not as a response of climate change please list down those off-farm activities. (Refer the lists from the above table)
____
____
____

Part IV: The rural livelihood resources and rural infrastructures of the sampled household

37. Do you have an access to formal credit services? A. Yes B. No

38. Have you taken credit in the past? A. Yes B. No

39. If yes for Question number '38', for what purpose did you take the credit?
A. for off-farm activities B. Cover food gap C. Purchase agricultural inputs
D. health fee services E. Buy livestock F. School fee service
G. Other specify, __________

40. If your answer for Question number '38' is No, what was the reason?
A. I have not any interest to take credit
B. Due to high interest rate of repayment
C. Couldn't get it, though the service is available
D. Other specify____________________

41. Do you have a culture of participating in local saving (Equb) and other social capital activities like Edir. A. Yes B. No

42. In the past month, did your household helps other household and got a help from other household? Which one? Please specify? ___________________________________

43. Did you borrow from relatives and lend money to relatives in the past month? Which one? Please specify ____

44. Does your household request assistance from your local government in the past 12 months?
A. Yes B. No

45. Do you have access to all-weather road services? A. Yes B. No

46. Do you have access to public transport services and for your products to market? A. Yes B. No

47. Do you have access for electricity services? A. Yes B. No

48. Do you have access for clean water facility? A. Yes B. No

48.1 If no, does your household use a natural water source like rivers? A. Yes B. No

49. Do you face water conflict due to water shortage for drink, animal, irrigation? A. Yes B. No

50. How long does it take to fetch water from the source once? (In minutes) _____________

51. Does your household consistently get water from the source? A. Yes B. No

52. How many litres of water per family member will be commonly used in your home per day? ___

53. Do you have access to school in your village? A. Yes B. No

54. Do you send your children to school? A. Yes B. No C. No children

55. If your answer for Question number '54' is No, what was the reason?

A. No school near my surrounding area
B. I could not afford school fees & education materials for them
C. They are on work in support of the family
D. Other, specify____

56. Do you have access for health services? A. Yes B. No

57. How long does it take you to get to a health facility? (In minutes) ______________________

58. Does any member of your household faced with chronic illness? A. Yes B. No

59. Does any of your household members missed his/her work or class in this year due to illness? A. Yes B. No

60. In which months of the year that malaria epidemic is a serious problem? ______________

61. How many mosquito nets available in your household? ___________________________

62. Do you have an access for mobile network service? A. Yes B. No

63. Do you have radio or TV in your home? A. Yes B. No

64. Do you have an access for market in your village? A. Yes B. No

65. How far your household from the nearest product market (in kilometres) ____________

66. Are you near to the town A. Yes B. No

66.1 Please specify how far from the nearest town in Km or minutes spent? ________________

Part V: Determinants of participation into rural off-farm activities and their earning

67. Please specify what factors caused your household to engage in off-farm activity in detail (For off-farm participants).

Factors	**Yes**	**No**	**Rank**
Insufficiency of income from agriculture			
Growing family size			
Decline land size, soil fertility or productivity			
Availability of credit			
The presence of road, electricity and market in your village			
Seasonal nature of agricultural labour			
Climate shocks/drought (rain failure, short rainy season, pests swarm, flood, etc			
Possession of special skill such as masonry, handcrafts, etc			
Favourable demand for goods/services			
Others, specify			

68. What was your start-up capital to establish off-farm activities?

A. Crop sale
B. Livestock sale
C. credit
D. Cooperatives
E. Established without starting capital
F. Other, specify___________________

69. Please mention factors that constrain your household from engaging in any off-farm activities and to expand off-farm activities you engaged (for both participants and non- participants of off-farm activities):

Factors	**Yes**	**No**	**Rank**
Lack of financial and credit facilities			
Lack of awareness			
Education and Skill deficiency			
Lack of support			
Age of household members			
Afraid to risk or diversify from current activities			
Gender roles/relations and gender biasedness			

Lack of site to carry out activity			
Lack of infrastructure (market, electricity, road, transportation, Far from towns etc)			
Low profitability of products			
Busy with farming and own domestic work			
Socio-cultural barriers			
Lack of raw materials			
Competition from urban products			
If others, specify			

70. Does government encourage you to diversify into off-farm activities? A. Yes B. No

71. When does your household (members) engage in off-farm activity?

A. Throughout the entire year
B. During off-farming season
C. After farming activities (in the evening)
D. if other, please specify________________

72. What factors affect the earnings from off-farm activity your household is engaged in? Specify how? And rank if possible.

A. Finance, ________________
B. Education and skills required, ___
C. Health, ____________________
D. Age of household members, _____
E. Electricity, ______________
F. Telecommunication, ___________
G. Market, ______________
H. Roads and transportation services, ________
I. Gender roles/relations, _______________
J. Lack of cooperation and associations_____
K. Social outlooks towards off-farm sector and its outputs, _________________________
L. If others, specify__________________

73. In the off-farm activity you engage in, have you (or any of your household members) had any training/education A. Yes B. No

74. If yes for Question number '73', which type of training?

Basic business development skills Types	**Yes**	**No**	**Technical Training type**	**Yes**	**No**
Marketing			Basketry		
Business management/entrepreneurship			Pottery		
Project planning			Carpentry		
Saving			Blacksmithing		
Costing and pricing			Weaving (cloths, mats)		
Management of money			Dressmaking/tailoring		
Cooperatives			Leather tanning/ hide work		
Problem solving			Others, specify_________		
Others, specify_________________					

75. Who offered this training?

A. Central Government
B. Local Government
C. NGO
D. If others, specify ___________________

76. If no, why? (Mention the reason/s that prevented you from attaining such training

____

77. Does your household decision to participate in off-farm activities influenced by poor condition of your household or to respond to the emerging opportunities in the off-farm sector (such as markets)? Explain briefly____
____

78. How many months a year do your household faced food deficit? (For non-participants and before participation for participants) ____

79. Is there any factor/s that make/necessitate women in the household to engage in off-farm activities?

A. To be independent from husband's support
B. Husband's migration out of village to urban areas
C. Poor earnings of husband
D. Being head of household and therefore increased responsibility
E. Inadequate land owned by the household
F. If others, please specify______________________________

80. Are there any factors affecting women participation in off-farm activities?

A. Gender roles/relations (children raring, cooking, etc.)
B. Husband not allowing
C. Lack of power to access financial credits
D. Lack of power to own products/outputs
E. Lack of power to own productive assets, for example, land etc.
F. Lack of power to own and control economic activity in the household
G. Culture and religious norms
H. If others, specify ____

81. What would you like to do most in the future?

A. Remain on farming only
B. Do both farm and off-farm activities
C. Practice only off-farm activities
D. If others, specify _____________

82. What would you like to have for starting or expanding off-farm activities in the future?

A. government and/or NGO support in skill training and awareness creation, finance, infrastructure and market
B. No need of any support
C. I don't like to start or expand off-farm activities
D. If others, specify ____

Section VI: The farm and off-farm linkages and contribution of off-farm activities existing in the study area

83. How much did you earn from off-farm activities you engaged in the last 12 months? Specify the estimated amount in Ethiopian birr. ____

84. For what purpose do you use the income you earn from off-farm activities?

A. . For consumption and essential HH expenses
B. To expand off-farm activity
C. To invest on farm and farm inputs
D. To repay previous credit
E. For asset building
F. If others, specify________________

85. Does the income from your off-activities support your farm activities? A. Yes B. No

85.1 If yes how? ____

85.2 If no why? ____

85.3 If no, do you think your engagement in off-farm activities retards your farm activities? A. Yes B. No

85.3.1 If yes, how? ____

86. Does food security of the household improved due to participation in off-farm activities? A. Yes B. No

87. Which livelihood change does observe due to participation in off-farm activities?

A. Food self-sufficiency B. Improved housing
C. Schooling of children D. Reduced borrowing
E. Increase confidence & independence F. No change

88. Do you think off-farm activities are an essential component for your survival? A. Yes B. No

89. Compared to non-participants of off-farm activities how did your living condition change over the past years? A. Improved B. Worse C. Same

88. Do you think off-farm activities are an essential component for your survival? A. Yes B. No

89. Compared to non-participants of off-farm activities how did your living condition change over the past years? A. Improved B. Worse C. Same

90. What does the condition of your livelihood look like since you have been engaged in undertaking off-farm activities? A. Improved B. Worse C. Same

91. Please fill out the following table regarding your expenditures in the last 12 months.

Expenditure Type	**Expenditure amount**	
	Birr	**Cents**
For medication		
For education		
For agriculture (seed, fertilizer, etc)		
Food stuff and related		
Clothing and shoes		
Land use charge		
Transport		
Kerosene		
For social issues (maheber, zikere Iddir,senbate, etc)		
Others		
Total		
Estimated per capita household expenditure		

Check list for interviewing key-informants and experts

1. Do you think that rural households in your locality are vulnerable to climate shock?
2. Did you anticipate climate shocks before happening? And did you give the warning for rural households' in your locality?
3. What are the major climatic shocks and trends observed in the last years? Do they affect the rural households to participate/or not to participate in rural off-farm activities?
4. Did you think that rural households are diversified into off-farm activities as a response of climate shock?
5. What are the common types of off-farm activities practiced by rural households in your area?
6. Are those activities unique only to the area you are living?
7. What is the trend of those rural off-farm activities?
8. What motivates people to practice such rural off-farm activities? And/or what conditions pushed/enabled them to start practicing those rural off-farm activities?
9. What factors constrain rural households from participation in off-farm activities?
10. What do you think are the major factors limiting the growth of existing rural off-farm activities in your locality?
11. What remedies should be taken in order to stimulate the growth of rural off-farm activities in your area?
12. How is the acceptance of such activities in the society? Which section of the society undertakes such activities?
13. What contributions have these activities to the farmers and to rural livelihood as well?
14. What do you think should be the role of the government in promoting rural off-farm activities? And what should be done to promote off-farm economy in general?