Essays on the coffee supply chain in Uganda

by

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B.S., Makerere University, 2013
M.S., Makerere University, 2018

AN ABSTRACT OF A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Agricultural Economics
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Abstract

Coffee is grown by many countries worldwide (Killeen & Harper, 2016). Africa contributes 12% to total world production (Wondemu, 2017). Uganda is the second largest producing country in Africa, after Ethiopia (Mwesigye & Nguyen, 2020). Coffee is a labor-intensive industry employing over 100 million people in 60 developing countries (Collinson *et al.*, 2005). It has been particularly important to Uganda's economy since 1961. It has employed over 12 million people (ICO, 2019) generating export revenues of US$ 492 million in 2018 (UCDA, 2018). The current annual value of export revenues from coffee exceeds US$17 billion (FAOSTAT, 2018), contributing to 1.5% of Uganda's Gross Domestic Product (GDP) in 2019 (ICO, 2019). Uganda contributes over 31.24% of total coffee exports from Africa (FAOSTAT, 2018), placing it among the major coffee exporting countries in the world. Despite the paramount importance of coffee to Uganda's economy, the industry still faces bottlenecks in the coffee supply chain that limit growth. The purpose of this dissertation is to examine and assess two primary bottlenecks in the Uganda's coffee supply chain, productivity at the farm level and maintaining quality through the supply chain.

The total area under coffee production in Uganda has increased over the past ten years with no substantial increase in productivity. Standard productivity measures that examine technical efficiency and productivity though are not able to \account for the age of coffee trees or plantations, which is a limiting factor in coffee productivity. Productivity assessments assume a homogeneous production frontier across farms, which may result in biased productivity estimates due to differences in age of trees on a plantation. The purpose of the first essay is to analyze coffee farm efficiency and productivity change over time accounting for the average age of trees on coffee plantations. Data for the study comes from the two main coffee producing countries in Africa:

Uganda, and Ethiopia. Uganda is the primary study area, with Ethiopia being used for comparative purposes and to provide a foundation for generalization of research findings. World Bank data from the 2013/2014 and 2015/2016 growing seasons is used, comprising of 187 Ugandan and 606 Ethiopian farm households. Efficiency and productivity change are estimated using Data Envelopment Analysis (DEA) techniques to derive measures based on the Malmquist Index and its decomposition. This estimation is completed in two stages. In the first stage, technical efficiency scores are estimated separately using an unconditional DEA model and a conditional DEA model that accounts for differences in the average age of the coffee trees at the farm household level. The two indexes are compared to determine the impact of the age of the coffee tree on efficiency and productivity change. Finally, in the second stage, CMI scores are whitened and a nonparametric Kernel regression of land and labor on CMI is conducted to determine the impact of land and labor efficiency on productivity change.

Estimating coffee farm productivity in the short run using unconditional scores results in biased productivity estimates and misleading conclusions. The average age of the coffee trees has a negative and statistically significant marginal effect on coffee farm productivity change in both Uganda and Ethiopia. As the trees get older, the efficient frontier retracts. This is important for development programs such as extension to identify the actual productivity loss due to managerial inefficiency. In addition, it provides evidence for the potential efficacy of coffee tree planting programs to help small famers. Increasing land input in coffee production decreases productivity due to thinning of other inputs, while increasing labor inputs improves productivity since this is a limiting factor in coffee production.

The second essay analyzes coffee marketing channels and the current quality incentive structures to understand their impact on coffee quality through the coffee supply chain. This essay

specifically considers two market channels through which exporters make transactions: the middleman market channel and the farmers' group market channel. Data for this study comes from two main coffee producing districts in Uganda, Masaka and Mbale. Primary data were collected using pre-tested questionnaires. The data is comprised of interviews with 120 middlemen and 30 exporters, as well as four focus group discussions with producers. We use discrete choice methods based on actor decisions in the coffee supply chain to test for differences in quality of coffee transacted through the middlemen and farmers' group channels. We apply the Principal-Agent framework to explain the impact of market channels on coffee bean quality. Results show a significant positive marginal effect of the market channel on coffee quality. If the market channel changes from middlemen to farmers' group, the probability of the quality of coffee being high increases by 55 percentage points. The farmers' group channel leads to high quality because of symmetric information between farmers, farmers' groups, and exporters and availability of price incentives. The low quality through the middlemen channel is due to lack of incentives and information asymmetry between the farmers, middlemen and exporters. The government of Uganda can help improve coffee quality through promoting formation of farmers' groups. This can be done through providing extension services to create awareness and infrastructural support to poorer and more remote farmers.

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Approved by:

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Jason Bergtold

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Table of Contents

List of Figures

List of Tables

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Dedication

To my parents; Mr. Amisi Kizza and Mrs. Farida Naigaga, siblings; Amina, Mariam, Abdallah, Hawah, Zaharah, Hafuswa, Fauzia, Idd, and Jannat, husband; Dr. Farooq Keyune, and beautiful daughter Tahira Kyeyune. You are all amazing!!

Chapter 1 - Introduction

This chapter provides a general overview of the dissertation. The chapter presents the general background to the study, motivation, purpose and objectives, contribution, and the overall organization of the dissertation.

1.1. Coffee Markets and Production

Coffee is grown by many countries worldwide (Killeen & Harper, 2016). South America contributes about 44.6%, Asia 31%, Africa 12.2%, and Central America 10.1% to total coffee production worldwide (Wondemu, 2017). Brazil, Vietnam, and Colombia are the first, second and third largest coffee producers contributing more than 50% of total world production. Uganda is the second largest producing country in Africa after Ethiopia, (Mwesigye & Nguyen, 2020). Robusta coffee is the main variety grown in Uganda, representing 73% of the value of coffee exports (Mwesigye & Nguyen, 2020). Uganda also produces wet-processed Arabica coffee, which is mainly grown by small holder farmers (Verter *et al.*, 2015). In Uganda, coffee is commonly intercropped with banana and beans, with a variety of shade trees to enhance sustainability (Wang *et al.*, 2015). Farmers often use a low input production system (fertilizers, pesticides and fungicides) and strongly rely on family labor (Ahmed, 2012). Coffee is grown in the highland areas mainly on the slopes of mountain Elgon (at the Kenya border) and the slopes of mountain Rwenzori (at the DR Congo border) (Verter *et al.*, 2015). Coffee is also grown in the West Nile region, which is the northwest part of the country.

Before 1991, coffee trade in Uganda was controlled by a marketing board. Producers were organized in cooperatives through which the marketing board paid a fixed price upon delivery and a quality premium at a later stage (Chiputwa *et al.*, 2015). With this arrangement, producers often received prices below world market prices. The industry was later liberalized in 1991 (Mwesigye & Nguyen, 2020). The industry is currently operated by the private sector, which allows free competition at all nodes of the supply chain. However, export quality is still controlled by the Uganda Coffee Development Authority (UCDA, 2020).

1.1.1 Overview of the coffee supply chain in Uganda

The coffee supply chain consists of many actors, including: input suppliers, farmers, associations/cooperatives, middlemen, primary processors, secondary processors (export companies), and local roasters, as well as importers and roasters at the international level (Figure 1.1) (USAID, 2010). As shown in Figure 1.1, the supply chain is comprised of: (1) input suppliers, (2) primary producers (individual farmers and farmers' groups), (3) processors (roasters, primary and secondary processors), (4) marketers (middlemen and exporters), and (5) consumers. Like other supply chains in developing countries, trading activities in the Ugandan coffee supply chain occur at each stage of the production process as pure transfers of goods within the supply chain (Gómez & Ricketts, 2013).

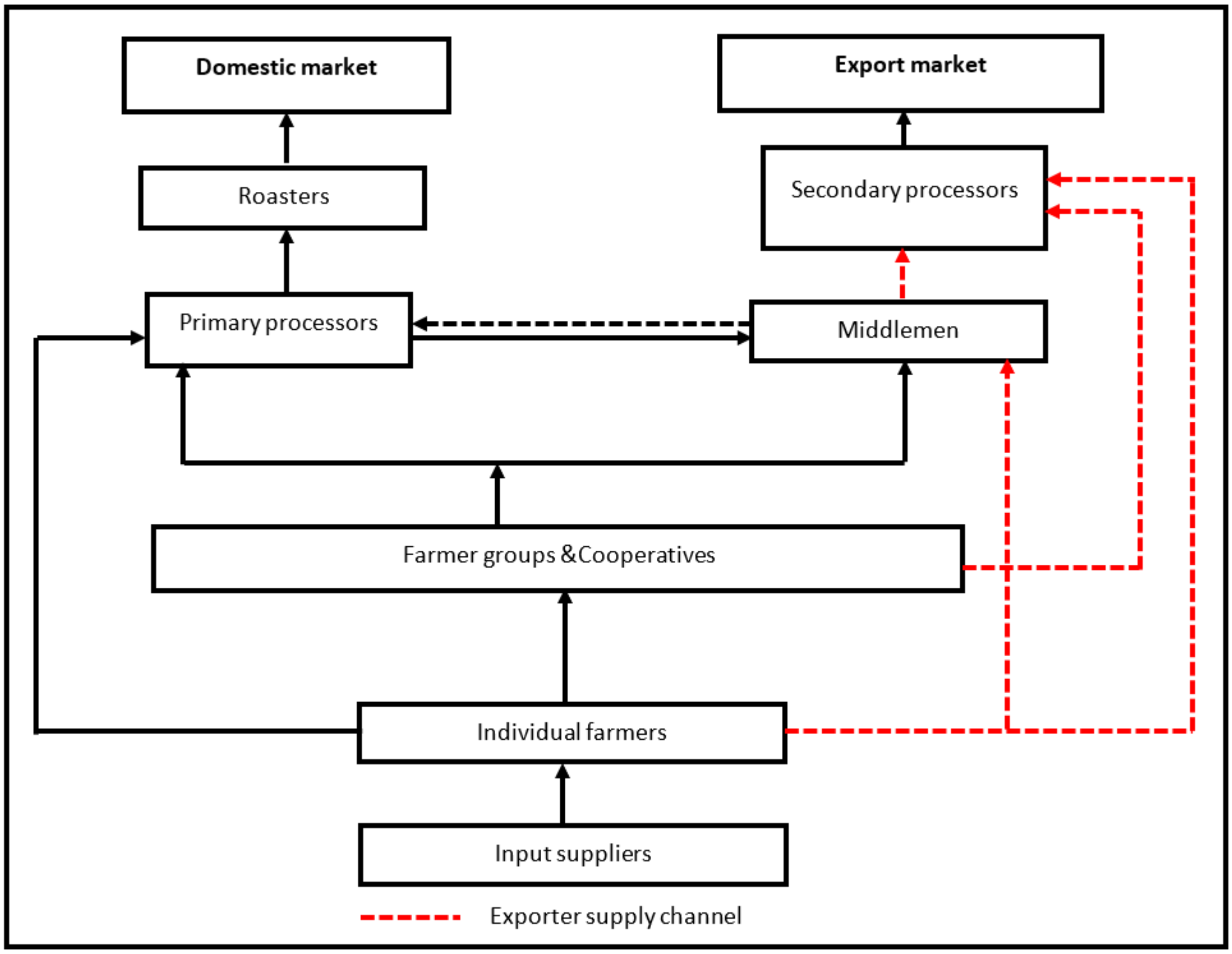

Figure 1.1 The Uganda Coffee Supply chain (USAID, 2010)

1.1.1.1 Producers and input suppliers

Research and development institutions supply seeds to UCDA for distribution to nursery operators. The government, through UCDA, has a sustainable strategy to provide clean certified seed to private commercial nursery operators that are licensed to distribute planting material to farmers in the country. Seedlings, fertilizers, pesticides, and other farm implements are also distributed by Non-Government Organizations and agro-input dealers who are organized under the umbrella organization, Uganda National Agro-input Dealers Association (UNADA). The organization has a total of 2,200 members spread across the country (Kilimo, 2012). Coffee production in Uganda is dominated by small scale farmers (90%) whose farm size is often less than 2.6 hectares on average (World-Bank, 2011). These small producers engage in activities including land preparation, planting, weeding, fertilizer applications, chemical applications, harvesting, and drying of coffee. About 80% of the farmers grow the Robusta type of coffee with the remaining growing the Arabica type of coffee. Total coffee supply increased by 5% to 5.67 60-Kg million bags in the 2017/18 production year (UCDA, 2018).

1.1.1.2 Processors

Processors play a central role in the coffee supply chain. They include both primary and secondary processors. Primary processors are mostly located in the trading centers, where they also act as marketing centers for buyers and sellers in coffee producing districts. Small local traders deliver coffee for primary processing and later sell to large middlemen. Some farmers also transport their coffee to processing plants, as well as sell directly to middlemen. The middlemen then transport the product to Kampala for secondary processing by export companies (UCDA, 2015). Coffee ripe cherries undergo several operations aimed at extracting the beans from their covering of pulp, mucilage, parchment, and film to improve their appearance (UCDA, 2020). The resulting beans can be roasted and ground to obtain the coffee powder which is fit for human consumption. The two main techniques used in primary processing include wet processing and dry processing. Wet processing involves three stages (1) removal of pulp and mucilage followed by washing to obtain clean wet parchment, (2) drying the parchment coffee, and then (3) removal of the parchment and film through hulling. Wet processing is mainly done for Arabica coffees grown at high altitudes (above 1,500m above sea level). Dry processing on the other hand involves two stages (1) drying the cherries (mostly sundried) and (2) removal of the dried coverings (husks) in a mechanical operation (hulling). Dry processing is mainly done for Robusta coffee.

1.1.1.3 Marketers

Coffee is sold in various forms depending on labor availability or financial need. When cash is needed urgently, farmers may sell coffee at the flowering stage to middlemen, though this goes for a lower price due to quality issues (Chiputwa *et al.*, 2015). After harvesting, farmers can either sell immediately on farm or dry and store their produce for later marketing. Farmers either bulk and sell through farmer groups/cooperatives or sell individually to small local traders and middlemen (Murphy & Dowding, 2017). Small traders travel to the hard-to-reach areas and villages in Uganda to purchase coffee on-farm. Some middlemen buy from small local traders at primary processing plants (Ahmed, 2012). Middlemen then bulk and transport the primary processed coffee to Kampala where it is sold to exporters after meeting the minimum requirement of 10 60-Kg bags. Exporters, also referred to as secondary processors, buy coffee directly from farmer groups/cooperatives, but rarely from individual farmers, as 95% of individual producers are smallholders who cannot meet the minimum volume requirements (e.g., 10 60-Kg bags). Exporters play the role of sorting, grading (i.e., the green beans are graded by quality based on size, shape, moisture content and maturity), weighing, packaging, and shipping. The export business is dominated by 10 large companies holding a 77% market share. Export companies are licensed to deliver Uganda’s coffee to various export markets or countries, which are shown in Figure 1.2. The European Union is the largest importer, importing over 80% of the country’s coffee exports (ICO, 2019). Sudan is the second largest importer, which is also the largest buyer in Africa. Coffee price is set by the international market and varies based on the U.S dollar exchange rate.

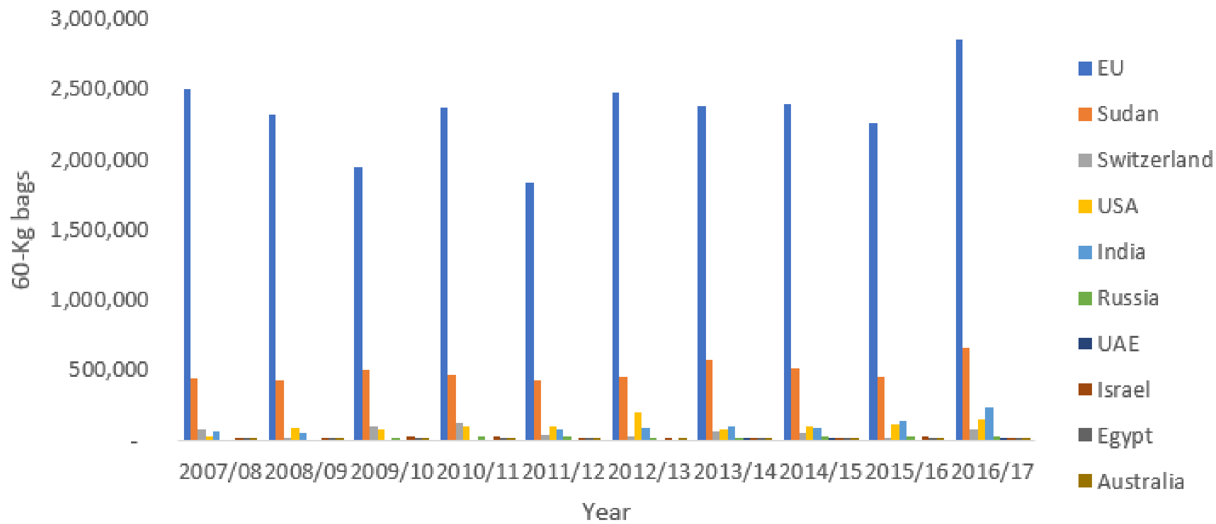

Figure 1.2. Major buyers of Ugandan Coffee (UCDA, 2018)

In the production year 2017/18, 4.71 million bags of coffee were sold (total marketed) (Figure 1.3), of which 5% were sold domestically and 95% were exported, amounting to a 1.3% increase from the previous production year. The country earned US$ 492 million in export revenue. The average weighted price was US$ 1.84 per Kg with Robusta coffee selling at US$ 1.75 and Arabica coffee selling at US$2.13 Kg. The price difference is attributed to difference in quality attributes and the high demand of Arabica coffee that resulted from a slump in production from Brazil (UCDA, 2018).

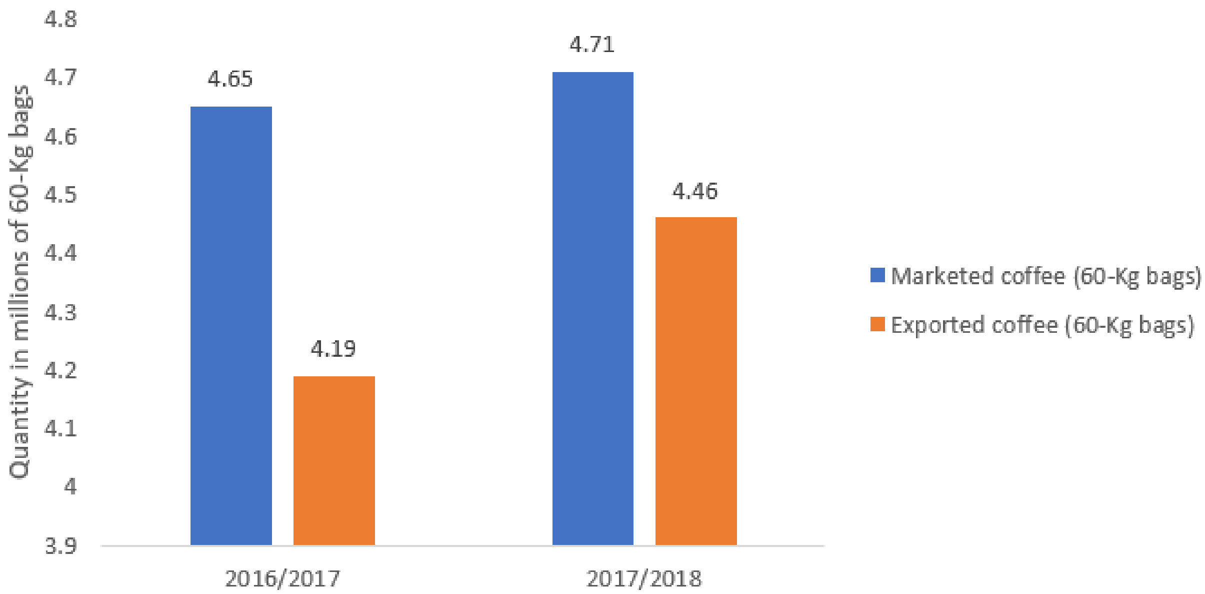

Figure 1.3. Marketed and Exported coffee from Uganda (UCDA, 2018)

1.1.1.4 Consumers

Consumers are the main drivers of the supply chain since they determine the volume and quality of coffee that flows through the coffee supply chain (Gómez & Ricketts, 2013). About 95% of Ugandan coffee is consumed internationally and only 5% is roasted and consumed locally. Coffee was introduced in Uganda as a cash crop and people have since then viewed it as something only meant for export. According to the 2016 Uganda Annual Coffee Report, low domestic consumption is due to low purchasing power and an entrenched tea drinking culture inherited from the British. However, there was a 2.4% increase in domestic consumption levels in 2018. According to the (UCDA, 2019a), per capita consumption of coffee in Uganda is 1.4Kg/year and consumption by youth is rising slowly. Table 1.1 shows domestic consumption of coffee between 2010 and 2017

Table 1.1. Domestic Ugandan consumption of coffee (2010-2017) in 60-Kg bags (ICO, 2019)

Coffee Production Year	Robusta Coffee	Arabica Coffee	Total Coffee Consumption
2009/10	147,900	40,800	188,700
2010/11	159,120	44,880	204,000
2011/2012	164, 400	45,600	210,000
2012/13	168,000	48,000	216,000
2013/14	171,600	49,200	220,800
2014/15	175,200	54,000	229,200
2015/16	178,800	57,600	236,400
2016/17	180,000	60,000	240,000
2017/18	183,600	61,200	244,800

1.2 Motivation

Coffee has the highest turnover in international trade after petroleum (Muratori, 2016). The current annual value of export revenues from coffee exceeds US$17 billion (FAOSTAT, 2018). Coffee is a highly labor-intensive industry employing about 100 million people in over 60 developing countries (Collinson *et al.*, 2005). It has been particularly important to Uganda's economy since 1961 where it has employed over 12 million people (ICO, 2019) generating export revenues of US$ 492 million in 2018 (UCDA, 2018). Coffee exports contributed to 1.5% of Uganda's Gross Domestic Product (GDP) in 2019 (ICO, 2019). Uganda contributes over 31.24% of total coffee exports from Africa (FAOSTAT, 2018), placing it among the major coffee exporting countries in the world. Despite the paramount importance of coffee to Uganda's economy, the industry still faces some bottlenecks within the supply chain that limit its potential.

A significant challenge is that coffee farm productivity has declined and remained low since 2003. The government, through the Uganda Coffee Development Authority, intervened in the market by establishing a seed distribution program that ensured the supply of good quality planting materials to farmers. This program was started more than ten years ago with the aim of replacing old coffee trees that were assumed to be less productive. With the high supply of planting materials, the total land area under production has expanded tremendously. In 2017/2018, the country recorded its highest output of about 4.71 million bags, resulting from the maturity of newly planted coffee trees. However, the increase in output was also associated with an increase in total area planted rather than improvement in productivity. With the growing population of the country, expanding the area under production does not seem to be a sustainable way of increasing output. It is therefore imperative to study the productivity of coffee farms in Uganda. Studies such as (Baffes, 2006) and (Wang *et al.*, 2015) have attributed declines in coffee farm productivity to soil factors, pests, and diseases, among other factors. This study aims at expanding on this literature by examining the impact of land, labor, and age of coffee trees (plantations) on farm productivity. For robustness, we conduct a similar study in Ethiopia to provide a comparison for generalization purposes. Ethiopia is the leading producer of coffee in Africa, and it is more similar to Uganda in terms of economic and production characteristics.

A second highly significant issue in the coffee supply chain is the low quality of coffee beans. Low quality has further constrained the economic potential of the coffee industry. Quality deterioration occurs at almost all levels of the supply chain (Kilimo, 2012). Exporters make coffee transactions through two market channels: middlemen and farmers’ groups. Middlemen are an important component of the supply chain when it comes to bulking and providing required volumes to export companies; however, their unprofessional actions such as adulteration of coffee (adding foreign materials such as stones to the coffee in order to increase the weight of their bags) have damaged coffee quality, reducing its economic value. Therefore, an examination of the impact of market channels on coffee quality is needed to improve quality of coffee coming to the market from Uganda.

1.3. Purpose and Objectives

The overall purpose of the dissertation is to analyze the productivity and quality challenges facing the coffee industry in Uganda. More specifically, this dissertation analyzes coffee farm productivity and assesses the incentive structures for investing in coffee quality production and marketing. This purpose will be achieved by meeting the following specific objectives:

1. To model coffee productivity, specifically considering the impacts of aging coffee trees (plantations) and of the expansion in area (land) planted to coffee.
2. To examine the transaction arrangements between coffee supply chain actors and the impact of market channels on coffee quality.

1.4. Contribution

The findings will contribute to literature by providing a robust method for incorporating the age of coffee tree into a DEA model for estimation of productivity of farms growing perennial crops. The study will address productivity issues, which will provide suggestions on how to increase output from coffee farms. This will eventually improve the income of all stakeholders in the long run. Results from this study will inform policymakers and help in reorganization and restructuring the Ugandan coffee industry to ensure efficient flow of higher quality products throughout the supply chain. Results will provide mechanisms and strategies for promoting higher quality coffee for export, helping to overcome bottlenecks in the supply chain.

1.5. Internal Overview

The remainder of the dissertation is presented as follows. Chapter 2 will present the empirical analysis of productivity of Ugandan coffee farms. Chapter 3 will present an examination of quality differences in coffee along the supply chain in Uganda and the implications for the industry and economy.

Chapter 2 - Empirical analysis of productivity in Ugandan coffee farms

2.1. Introduction

Productivity is an important engine of economic growth both at the micro and macro levels. Higher productivity can result in higher production and income holding other factors constant. The underlying approaches for development in Africa primarily focus on elevating agricultural productivity and hastening agricultural growth (Binswanger & Townsend, 2000). A majority of Africa's population depends on farming, which makes these approaches potential instruments for reducing poverty and hunger (Benin, 2016). Similarly increasing agricultural productivity and growth has been one of Uganda's main objectives, but the country has experienced slow progress towards these goals.

Uganda's vision is to become a world leading producer and exporter of coffee, like Vietnam. However, Uganda's average yield is only 0.6 tons per hectare compared to 2.2 tons per hectare in Vietnam (USAID, 2010). According to Uganda's National Coffee Strategy, productivity was anticipated to improve from 0.6 tons per hectare in 2015 to 1.6 tons per hectare in 2019/2020, which has not been achieved. Currently, the average yield for traditional[1] farmers in Uganda is 0.57 tons per hectare and 1.2 tons per hectare for improved farmers[2] (ICO, 2019). Generally, total coffee production has fluctuated since its peak in 1995 (Figure 2.1). The total area under coffee

[1] A farmer who carries out basic agronomic practices exclusively use family labor and does not apply fertilizers (whether organic or inorganic) and neither uses any pest nor disease management practices.

[2] A farmer who significantly adopts recommended best agricultural management practices and applies fertilizers as well as ensures proper canopy management and effective pest and disease management.

production has risen over the past ten years with no substantial increase in productivity. Uganda's current population density is 593 people per mi^2 based on UN data. The registered population growth rate was 3.7% in 2018 (World-Bank, 2020a) which falls under the category of a high population country. This necessitates improvement in farm productivity to increase total output rather than expanding coffee production area. Increasing productivity is important for increasing output since more land may be required for settlement. Low coffee productivity is a threat to farm household incomes and the country's overall economy prompting the need for strategies to increase productivity.

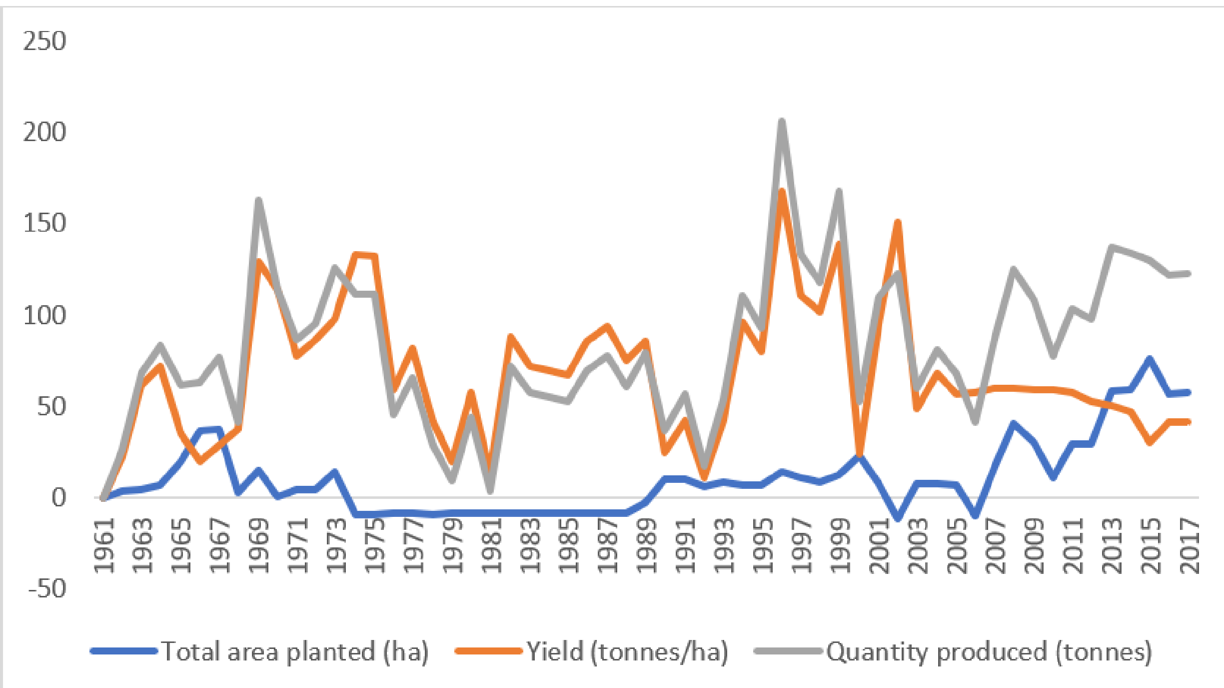

Figure 2.1. Coffee productivity: 1961-2017 (FAOSTAT, 2018)

Addressing low productivity can be best achieved by first understanding the drivers and limitations of farm productivity (Benin, 2016). Low agricultural productivity is influenced by technical inefficiency and limited access to resources (Zhang *et al.*, 2017). Crop productivity is influenced by factors such as quality of inputs, environmental characteristics (weather, rainfall, and soil quality), crop variety, farmer characteristics, management practices, among others. Productivity of perennial crops such as coffee, rubber, and forestry, among others, is greatly affected by the age of the trees, as well (Thang *et al.*, 2009). This implies that coffee productivity is a function of production inputs and the age of the coffee tree (a primary input). Coffee productivity usually starts in the 3rd year of life with very low yield for the first two years after planting. Maximum productivity commonly occurs at the age of 8 years and starts decreasing after the age of 15 years (Thang *et al.*, 2009). According to the National Coffee Association, (2020), coffee trees have a lifespan of 100 years though they are most productive between the age of 7 and 20 years.

The age of coffee trees is essentially an external factor for many Ugandan farmers for a number of reasons. In the short run (e.g., 1-5 years), farm households that produce coffee could plant new coffee trees, but this requires significant capital for investment and high transaction costs (e.g., search costs for planting materials), which they may not have or be able to meet. Further, the age of the coffee tree can limit a farmer's ability to optimize their wellbeing and reach a desired production frontier. Characterizing plot average age of coffee trees is very important in estimating productivity (Defrenet *et al.*, 2016). Differences in average age of coffee trees on a plantation results in differences in production potential, and hence the production frontiers of a coffee plantation. Standard efficiency measures in the literature often assume a homogeneous production frontier across farms, that can result in biased efficiency and productivity estimates. Therefore, consideration of the average age of coffee trees on a plantation is important in analyzing the productivity of coffee farms. To the best of our knowledge, studies on coffee productivity have not considered potential biases arising from the average age of the trees. Such studies assume that inefficiencies arise from farmers' poor management practices, yet it could arise from differences in the average ages of coffee trees on-farm. The methodological approach adopted in this study can be used to analyze other perennial crops and orchards.

The purpose of this study is to analyze coffee productivity in a more robust way by accounting for average age of the coffee trees on a coffee plantation in estimating productivity. In addition, the approach adopted here allows for an assessment of the impact of the average age of the coffee tree on a farm's productivity. We further assess impacts of input use, such as land and labor, on coffee productivity across farms. We hypothesize:

I. The average age of the coffee trees on a farm negatively impacts farm productivity; and

II. The amount of land and labor allocated to coffee production increases coffee productivity for farms

For reliability and generalization of our findings, we conduct a similar analysis using Ethiopian data and compare the findings. We chose Ethiopia because it is the leading producer of coffee in Africa and it's more similar to Uganda in terms of environmental, socio and economic characteristics. Ethiopia is the largest producer of coffee in Africa and is ranked among the top 10 producers in the world. Coffee is the leading export commodity in Ethiopia and plays a unique role in the national economy (Tesfa, 2019). It is a source of livelihood for 15 million Ethiopians (16% of the population). About 95% of the coffee in Ethiopia is produced by small scale farmers (USDA, 2019). There are four coffee farming systems in Ethiopia namely, plantation coffee, forest coffee, semi-forest coffee, and garden coffee (Amamo, 2014). The plantation coffee system is where coffee is grown on large scale farms (more than 10 ha) and usually owned by the state.

Forest coffee systems are where coffee is grown wildly amidst other trees and bushes in a natural way with very minimal management and intervention. Normally the person who prunes the trees claims ownership (Moat *et al.*, 2017). Semi-forest systems are where trees are given more care compared to the forest system. Garden coffee systems are where famers grow coffee on small plots (usually containing a maximum of 100 plants) near their households (Tesfu, 2012). Garden coffee systems are also the most common method of coffee production. Unlike Uganda, Ethiopia has a bigger domestic consumption of coffee (about 50% compared to only 5% in Uganda). However just like Uganda, Ethiopia's coffee productivity and quality are still low (Birhanu *et al*, 2013).

Based on the role of agricultural productivity to the country's development, using proper measures and indicators of agricultural productivity is critical for Uganda (and Ethiopia). Agricultural productivity can be analyzed based on partial factor productivity (PFP) or total factor productivity (TFP) (Benin, 2016). PFP is the ratio of output to a subset of inputs (usually one input), for this reason, it is also described as single-factor productivity. The most popular measures of PFP are labor productivity (ratio of output to total number of hours worked) and land productivity (ratio of output to total harvest area). With PFP measures, focusing on one variable to evaluate how it varies in relation to output is feasible. On the other hand, TFP is an extension of PFP and is measured as an index of the ratio of total agricultural outputs to total agricultural inputs. The choice of an agricultural productivity measure and indicator is influenced by level of information regarding the various elements embodied in productivity as summarized in Table 2.1.

Table 2.1. The dimensions of the different components embodied in productivity measures (Benin, 2016).

Dimension	Description
Composition of agriculture	Sector (all agriculture), subsector (crops, livestock, fisheries, forestry), commodity group (e.g., cereals, export crops, meat), and commodity (e.g., coffee, beans, bananas, beef, fish) being assessed.
Type of factor and inputs	Land, labor, and capital, as well as pesticides, fertilizers, and seed.
Measure of output and input	Physical quantity or monetary value. This is important when aggregating, especially when summing over weights is not meaningful
Time scale	Annual, long-term average, most recent years
Spatial scale	Country, state, county, region, agroecology
Level of aggregation	Plot, farm, household, national, regional, continental

TFP is widely applied in the applied economics literature because it measures the part of growth that is not accounted for by changes in the factors of production. TFP growth can be decomposed into a product of measures including technical change, technical efficiency change and scale-efficiency change. Measuring TFP in developing countries can be challenging due to lack of price data that can be used in the aggregation of outputs and inputs. There are several methods of measuring TFP, and these can be broadly categorized into two approaches: (1) parametric methods, where the technology is estimated econometrically (e.g., stochastic frontier analysis) and (2) nonparametric methods, where estimation is conducted using simulation or math programming approaches (e.g., Data Envelopment Analysis (DEA)). This study uses the Malmquist index approach based on conditional DEA (referred to as the Malmquist DEA approach). Details of this approach are presented in the methods section of the paper.

2.2 Methodology

2.2.1 Study area

The study focused on two main coffee producing countries in Africa: Uganda, and Ethiopia. Uganda is the primary study area, with Ethiopia being used for comparative purposes and to provide a strong foundation for generalization of research findings. Uganda and Ethiopia are located in the Eastern part of Africa (Figure 2.2) and have a lot of similarities.

Uganda is located between 1^0 N and 4^0 N latitude and 30^0 E and 35^0 E longitude. The country is bordered by South Sudan in the north, Kenya in the east, Democratic Republic of Congo in the west, and Tanzania and Rwanda in the south. Uganda is surrounded by Lake Albert, Lake Edward, and Lake Victoria. Uganda is a landlocked country with no access to the sea. The country is relatively small occupying an area of 241,551 km^2 (e.g., slightly smaller than the U.S. state of Oregon). Uganda experiences a tropical type of climate and is generally rainy during most of the year.

Ethiopia is bordered by Eritrea to the north, Sudan and South Sudan to the west, Kenya to the south, Somalia to the southeast, and Djibouti to the east. Ethiopia is the only country in Africa that was never colonized. Like Uganda, Ethiopia is a landlocked country that lies in a region known as the Horn of Africa. The country covers an area of 1,126,829 km^2 (i.e., about double the size of the U.S. state of Texas).

Figure 2.2. A map of Africa showing the location of Uganda and Ethiopia

2.2.2 Data

Data used for the study for productivity estimation and its components for Uganda was extracted from the Uganda National Panel Survey (UNPS) data supported by the Living Standards Measurement Study-Integrated Surveys on Agriculture (LSMS-ISA) initiative of the World bank[3](UBOS, 2014, 2016). The data was extracted from surveys conducted during the growing seasons in 2013/2014 and 2015/2016 since data on average age of coffee trees was not collected for earlier years. This is a nationally representative and rich data set. Each survey covers about 3,000 households. After extracting the variables of interest, a sample size of 187 farm households was obtained for Uganda. This sample included farms that were involved in coffee production from 2013/14 to 2015/16. We extracted data on average age of coffee trees on the farm, as well as inputs and outputs used in coffee production, from the agriculture section of the survey. Since coffee in Uganda is intercropped with bananas, we also extracted output data from bananas grown on the same piece of land with coffee at the time of the survey. The main inputs into coffee production are land and labor. Ugandan farmers often use a low input system with minimal amounts of pesticides and fertilizers. Most of the labor used on Ugandan coffee farms is manual, which is especially needed at harvest time when coffee berries are handpicked.

Similar data (surveys conducted in 2013/2014 and 2015/2016) were extracted from the Ethiopian Socioeconomic Survey (ESS) data supported by the Living Standards Measurement Study-Integrated Surveys on Agriculture (LSMS-ISA) initiative of the World bank[4] (CSA[5], 2014, 2016) for comparison purposes. This is also a nationally representative dataset. After extracting the variables of interest (same variables as Uganda), a sample size of 606 farm households was obtained. Like Uganda, we extracted data on average age of the coffee trees, as well as data on inputs and outputs used in coffee production in Ethiopia from the agriculture section of the survey. For Ethiopia, we only considered coffee output since it was easy to extract data on coffee grown

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[3]The data can be accessed at this link: https://microdata.worldbank.org/index.php/catalog/2663/get-microdata

[4]The data can be accessed at this link: https://microdata.worldbank.org/index.php/catalog/2783/get-microdata

[5] Central Statistical Agency of Ethiopia

as a pure stand. Ethiopia also uses a low input system with minimal amounts of fertilizers and pesticides. For this reason, we focused on two main inputs: land and labor. The plantation coffee system where coffee is grown on a large scale (more than 10 ha) was not considered in this study since such plantations are mainly owned by the state.

Tables 2.2 and 2.3 present the descriptive statistics of the survey data extracted for Uganda and Ethiopia used in the study, respectively. The average coffee output for Ugandan farm was 485 Kg (about 8 60-Kg bags) in the year 2015/16. There was no significant difference between the average coffee output for 2013/14 and 2015/16. Similarly, there was no significant difference between banana output of 2013/14 and 2015/16. The average land allocated to coffee production was 2.67 acres in 2015/16 and was higher than land allocated to coffee in 2013/14 (2.39 acres). There was a significant increase in the amount of labor allocated to coffee in 2015/16. The average age of coffee trees was about 15 years in 2015/16 implying, with the majority of trees being older. Thang *et al.* (2009) indicates that coffee tree productivity declines just after 15 years of age.

The average coffee output for Ethiopian farms in 2015/16 (176 Kg) was higher than the output in 2013/14 (157 Kg). Ethiopia's average coffee output for smallholder farmers is less than that of Uganda because smallholder farmers in Ethiopia operate on relatively smaller plots of land compared to Uganda (0.77 acres Vs. 2.67 acres in 2015/16). Similarly, total land and labor allocated to coffee in the year 2015/16 were also higher than those for 2013/14. The average land and labor inputs for Ethiopian farms was lower than that of Ugandan farms.

Table 2.2. Descriptive statistics and outputs used in productivity estimation for Uganda (N=187)

Variable	**2013/2014**		**2015/2016**		
	Mean	**Std. Dev.**	**Mean**	**Std. Dev.**	**Means Difference Test**
Coffee output (Kg)	446.0	624.0	485.4	1815.2	39.4
Banana output (Kg)	1652.2	2452.4	1660.2	2859.2	8.1
Land (acres)	2.4	2.8	2.7	2.8	0.3*
Labor (hours)	410.3	295.7	452.3	295.5	41.9**
Tree age (years)	13.9	6.4	14.9	6.4	1.0**

* P<0.10, ** P<0.05, *** P<0.01

Table 2.3. Descriptive statistics of inputs and outputs used in productivity estimation for Ethiopia (n=606)

Variable	**2013**		**2015**		
	Mean	**Std. Dev.**	**Mean**	**Std. Dev.**	**Means Difference Test**
Coffee output (Kg)	156.7	320.7	176.4	349.5	19.7*
Land (acres)	0.6	1.2	0.8	1.6	0.2***
Labor (hours)	165.8	169.8	195.6	326.6	29.8**
Tree age (years)	15.1	10.6	16.1	10.6	1.0**

* P<0.10, ** P<0.05, *** P<0.01

2.2.3 Methodological Approach

Production is a process that converts inputs into outputs. We assume that there are two inputs (land and labor) which are transformed into two outputs (coffee and banana) in the coffee production process (Figure 2.3). Fertilizer and pesticide are two additional inputs that could be included but are not due to limited use by farm households. We consider two outputs in the base framework, as coffee is often intercropped with bananas and competes for inputs. That is considering only coffee output would underestimate TFP without taking banana production into consideration.

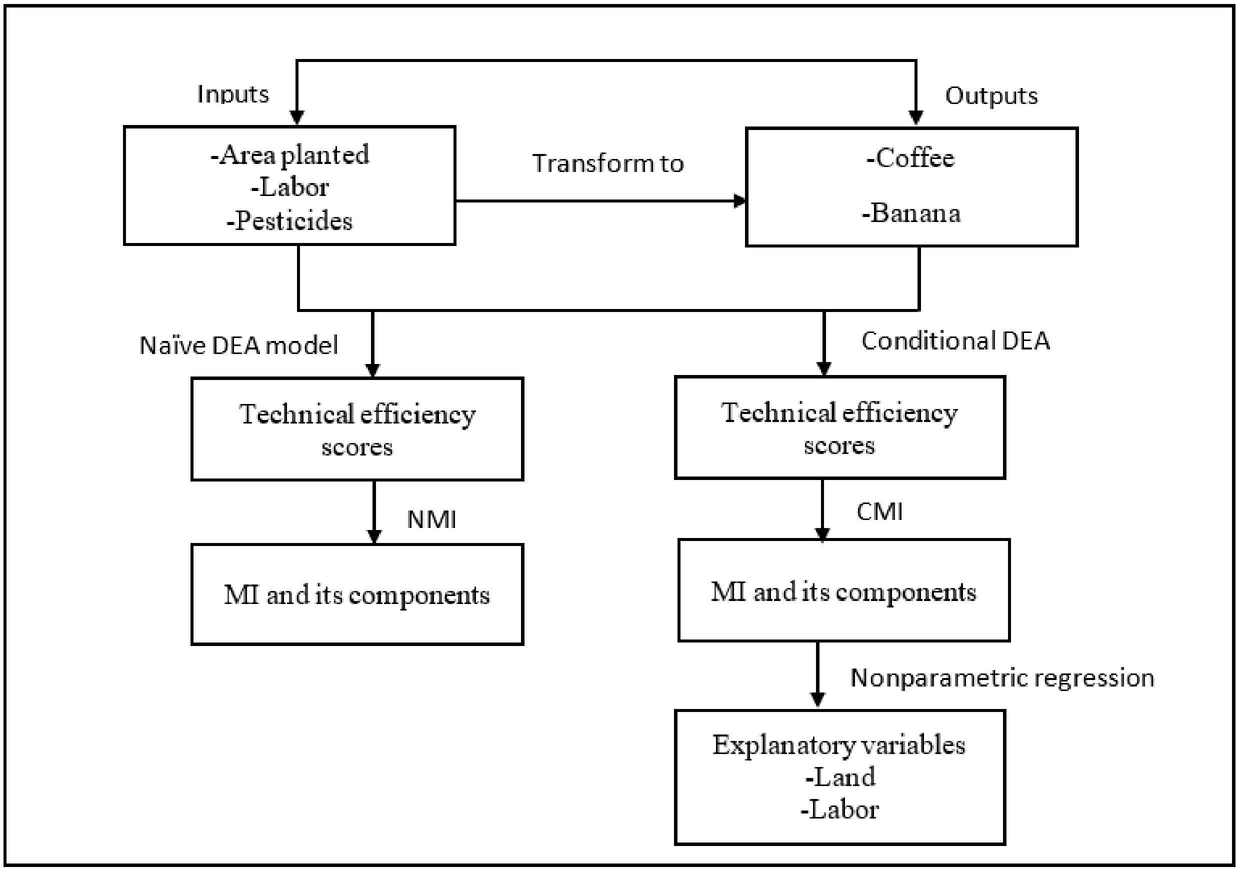

Figure 2.3. Methodological approach

Productivity is measured using the Malmquist Index based on technical efficiency estimates using Data Envelopment Analysis (DEA). Productivity estimation is completed in several stages. In the first stage, technical efficiency scores are estimated separately using an unconditional DEA model, as well as a conditional DEA model that accounts for differences in the average age of coffee trees across farms. Then an unconditional Malmquist index (NMI) is estimated using the technical efficiency scores from the unconditional DEA model, while conditional Malmquist index (CMI) is estimated using the technical efficiency scores from the conditional DEA models. The two indexes are compared to determine the impact of the average age of coffee tree on TFP. Finally, in the second stage, we whiten the CMI scores to take out the effect of the average age of coffee trees and estimate a nonparametric regression model to assess the impact of land and labor inputs on the CMI and its components.

2.2.3.1 The Malmquist Index

There are several indexes in the literature that have been used in measuring productivity (TFP) over time such as the Paasche, Fisher, Laspeyres, Tornqvist, Hicks-Moorsteen and Malmquist indices. The most often applied index in the DEA literature is the Malmquist Index. Following Färe *et al.* (1994) , the Malmquist Index (MI) approach is used to estimate total factor productivity (TFP). The MI is a non-parametric measure of TFP which can be estimated using Data Envelopment Analysis (DEA) to construct the measure. According to (Coelli *et al.*, 2005) and (Ludena, 2010), the MI has been applied widely in measuring farm productivity, because of its advantages that: (i) price data is not required, (ii) all farms are not assumed to be efficient, and (iii) the objective function is not assumed to be behavioral (e.g. cost minimization or profit maximization) (Defrenet *et al.*, 2016). Furthermore, with the MI, TFP can be decomposed into technical change (shift in the efficient boundary between period t and $t+1$) and efficiency change (or catch-up, the relative position of the farm to the production frontier between period t and $t+1$).

The catch-up component of the MI examines the change in the cross-sectional efficiency of a farm from period t to $t+1$, while the technical change (shift) component examines the movement in the efficient frontier from period t to $t+1$ (in terms of how much more output can be produced from a given level of input when operating efficiently) (Färe *et al.*, 1994). It is therefore assumed that frontiers can shift over time (Berg *et al.*, 1992). In the presence of inefficiency, relative movements of a farm over time will thus depend on its position relative to the corresponding frontier and the position of the frontier itself. Productivity growth over time fails to differentiate between changes that arise from a farm ‘catching-up’ to its own frontier and those arising from shifts over time of the frontier when inefficiency is not considered. Following Emrouznejad and Thanassoulis (2010), Figure 2.4 shows the MI decomposition, where a production frontier represents the efficient level of output *y* that can be produced from a given level of input *x*. While the figure illustrates a single-input, single-output case, DEA does allow for multiple inputs and multiple outputs.

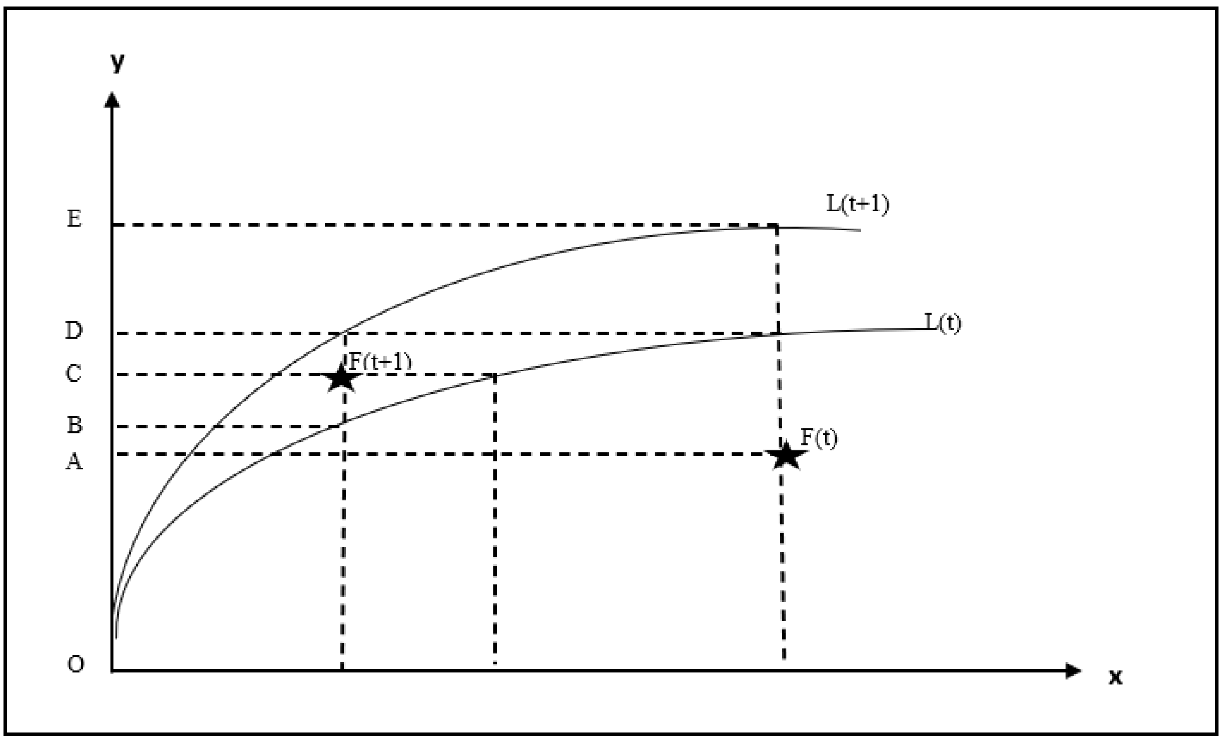

Figure 2.4. Decomposition of the Malmquist productivity index (Emrouznejad & Thanassoulis, 2010)

In Figure 2.4, each production function represents the frontier of the production possibility set defined by the underlying technology. L(*t+1*) represents the frontier at period *t+1* and L(*t*) represents a frontier at period *t*. Suppose F(*t*) represents an input-output bundle for a given farm in period *t*, (x^t, y^t) and F(*t+1*) represents an input-output bundle for the same farm in period *t+1*, (x^{t+1}, y^{t+1}) . In this study, we consider the output-based Malmquist Index of productivity change. Following Färe *et al.* (1994), to define the output-based Malmquist Index we assume that for each period *t=1…, T*, the production technology at L(*t*) models the transformation of inputs, $x^t \in \mathbb{R}_+^N$, into outputs, $y^t \in \mathbb{R}_+^M$,

$$\mathrm{L}(t) = \{(x^t, y^t): x^t \text{can produce } y^t\}$$

The output distance function is defined at *t* according to Shephard (1970) as:

$$d_o^t(x^t, y^t) = \inf\{\theta: (x^t, {y^t}/_{\theta}) \in \mathrm{L(t)}$$

$$= (\sup\{\theta: (x^t, \theta y^t) \in \mathrm{L(t)}\})^{-1}$$

The function $d_o^t(x^t, y^t) \leq 1$ if and only if $(x^t, y^t) \in$ L(t). In addition, $d_o^t(x^t, y^t) = 1$ if and only if production is technically efficient. In terms of the *y*-axis in Figure 2.4, the output-oriented efficiency measure for a farm operating at F(*t*) can be defined by the ratio ${A}/_{D}$, which implies that output can be expanded holding the level of input fixed to make production technically efficient with respect to the frontier in period *t*.

The distance functions considered can be defined with respect to two different time periods. For example:

$$d_o^t(x^{t+1}, y^{t+1}) = \inf\{\theta : (x^{t+1}, {y^{t+1}}/{\theta}) \in \text{ L(t)}$$

Such a distance function represents the maximal proportional change in output required to make a farm at F(*t+1*) in Figure 2.4 using (x^{t+1}, y^{t+1}) feasible relative to the production function or technology in period *t*. This is equivalent to the ratio ${C}/{B}$ according to the graphical analysis in Figure 2.4. The value ${C}/{B}$ exceeds unity because of the shift in the frontier, however the farm operating at F(*t+1*) is technically inefficient compared to the frontier in period *t+1*. A distance function $d_o^{t+1}(x^t, y^t)$ which measures the maximal proportional change in output required to make (x^t, y^t) feasible at period *t+1* can be constructed in a similar manner.

The output-based Malmquist Index is defined as the geometric mean of two Malmquist Indexes from period *t* and *t+1* following Färe *et al.* (1994) as:

$$m_o(y^{t+1}, x^{t+1}, y^t, x^t) = \left[\frac{d_o^t(y^{t+1}, x^{t+1})}{d_o^t(y^t, x^t)} \times \frac{d_o^{t+1}(y^{t+1}, x^{t+1})}{d_o^{t+1}(y^t, x^t)}\right]^{1/2}$$

The Malmquist Index can be decomposed into efficiency and technical change components, where the expression outside the brackets represents efficiency change and the expression inside the brackets represents technical change. That is:

$$m_o(y^{t+1}, x^{t+1}, y^t, x^t) = \frac{d_o^{t+1}(y^{t+1}, x^{t+1})}{d_o^t(y^t, x^t)}\left[\frac{d_o^t(y^{t+1}, x^{t+1})}{d_o^{t+1}(y^{t+1}, x^{t+1})} \times \frac{d_o^t(y^t, x^t)}{d_o^{t+1}(y^t, x^t)}\right]^{1/2}$$

From the graphical illustration in Figure 2.4, the output-oriented Malmquist index can be expressed as:

$$m_o(y^{t+1}, x^{t+1}, y^t, x^t) = \left(\frac{C}{D}\right)\left(\frac{D}{A}\right)\left[\frac{E}{D} \times \frac{D}{B}\right]^{1/2} = \left(\frac{C}{A}\right)\left[\frac{E}{B}\right]^{1/2}$$

where the expressions in the parenthesis represents efficiency change while the expression in the brackets represents technical change. Malmquist indexes greater (less) than unity imply increases (decreases) in productivity. Similarly, technical change and efficiency change values greater (less) than unity indicate improvement (deterioration) in technical change and efficiency change, respectively.

2.2.3.2 First stage of Malmquist Data Envelopment Estimation

This study adopts the output-oriented measure of the MI. The output-oriented measure is based on the idea of expanding output while holding the input level fixed (Grifell-Tatjé & Lovell, 1999). In the first stage one needs to estimate both the unconditional Malmquist index (NMI) and the conditional Malmquist index (CMI).

Estimation of NMI: The NMI is the standard MI estimated (in the literature) by using unconditional DEA models to estimate each associated distance function presented in Table 2.4. The DEA models are estimated using the bias correction procedure suggested by Simar & Wilson (2007) to correct for bias that arises from the serial correlation of DEA estimates. Consider *n* DMUs, where each DMU produces *g* outputs from different levels of *k* inputs in each period *t*. The output and input bundle (y_j^t, x_j^t) is for the j^{th} DMU in period *t*. For each DMU, the output-oriented distance functions are estimated based on the DEA models in Table 2.4. Where μ represents weights, *r* represents outputs, and i represents inputs.

Table 2.4. Linear programing models for calculating MI

Linear programing models for calculating MI	
$[d_o^t(y_t, x_t)]^{-1} = max\theta$ s.t. $\sum_j \mu_j y_{rj}^t \geq \theta y_{rjo}^t \qquad \forall_r$ $\sum_j \mu_j x_{ij}^t \leq x_{ijo}^t \qquad \forall_i$ $\sum_j \mu_j = 1, \mu_j \geq 0 \qquad \forall_j$	$[d_o^{t+1}(y_{t+1}, x_{t+1})]^{-1} = max\theta$ s.t. $\sum_j \mu_j y_{rj}^{t+1} \geq \theta y_{rjo}^{t+1} \qquad \forall_r$ $\sum_j \mu_j x_{ij}^{t+1} \leq x_{ijo}^{t+1} \qquad \forall_i$ $\sum_j \mu_j = 1, \mu_j \geq 0 \qquad \forall_j$
$[d_o^{t+1}(y_t, x_t)]^{-1} = max\theta$ s.t. $\sum_j \mu_j y_{rj}^{t+1} \geq \theta y_{rjo}^t \qquad \forall_r$ $\sum_j \mu_j x_{ij}^{t+1} \leq x_{ijo}^t \qquad \forall_i$ $\sum_j \mu_j = 1, \mu_j \geq 0 \qquad \forall_j$	$[d_o^t(y_{t+1}, x_{t+1})]^{-1} = max\theta$ s.t. $\sum_j \mu_j y_{rj}^t \geq \theta y_{rjo}^{t+1} \qquad \forall_r$ $\sum_j \mu_j x_{ij}^t \leq x_{ijo}^{t+1} \qquad \forall_i$ $\sum_j \mu_j = 1, \mu_j \geq 0 \qquad \forall_j$

Following Färe *et al.* (1994), the NMI can then be estimated as:

$$NMI = \left[\frac{d_o^t(y^{t+1}, x^{t+1})}{d_o^t(y^t, x^t)} \times \frac{d_o^{t+1}(y^{t+1}, x^{t+1})}{d_o^{t+1}(y^t, x^t)}\right]^{1/2} \tag{1}$$

where d_o is an output distance function based on the DEA model estimates. NMI is the productivity of the most recent production unit (F($t+1$)) under production technology in period $t+1$ relative to the previous production unit (F(t)) under production technology in period t. A value greater (less) than one implies positive (negative) total factor productivity growth between the two periods being examined. The NMI can equivalently be expressed as:

$$NMI = \frac{d_o^{t+1}(y^{t+1}, x^{t+1})}{d_o^{t}(y^{t}, x^{t})}\left[\frac{d_o^{t}(y^{t+1}, x^{t+1})}{d_o^{t+1}(y^{t+1}, x^{t+1})} \times \frac{d_o^{t}(y^{t}, x^{t})}{d_o^{t+1}(y^{t}, x^{t})}\right]^{1/2}.$$

In this sense:

$$NMI = \text{efficiency change } (\nabla eff) \times \text{technical change} (\nabla tech)$$

where:

$$\nabla tech = \left[\frac{d_o^{t}(y^{t+1}, x^{t+1})}{d_o^{t+1}(y^{t+1}, x^{t+1})} \times \frac{d_o^{t}(y^{t}, x^{t})}{d_o^{t+1}(y^{t}, x^{t})}\right]^{1/2}, \text{ and}$$

$$\nabla eff = \frac{d_o^{t+1}(y^{t+1}, x^{t+1})}{d_o^{t}(y^{t}, x^{t})}$$

The disadvantage of using the NMI is that it does not take account of environmental or external factors (frontier shifters) in estimating productivity. It assumes that all farms face the same production frontiers over time which is not the case in the presence of frontier shifters. This method therefore can result in biased estimates. For this reason, we adopt the CMI which corrects for potential frontier shifts, giving more accurate estimates.

Estimation of the CMI: External or fixed factors, such as the average age of coffee trees on a farm, are neither inputs nor outputs under the control of the producer in the short run, but are factors that can affect the production process (Daraio & Simar, 2007). Farmers can plant new trees and treat this input as variable in the long run (longer time horizons); however, this is not always possible in the short run as farmers may not have resources to do so. Moreover, farmers can only harvest coffee after the third year after planting a new tree. For this reason, we treat the average age of coffee trees as an external factor since we consider only the short run when examining TFP, which we assume to be between about 1 and 5 years, in this analysis. Several approaches have been suggested in the literature for introducing external-environmental variables in nonparametric frontier models such as one-stage approaches, two-stage approaches, and conditional DEA approaches. In the "one-stage" approach, environmental variables are directly included in the linear programming formulation along with the inputs and outputs, while in the two-stage approach the technical efficiency is computed in the standard way and used as the dependent variable in a second-stage regression where the environmental factors are regressed on estimated efficiency measures. The one-stage approach is criticized for requiring the classification of the environmental variables before the analysis and making assumptions about these factors such as free disposability. The two-stage approach is criticized by Simar & Wilson (2007) in that efficiency estimates are serially correlated and the first stage efficiency estimates are biased. Daraio & Simar (2007) introduced the conditional DEA approach, which overcomes most of the challenges posed by both the one-stage and two-stage approaches. This paper applies this approach in estimating TFP and its components. We term this the conditional Malmquist Index (CMI).

The CMI is estimated by solving the conditional DEA models for each corresponding distance function in the CMI presented in Table 2.5, where the DEA models are conditioned on the average age of coffee trees (*Z*). To achieve this conditional relationship, we first order the farm based on average age of the coffee trees used in production (or on the plantation) for each farm from youngest to the oldest. We then divide the set of farms into groups by partitioning the set of farms based on the age of trees, so that each successive group of farms represents farms with older coffee trees (on average) than the prior group. The assumption is that farms in the same group operate under a similar production frontier. This grouping is required since DEA is based on the fact that efficiency is estimated relative to the behavior of other decision-making units, so a group of decision-making units is needed for an efficiency estimate to be obtained and a large enough group to maintain reliability of the estimates. Based on the sample size, we divide the farms into five groups with each group containing approximately 37 farms for the Uganda sample and 120 farms for the Ethiopia sample. The subgroup sizes are smaller for the Uganda farms than Ethiopia because the sample size from Uganda is much smaller than that from Ethiopia. We then estimate the four conditional DEA models in Table 2.5 for each group separately, bootstrapped 1,000 times following Bădin *et al.* (2012) and Simar & Wilson (1998) to correct for bias. The bootstrap procedures help to overcome the bias that stems from serial autocorrelation (Simar & Wilson, 1998).

Table 2.5. Linear programing models for calculating CMI

Linear programing models for calculating CMI	
$[d_o^t(y_t, x_t)\|]^{-1} = max\theta\|Z$ s.t. $\sum_j \mu_j y_{rj}^t \geq \theta y_{rjo}^t\|Z \quad \forall_r$ $\sum_j \mu_j x_{ij}^t \leq x_{ijo}^t\|Z \quad \forall_i$ $\sum_j \mu_j = 1, \mu_j \geq 0 \quad \forall_j$	$[d_o^{t+1}(y_{t+1}, x_{t+1})\|Z]^{-1} = max\theta\|Z$ s.t. $\sum_j \mu_j y_{rj}^{t+1} \geq \theta y_{rjo}^{t+1}\|Z \quad \forall_r$ $\sum_j \mu_j x_{ij}^{t+1} \leq x_{ijo}^{t+1}\|Z \quad \forall_i$ $\sum_j \mu_j = 1, \mu_j \geq 0 \quad \forall_j$
$[d_o^{t+1}(y_t, x_t)\|Z]^{-1} = max\theta\|Z$ s.t. $\sum_j \mu_j y_{rj}^{t+1} \geq \theta y_{rjo}^t\|Z \quad \forall_r$ $\sum_j \mu_j x_{ij}^{t+1} \leq x_{ijo}^t\|Z \quad \forall_i$ $\sum_j \mu_j = 1, \mu_j \geq 0 \quad \forall_j$	$[d_o^t(y_{t+1}, x_{t+1})\|Z]^{-1} = max\theta\|Z$ s.t. $\sum_j \mu_j y_{rj}^t \geq \theta y_{rjo}^{t+1}\|Z \quad \forall_r$ $\sum_j \mu_j x_{ij}^t \leq x_{ijo}^{t+1}\|Z \quad \forall_i$ $\sum_j \mu_j = 1, \mu_j \geq 0 \quad \forall_j$

The CMI is then calculated as:

$$CMI|Z = \left[\frac{d_o^t(y^{t+1}, x^{t+1})|Z}{d_o^t(y^t, x^t)|Z} \times \frac{d_o^{t+1}(y^{t+1}, x^{t+1})|Z}{d_o^{t+1}(y^t, x^t)|Z}\right]^{1/2} \tag{2}$$

where Z represents the average age of the coffee tree, which is the conditioning or external variable. The CMI can be decomposed into technical efficiency change (catch-up effect) and the technical change (frontier shift) as:

$$CMI|Z = \frac{d_o^{t+1}(y^{t+1}, x^{t+1})|Z}{d_o^t(y^t, x^t)|Z}\left[\frac{d_o^t(y^{t+1}, x^{t+1})|Z}{d_o^{t+1}(y^{t+1}, x^{t+1})|Z} \times \frac{d_o^t(y^t, x^t)|Z}{d_o^{t+1}(y^t, x^t)|Z}\right]^{1/2}$$

where:

$$\nabla tech|Z = \left[\frac{d_o^t(y^{t+1}, x^{t+1})|Z}{d_o^{t+1}(y^{t+1}, x^{t+1})|Z} \times \frac{d_o^t(y^t, x^t)|Z}{d_o^{t+1}(y^t, x^t)|Z}\right]^{1/2}$$

$$\nabla eff|Z = \frac{d_o^{t+1}(y^{t+1}, x^{t+1})|Z}{d_o^t(y^t, x^t)|Z}$$

The individual ratios of conditional and unconditional productivity scores and the components $\left(R_1 = \frac{CMI|Z}{NMI}, R_2 = \frac{\nabla eff|Z}{\nabla eff}, R_3 = \frac{\nabla tech|Z}{\nabla tech}\right)$ are examined using nonparametric regression analyses to estimate the local effect of Z on the estimation of the CMI versus the NMI (i.e. the bias), as well as for the related efficiency change and technical change measures. Analyzing ratios as a function of Z enables the capture of the marginal effect of Z on an efficiency measure such as the MI (Daraio & Simar, 2007). This approach provides an illustration of how the average age of coffee trees impacts the MI and its components over time. The marginal effect is estimated using equation (3) below.

2.2.3.3 Second stage of Malmquist Data Envelopment Analysis

The concept of regressing efficiency scores on external or environmental variables (to the production process) has been widely applied in the DEA literature. However, this second stage regression is likely meaningless when using unconditional efficiency scores in the presence of environmental variables external to the problem that result in shifts in the efficiency frontier (Simar & Wilson, 2007, 2011). Thus, in this study we use the conditional scores for the second stage of analysis. In this stage, we estimate the impact of land and labor on farm productivity on a conditional estimate of the MI and its components (CMI, $\nabla tech|Z$ and $\nabla eff|Z$) to be able to assess effects across farms. According to Bădin *et al.* (2012), this can be achieved by first whitening the conditional productivity measures of the effects due to the external or environmental variables of conditions (i.e. average age of coffee trees). The whitening procedure involves two steps. First, the marginal effect of the average age of the tree on the productivity measures is estimated using the following regression:

$$\widehat{\omega^{z}} = \beta(Z) + \sigma(Z)\varepsilon \qquad (3)$$

where $\widehat{\omega^{z}}$ is CMI, $\nabla tech|Z$ or $\nabla eff|Z$, $\beta(Z)$ is the average effect of the average age of the tree on the productivity measure, $\sigma(Z)$ measures the dispersion of productivity distribution as a function of average age of the tree, and ε is the unexplained part of the productivity score for a farm. Following Badin *et al*. (2012), $\beta(Z)$ is estimated using nonparametric regression methods (e.g., local polynomial) of the average age of the tree on productivity and $\sigma(Z)$ is obtained by regressing the squares of the fitted residuals from the first step on Z (average age of coffee trees) using the same nonparametric regression methods.

To whiten the productivity scores, we take out the impact of the conditioning variable or average age of coffee trees, by calculating:

$$\hat{\varepsilon} = \frac{\widehat{\omega^Z} - \beta(Z)}{\sigma(Z)} \tag{4}$$

What is left over in equation (4), $\hat{\varepsilon}$, is the normalized residual productivity net the effect of the external or environmental variable(s). If Z and ε are not strongly correlated in equation (3), the result in equation (4) can be interpreted as a pure productivity measure for the farm. The result in equation (4) can be used as a proxy for managerial productivity in cases where Z and ε are correlated since it is the remaining part of productivity after removing the location and scale effect due to Z. A large value of $\hat{\varepsilon}$ represents a farm with low productivity, while a small (negative) value represents higher productivity. The measure allows for the comparison of farms that originally faced different efficiency or production frontiers, which would not be possible using the NMI (Bădin *et al.*, 2012).

We use STATA16 to measure the impact of land and labor on productivity indices using a nonparametric kernel regression (equation 5). We use a bootstrap procedure to obtain standard errors as the dependent variable is estimated.

$$\varepsilon_i = \theta_t X_i + \rho_{ti} \tag{5}$$

where X is the amount of land under coffee production for farm i, θ represents parameters to be estimated and ρ is a mean zero IID error term. We further test if regressions using the unconditional productivity index and the conditional productivity index give similar marginal effects for land and labor.

2.3 Results and discussion

This section analyses coffee farm productivity conditional on the average age of coffee trees on a farmer's land and the impact of inputs on TFP and its components (based on the Malmquist Index) in Uganda and Ethiopia.

2.3.1 Analysis of unconditional and conditional scores of MI and its components

We compare conditional estimates of the MI and its components (efficiency and technical change) for each age category used to estimate the conditional MI scores with the corresponding unconditional estimates by each age category using the unconditional MI estimator (Tables 2.6 and 2.7). The comparisons help to illustrate the bias arising from using unconditional productivity scores compared to the conditional scores. Based on the results, there are some farms that happen to be productive when the unconditional scores are used, which should not actually be as productive as estimated.

For Uganda, the unconditional scores indicate that farmers are more productive, with less progress toward moving to the frontier over time (efficiency change), and greater shifts in the frontier over time (technical change) relative to the conditional scores. For Ethiopia, we see similar patterns, but it is not always clear. The conditional scores indicate that generally farm productivity decreases with the average age of the coffee trees. The decrease in overall farm productivity is due to the decrease in technical change with average age of the trees.

Table 2.6. Comparison of conditional and unconditional productivity scores for Uganda

Uganda (n=187)					
		Conditional model		**Unconditional model**	
Productivity measure	**Average age of the trees (years)**	**Mean**	**Standard deviation**	**Mean**	**Standard deviation**
Malmquist Index	<10.1	0.85	0.71	1.34	0.99
	10.1-14	1.32	1.16	1.42	1.17
	14.1-17	0.96	0.45	1.08	0.40
	17.1-20	0.50	0.35	1.01	0.47
	>20	0.72	0.30	1.07	0.51
Efficiency Change	<10.1	1.70	2.83	1.13	1.81
	10.1-14	2.24	2.45	0.98	0.97
	14.1-17	1.69	1.69	1.04	1.64
	17.1-20	3.24	4.78	1.35	2.56
	>20	1.02	1.37	1.01	0.94
Technical Change	<10.1	2.35	3.94	2.73	2.56
	10.1-14	1.71	2.46	2.34	2.45
	14.1-17	1.45	1.99	2.05	1.44
	17.1-20	0.47	0.63	2.00	1.90
	>20.9	1.58	1.51	1.72	1.10

Table 2.7 Comparison of conditional and unconditional productivity scores for Ethiopia

Ethiopia (n=606)					
		Conditional model		**Unconditional model**	
Productivity measure	**Average age of the coffee trees (years)**	**Mean**	**Standard deviation**	**Mean**	**Standard deviation**
Malmquist Index	<5	1.38	1.13	2.06	3.06
	5-8.9	2.14	1.75	1.78	1.42
	9-14.9	2.74	4.87	2.46	4.80
	15-20.9	1.38	0.88	1.54	0.96
	>20.9	0.95	1.07	1.84	1.80
Efficiency change	<5	3.83	8.60	1.02	1.94
	5-8.9	0.78	1.24	0.98	1.58
	9-14.9	8.08	47.58	5.71	36.99
	15-20.9	1.46	1.86	0.73	1.15
	>20.9	7.84	23.08	1.76	6.07
Technical change	<5	1.38	1.94	4.50	4.72
	5-8.9	8.79	14.35	5.45	7.18
	9-14.9	3.66	4.22	6.96	11.98
	15-20.9	3.17	6.96	8.01	19.84
	>20.9	0.61	0.86	5.02	6.50

2.3.2 Examining the impact of the average age of coffee trees on the ratios of CMI and NMI (and their components).

We estimated the marginal effect of the average age of the coffee tree (*Z)* on the ratio of farm level conditional MI (and its components, efficiency, and technical change) to their unconditional counterparts using non-parametric kernel regressions. The results are presented in Table 2.8. The ratios of conditional to unconditional estimates enables us to measure the marginal effect of the average age of the coffee trees for a given farm on farm productivity. Analysis of the ratios enables estimation of the bias arising from using unconditional DEA and the direction of the bias.

Based on the results, most of the marginal effect of the average age of coffee trees on the ratio of scores of the MI and its components were statistically significant for all productivity measures for both Ugandan and Ethiopian coffee farms. These results indicate that the average age of the coffee trees on the farm is important to take into consideration when examining productivity in the short run in both countries. The Malmquist index ratio and technical change ratio showed negative effects for both Ugandan and Ethiopian coffee farms, which implies that generally the unconditional model overestimate farm productivity (MI) and technical change (frontier shift). Efficiency change ratios were negative for Ugandan coffee farms (though not significant) but positive for Ethiopian coffee farms, which means that the unconditional model overestimates efficiency change for Uganda but underestimates it for Ethiopia. Therefore, results provide evidence that the unconditional estimates are biased because of the shift in the frontier due to the changes in efficiency frontiers as the average age of the coffee trees changes over time (Bădin *et al.*, 2012). Thus, we only examine and interpret the conditional scores moving forward.

Table 2.8.Associaation of the average age of the coffee tree and productivity ratios (Malmquist Index, Efficiency change and Technological change)

		Uganda (n=187)	Ethiopia (n=606)
Ratio (Conditional/Unconditional)		**Observed Estimate**	**Observed Estimate**
Malmquist Index Ratio	Mean	0.82***	0.87***
		[0.55]	[0.38]
	Effect (average age of the tree)	-0.02**	-0.02***
		(0.01)	(0.02)
	R-squared	0.16	0.50
Efficiency change Ratio	Mean	11.78***	3.85***
		[45.99]	[0.32]
	Effect (average age of the tree)	-0.63	0.11***
		(0.72)	(0.05)
	R-squared	0.01	0.29
Technical change Ratio	Mean	1.85**	0.65***
		[5.15]	[0.70]
	Effect (average age of the tree)	-0.06*	-0.03***
		(0.06)	(0.03)
	R-squared	0.01	0.48

Bootstrap Standard Errors in parentheses
Standard deviations in brackets
* P<0.10, ** P<0.05, *** P<0.01

Figure 2.5 and 2.6 present graphs of the marginal effects of the average age of the coffee trees on the MI ratios and its components for Uganda and Ethiopia, respectively. The blue lines in the figures provide reference line where the conditional model estimate equates to the unconditional model estimate (i.e., when no bias is present). The red curve in each figure presents the marginal effect of the average age of the coffee trees on MI and its components.

The graph of the Malmquist index ratio vs average age of the coffee trees for Ugandan coffee farms (figure 2.5A) presents a similar trend to Ethiopian coffee farms (figure 2.6A). The graphs indicate a downward bias as coffee trees get older. It is evident from figures 2.5A and 2.6A that the unconditional model overestimates the productivity of young coffee trees (below 15 years for Ethiopia and below 5 years for Uganda) and underestimates productivity for older coffee trees (above 20 years for both countries). For Ethiopian farms, the unconditional model underestimates efficiency change (figure 2.6B) and overestimates technical change (figure 2.6C) of younger trees (below 20 years). Figure 2.6C further indicates that the unconditional model underestimates technical change for trees older than 20 years. The shape of the Malmquist index graph (figure 2.6A) is greatly influenced by the effect from technical change. For Ugandan farms, the shape of the Malmquist index graph is influenced by a combination of both efficiency change and technical change. These results show that generally farm productivity in Ugandan and Ethiopian coffee farms is declining faster than expected, this is due to older coffee plantations that get less productive with increases in the average age of the coffee trees

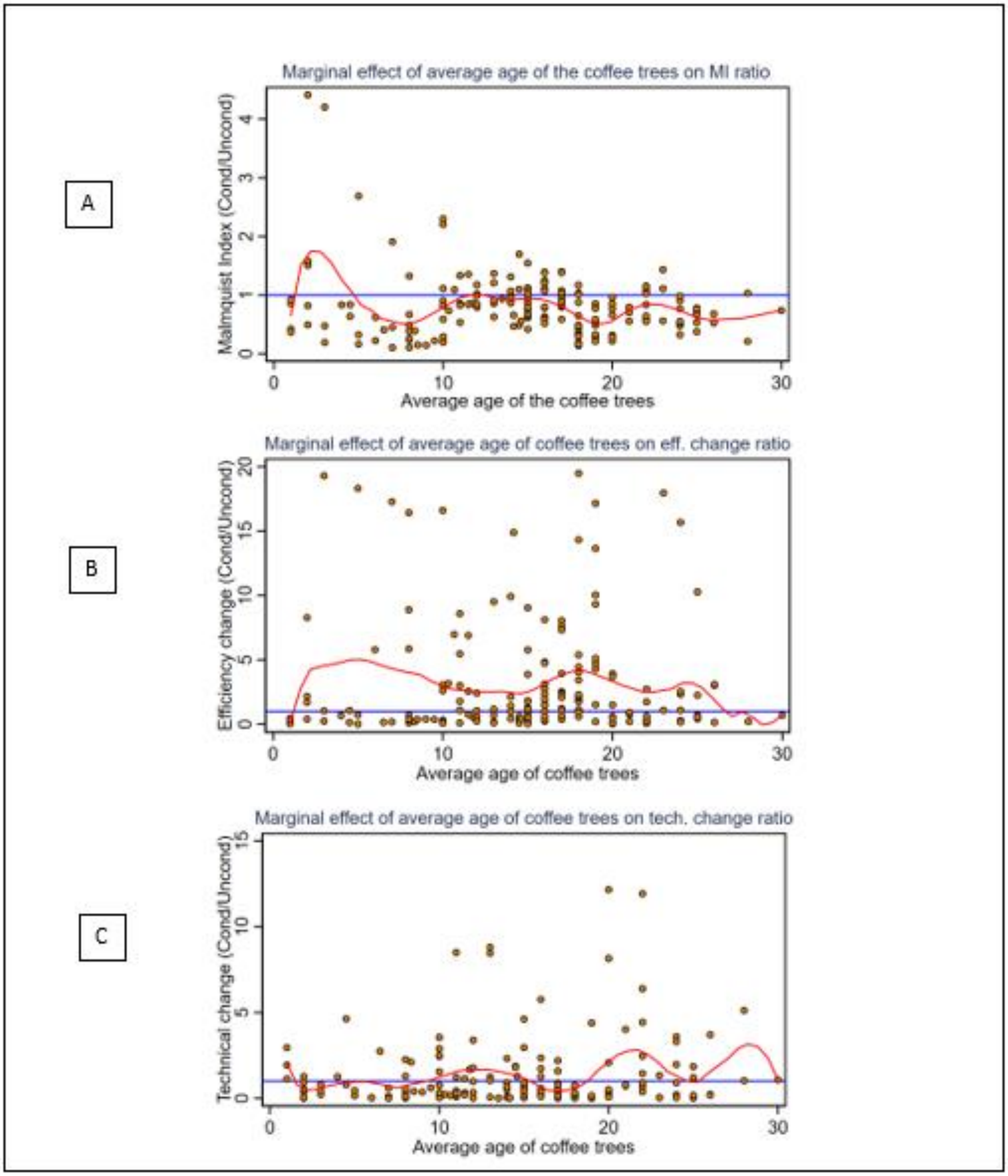

Figure 2.5 Marginal Effect of average age of the coffee tree on the ratios (Malmquist Index, Technical change, and Efficiency change) for Uganda

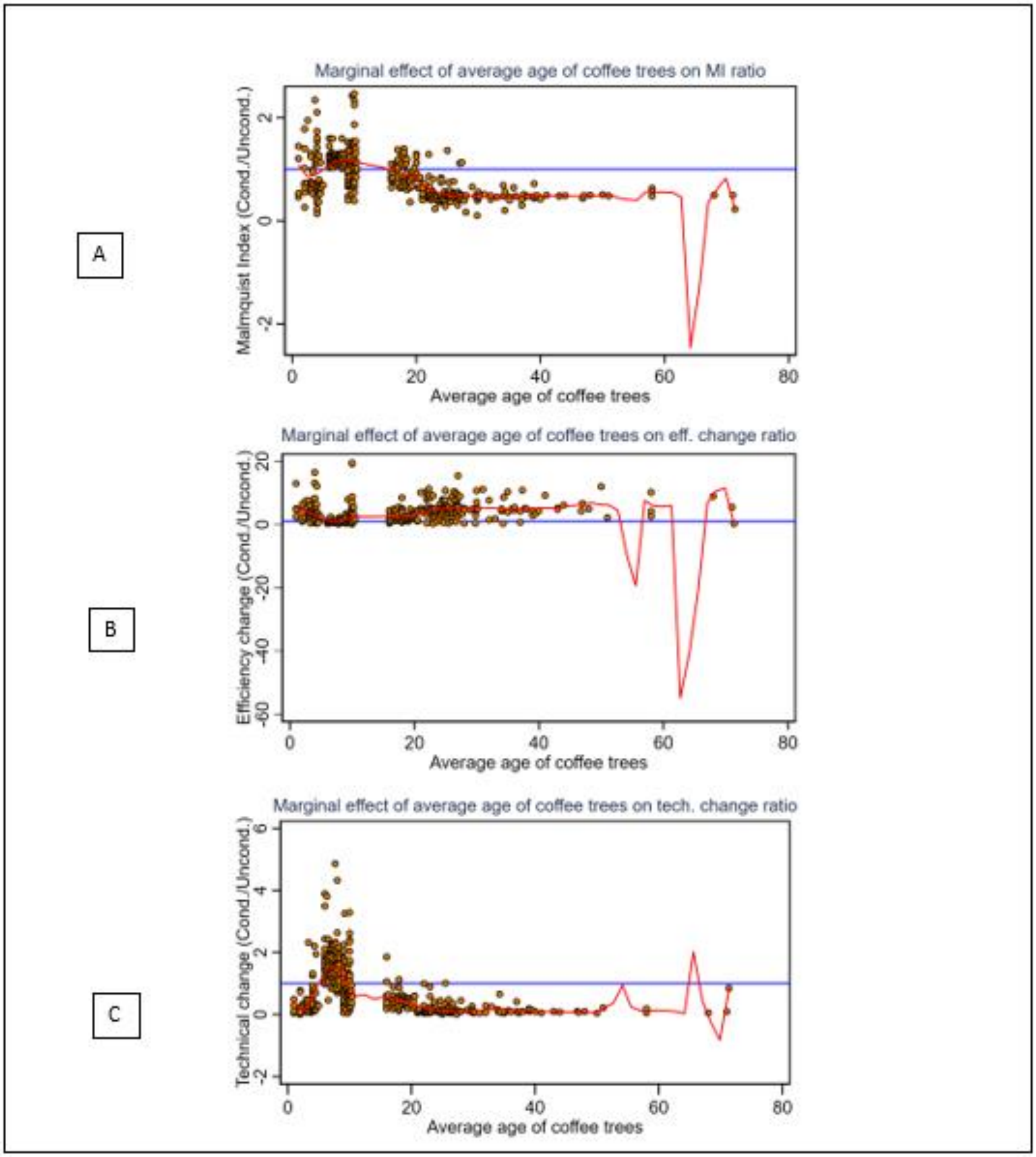

Figure 2.6 Marginal effect of average age of the coffee tree on the ratios (Malmquist Index, Technical change, and Efficiency change) for Ethiopia

2.3.3 Examining the impact of average age of the coffee tree on CMI and its components.

In the second stage of the analysis, we whiten the conditional MI, efficiency change and technical change scores to remove the effect of the external variable (average age of the coffee trees) following Bădin *et al*. (2012). The whitening process makes the conditional estimates more meaningful and enables ranking of farms independent of the average age of the coffee trees. We first present the effect of the average age of the coffee trees on the conditional scores and later present the ranking of farms based on whitened scores and how these are distributed based on the average age of the coffee trees on-farm for both Uganda and Ethiopia.

In estimating the marginal effect of average age of the coffee tree on the conditional scores, the dependent variable was the conditional score unlike in the previous section where the dependent variable was the ratio of conditional to unconditional estimates. The marginal effect of average age of the coffee trees on the conditional Malmquist Index scores was negative and significant for both Uganda and Ethiopia (Table 2.9). This implies that as the average age of the coffee trees increases, TFP decreases for both countries. Therefore, farms with older trees are less productive compared to those with much younger trees. A similar result was found in Vietnam by (Huong & Anh, 2019) and (Thang *et al.*, 2009) who also asserted that productivity of coffee trees declines as age increases.

Table 2.9. Effect of the average age of the coffee trees on CMI and its components (conditional efficiency change and conditional technical change

		Uganda (n=187)	Ethiopia (n=606)
Conditional measure		**Observed Estimate**	**Observed Estimate**
Conditional Malmquist Index	Mean	0.87***	1.58***
		[0.70]	[2.17]
	Effect (average age of the tree)	-0.03***	-0.04***
		(0.01)	(0.01)
	R-squared	0.21	0.08
Conditional efficiency change	Mean	1.92***	4.40***
		[2.88]	[21.63]
	Effect (average age of the tree)	-0.01	0.15**
		(0.03)	(0.08)
	R-squared	0.01	0.02
Conditional technical change	Mean	1.57***	3.38***
		[2.54]	[8.06]
	Effect (average age of the tree)	-0.08*	-0.16***
		(0.05)	(0.03)
	R-squared	0.08	0.10

Bootstrap Standard Errors in parentheses
Standard deviations in brackets
* P<0.10, ** P<0.05, *** P<0.01

The marginal effect of the average age of the coffee trees has the opposite effect on efficiency change for both countries. The marginal effect is negative and insignificant for Uganda, while Ethiopia shows a positive and significant (5%) marginal effect. This implies that the efficiency change increases with the average age of the coffee trees for Ethiopian farms. Farmers are becoming more efficient in how to deal with the trees as they get older. Therefore, farms get closer to the frontier as the trees get older on average. This is likely due to how the frontier is shifting with the average age of the coffee trees.

The marginal effect of the average age of the coffee trees on technical change is negative and significant for Ugandan and Ethiopian farms (10% and 1% respectively). This implies that the frontier is retracting inward as the average age of the coffee trees increases.

Figure 2.7 and 2.8 present the graphical relationship between the average age of the coffee trees and the conditional productivity scores. The productivity scores are represented on the vertical axis while the average age of the coffee trees is represented on the horizontal axis. The graphs present a similar trend and confirm the effect of the average age of the coffee trees on productivity of coffee farms in Uganda and Ethiopia.

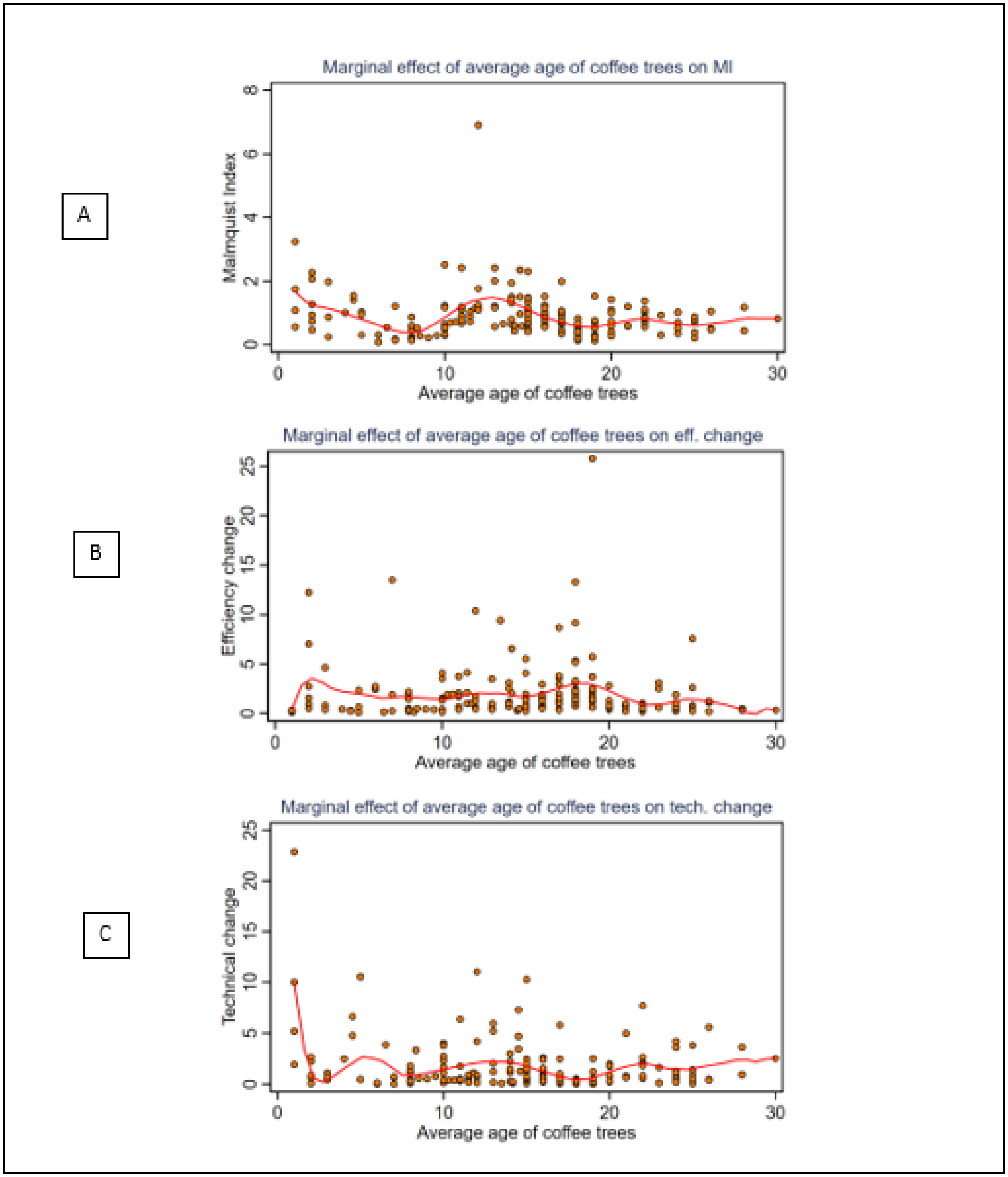

Figure 2.7 Marginal Effect of average age of the coffee trees on Malmquist Index, Technical change, and efficiency change for Uganda

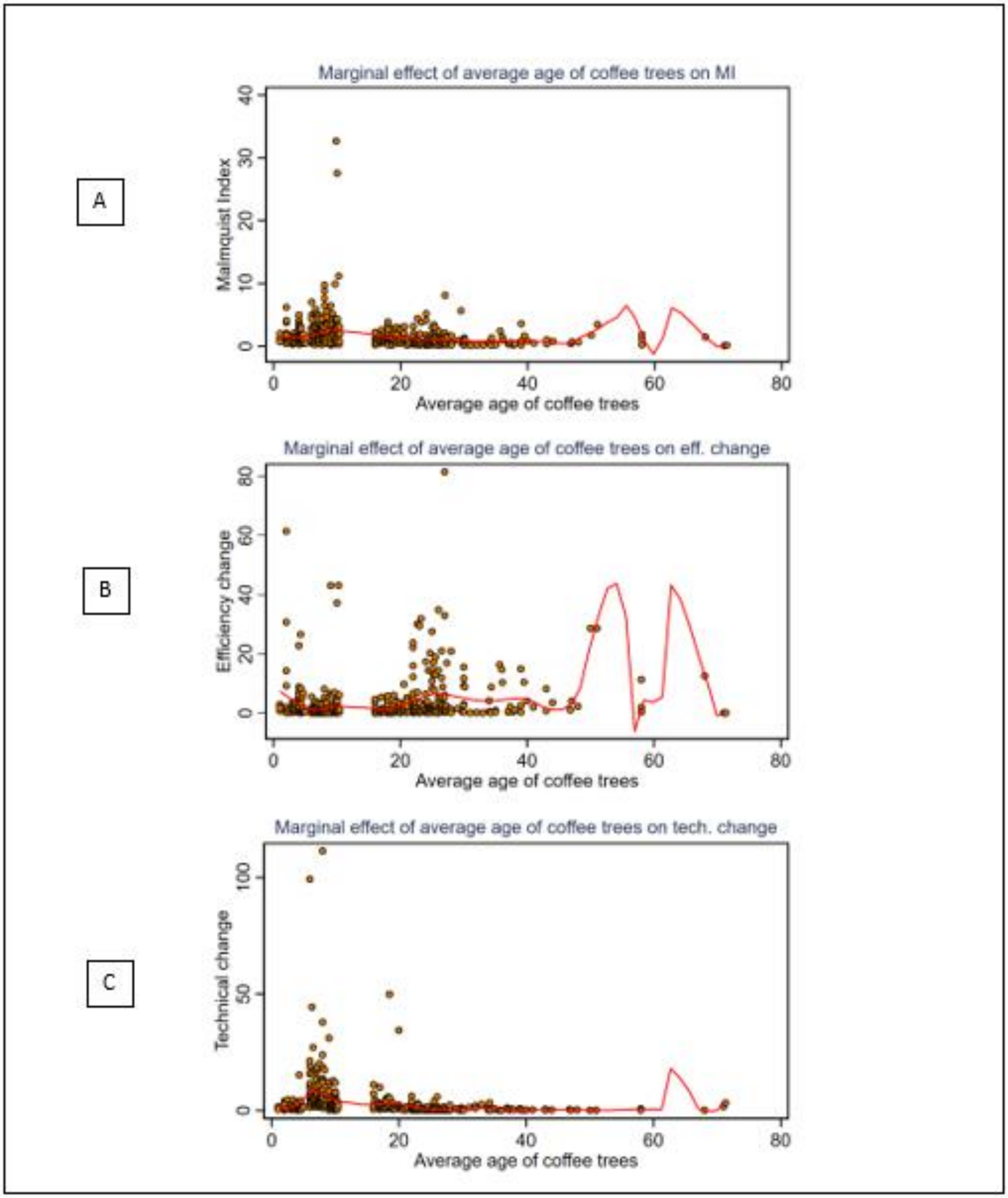

Figure 2.8 Marginal Effect of average age of the coffee trees on Malmquist Index, Technical change, and Efficiency change for Ethiopia

2.3.4 Whitening productivity scores and ranking farms based on average age of the coffee trees

The ranking of the farms based on average age of the coffee trees and whitened productivity scores is presented in Tables 2.10 and 2.11. After whitening, the smaller the score, the better the performance for traditional technical efficiency measures (Bădin *et al.*, 2012; Simar & Wilson, 2007). However, for productivity measures based on the Malmquist Index and its components, this is not the case. We find that the bigger the score the better the performance. For instance, a score of 1.6 indicates a better performance than a score of 0.5.

Table 2.10 Ranking based on whitened conditional productivity scores and average age of the coffee trees for Uganda

Uganda (n=187)			
Whitened conditional productivity measure	**Average age of the tree (years)**	**Mean**	**Standard deviation**
Malmquist Index	<10.1	1.62	1.31
	10.1-14	2.50	2.14
	14.1-17	1.83	0.83
	17.1-20	0.98	0.64
	>20	0.93	0.60
Efficiency Change	<10.1	2.26	3.73
	10.1-14	2.97	3.23
	14.1-17	2.23	2.24
	17.1-20	4.28	6.31
	>20	1.36	1.80
Technical Change	<10.1	2.60	4.21
	10.1-14	1.92	2.63
	14.1-17	1.64	2.14
	17.1-20	0.59	0.67
	>20	1.77	1.62

Table 2.11 Ranking based on whitened conditional productivity scores and average age of the coffee trees for Ethiopia

Ethiopia (n=607)			
Whitened conditional productivity measure	**Average age of the coffee tree (years)**	**Mean**	**Standard deviation**
Malmquist Index	<5	1.46	1.16
	5-8.9	2.24	1.79
	9-14.9	2.85	4.99
	15-20.9	1.45	0.90
	>20.9	1.01	1.10
Efficiency change	<5	3.27	7.64
	5-8.9	0.56	1.10
	9-14.9	7.04	42.26
	15-20.9	1.16	1.66
	>20.9	6.83	20.50
Technical change	<5	1.25	0.99
	5-8.9	1.86	1.41
	9-14.9	2.35	3.94
	15-20.9	1.25	0.71
	>20.9	0.90	0.87

According to the results, the overall Malmquist Index score indicates that for farmers with younger plantations (less than 15 years on average) we see higher managerial productivity compared to farmers with older plantations on average for both Ugandan and Ethiopian farms. Technical change and efficiency change show similar trends as the Malmquist Index scores for both countries. This might be the case since farmers with younger plantations may need to use less inputs for efficient production, while farmers with older plantations are overusing inputs to try to squeeze out some additional yield, which ends up being less productive and less efficient.

2.3.5 Estimating the impact of inputs on whitened conditional productivity scores

We analyzed the whitened scores (pure productivity) to determine the impact of inputs on coffee whitened farm productivity using nonparametric kernel regression. The advantage of this approach is that it does not make assumptions about the functional form of the examined relationship and is therefore not as subject to misspecification error (Čížek & Sadıkoğlu, 2020). The results in Table 2.12 present a summary of the regression results which include the average predicted value of whitened productivity measures such as (Malmquist Index, Efficiency change and Technological change) and the marginal effect of inputs (land and labor) on the whitened productivity measures.

Table 2.12. Non-parametric estimation of the impact of production inputs on productivity

		Uganda (n=187)	Ethiopia (n=606)
Productivity measure		**Observed Estimate**	**Observed Estimate**
Malmquist Index	Mean	1.66^{***}	1.661^{***}
		[1.29]	[2.222]
	Effect		
	Land	-0.34^{**}	-0.01
		(0.13)	(0.26)
	Labor	0.02^{**}	0.01^{*}
		(0.01)	(0.01)
	R-squared	0.16	0.07
Efficiency change	Mean	2.54^{***}	1.41^{***}
		[3.81]	[1.75]
	Effect		
	Land	-0.80^{***}	-0.12
		(0.68)	(1.66)
	Labor	0.02	0.02^{**}
		(0.02)	(0.01)
	R-squared	0.11	0.10
Technical change	Mean	1.76^{***}	3.76^{***}
		[2.71]	[19.21]
	Effect		
	Land	0.07	-0.01
		(0.18)	(0.21)
	Labor	0.03^{**}	0.01^{*}
		(0.01)	(0.01)
	R-squared	0.15	0.070

Bootstrap Standard Errors in parentheses
Standard deviations in brackets
* P<0.10, ** P<0.05, *** P<0.01

Based on the results in Table 2.12, Ugandan and Ethiopian farms show similar marginal effects of inputs on productivity (TFP). The land input has a negative and significant marginal effect (5%) on the Malmquist Index or TFP for farms in Uganda and though not significant, the marginal effect of land on TFP in Ethiopia is also negative. This implies that increasing the amount of land allocated to coffee farms decreases coffee farm productivity. This is likely because increasing the amount of land spreads out other resources too thin.

On the other hand, the labor input has a positive and significant marginal effect on the Malmquist Index for both countries (5% for Uganda and 10% for Ethiopia). This implies that increasing the amount of labor allocated to coffee production increases productivity. With the growing industrialization and urbanization of Uganda and Ethiopia, labor has been shifting away from the agricultural sector to the industry in form of rural-urban migration and search for white collar jobs (World-Bank, 2020b). The youth who are the most energetic and more productive tend to move to urban areas leaving the weak and elderly in the rural areas (World-Bank, 2013). This has reduced the labor force available on coffee plantations, yet coffee growing is a labor-intensive crop. Therefore, labor has become a key limiting factor in coffee production. The shift of labor from coffee to growing more staple foods has constrained labor availability for coffee growing and the available itself is less productive. Countries like Indonesia have greatly improved agricultural output through resource expansion (labor) and productivity improvement (Arifin *et al.*, 2019).

The land input has a negative significant marginal effect on efficiency change (1%) for Uganda. Similarly, the marginal effect on efficiency change is negative though not statistically significant for Ethiopia. This implies that for Uganda, increasing the land input decreases efficiency change and thus decreases overall productivity (TFP). This implies that farmers become more distant from the frontier over time because of spreading out other inputs too thin. On the other hand, the labor input has a positive marginal effect on efficiency change. Though the marginal effect is not significant for Ugandan farms, it is significant at 1% for Ethiopian farms. This implies that improving labor efficiency increases farmer's relative position to the frontier over time. This result would seem to imply that more labor improves productivity through improving efficiency change.

In terms of technical change, the land input does not have statistically significant marginal effects for either Ugandan or Ethiopian farms. However, the labor input has a positive marginal effect on technological change for both Ugandan and Ethiopian coffee farms (5% and 10%) respectively. This implies that increasing labor would cause an outward shift in the production frontier. This result supports the need for younger and more skilled labor.

Generally, labor positively impacts TFP through technical change in Uganda but shows no direct effect on efficiency change, while it impacts TFP in Ethiopia through both technical change and efficiency change. The positive effect of labor on efficiency change in Ethiopia implies that farmers get closer to the production frontier with increases in labor skill and quantity. Uganda could likely improve its TFP through improving labor efficiency. On the other hand, land negatively impacts TFP through efficiency change in Uganda, but does not significantly affect TFP in Ethiopia. High investments in the land input slows efficiency change (catching up) in Uganda likely due to spreading out of other inputs too thin.

2.4 Summary, conclusion, and policy implications

Standard approaches to measuring total factor productivity of farms when using techniques such as DEA, often ignore external or environmental effects, such as the average age of the coffee trees on a coffee plantation, assuming homogenous production frontier for all farms in the short run. However, differences in the average age of the coffee trees on a farm (or other external/environmental factors) leads to differences in production frontiers across farms. That is, farms with different average age of the coffee trees face different production frontiers in the short run. Estimating coffee farm productivity in the short run using an unconditional estimator of TFP or productivity fail to account for this potential heterogeneity in the production and efficiency frontiers across farms, resulting in biased productivity estimates and misleading conclusions.

In this study, we explicitly analyze the potential impact of average age of the coffee trees on productivity. We estimate total factor productivity based on the MI (and its components) using unconditional and conditional Data Envelopment Analysis. The conditional MI helps to account for differences in the average age of the coffee trees when estimating productivity. We find that the average age of the coffee trees has a negative and statistically significant marginal effect on coffee farm overall productivity (TFP) in both Uganda and Ethiopia and should not therefore be ignored in estimating productivity of coffee farms, especially in the short run. As the trees get older, the efficient frontier decreases (younger coffee trees are more productive compared to much older trees that are more than 20 years of age). This result is important for development programs such as extension to identify the actual productivity loss due to managerial inefficiency.

We further analyze the impact of inputs such as land and labor on productivity (TFP). Increasing land inputs in coffee production decreases productivity due to thinning out of other inputs while increasing labor inputs improves productivity since this is often a limiting factor in coffee production. Labor positively impacts TFP through technical change in Uganda but shows no direct effect on efficiency change while it impacts TFP in Ethiopia through both technical change and efficiency change. The positive effect of labor on efficiency change in Ethiopia implies that farmers get closer to the production frontier with increase in labor skills and productivity. Uganda could likely improve its TFP through improving labor efficiency, as well. On the other hand, land negatively impacts TFP through efficiency change in Uganda but does not significantly affect TFP in Ethiopia. High investments in land inputs slows efficiency change (catching up) in Uganda due to spreading out of other inputs too thin.

Based on the research findings, Uganda can improve productivity (TFP) by replacing old coffee trees. The government of Uganda through the UCDA has a coffee tree planting program that is aimed at distributing planting materials to farmers. However, the new tree planting rates (replacement rates) are not fast enough to replace older less productive trees, resulting in the average age of coffee trees increasing over time. We therefore recommend that the government should consider expanding the existing coffee tree planting program to enable more farmers to easily access planting materials for replacement as soon as the trees are due (after the age of 15 years). The government should incorporate an extension program within the tree planting program to sensitize farmers about the need to replace old coffee trees and when the replacement should be done. The existing tree planting program has instead facilitated expansion of coffee farms rather than replacement of the old trees (Lybbert *et al.*, 2018). An extension program could also help advise farmers to first replace the old coffee trees before opening more land to plant new ones, since opening new farms may require extra costs due to land expansion and yet they could improve output by using the existing land resources.

According to the results, increasing the labor force working on coffee farm can help improve productivity. With increasing labor constraints, the positive impact of labor on productivity implies that Uganda can improve its TFP by improving labor quality (efficiency and productivity) of existing workers. This can be done through training farmers and other employees who work on the coffee plantations. In Indonesia, higher schooling amongst the farm population account for about 10% of the growth in labor productivity (World Bank, 2017). Continued improvement in the quality of labor can offset the decline in the overall size of the farm labor force.

Chapter 3 - Examination of quality differences in coffee along the supply chain in Uganda. Implications for the industry and the economy

3.1. Introduction

The quality of a cup of coffee (end-product) is based on a set of attributes that meet consumer needs and preferences (Bote, 2016). There is a growing global demand for high-quality coffee (FAO, 2019; McCluskey, 2015), yet Uganda continues to observe low quality of coffee. After the 1991 market liberalization in the Ugandan coffee market, new policies were formed to ensure higher quality coffee. For instance the Uganda Coffee Development Authority (UCDA) was mandated by the national government to ensure that the quality of coffee that reaches the port of export should be of high quality[6] (UIA, 2016). As a result, more effort and quality control systems were instituted at the exporter level of the supply chain to help ensure higher quality. However, the policy resulted in lower quality coffee as foreign matter content in the coffee beans entering the export warehouses exceeded 10% of purchases, compared to only 5% or less before market liberalization (Baffes, 2006). Low coffee quality has led to revenue losses at all levels of the supply chain, as it results in lower prices and market rejections (UCDA, 2018). For instance, a total of 160,026 bags of coffee (3.6%) were referred for non-conformance to export standards in 2018, an increase from 2.4% in 2017 due to a high percentage of defects (28.79% of the rejects) (UCDA, 2018).

[6] High quality refers to coffee with average sized beans, green in color, a moisture content of less than 12.5%, and clean (free from foreign materials such as stones)

The quality of a coffee cup is determined by decisions made along the supply chain including at planting, harvesting, processing, and marketing (Wintgens, 2009). The current market system has prevented producers and other actors at lower levels of the supply chain from ensuring quality due to a lack of incentives, which were provided before market liberalization (Chiputwa *et al.*, 2015). As a result, we observe some actions in the coffee supply chain that lower quality, which could be related to incentive problems in the supply chain. At the farm level, quality is jeopardized at harvest and post-harvest stages. At harvest, farmers practice coffee stripping (where farmers harvest everything from the tree in one harvest), which leads to the harvest of immature coffee beans due to the need for quick cash (Beshah *et al.*, 2013). The unripe (green) coffee cherries are often mixed with the ripe (red) cherries, lowering quality. During harvest, coffee beans are gathered on the ground and collected all at once, which can further reduce quality. Poor post-harvest handling methods, such as rough hulling of fresh coffee using rudimentary tools like bare feet and sticks for hulling, as well as drying on the bare ground and inadequate drying also lower quality. Farmers mainly use the sun drying method, which requires at least three to five weeks and can impact quality especially when farmers need quick cash (Beshah *et al.*, 2013). During storage, if conditions are not favorable, coffee tends to mold due to moisture re-absorption, which can further reduce quality.

At the marketing stage, quality is jeopardized during transportation and at bulking centers (Kilimo, 2012). Middlemen have been reported to engage in unprofessional trading practices like adulteration of coffee with foreign materials that increase the weight of their coffee bags (USAID, 2010). The national coffee strategy set by (UCDA, 2015) states that middlemen sometimes process wetter coffee, which further decreases quality. Improper drying can discolor coffee beans and can result in molding. Blending lower quality coffee with higher quality compromises the final quality of the product. During transportation, coffee from different origins is sometimes mixed, which makes traceability impossible. Moreover, at times the transport systems used are inadequate. All the above actions create an unstable environment that prevents the efficient functioning of the coffee supply chain and lowers coffee quality and revenues for actors along the supply chain.

Studies on coffee quality in Uganda have often focused on either the production or processing level (Bolwig & You, 2007). This study analyzes coffee quality following a supply chain approach. Based on the coffee supply chain map presented in chapter one, exporters make coffee transactions through two market channels: middlemen and farmers' groups. There is limited empirical evidence of how incentive structures along different market channels impact coffee quality in Uganda. Public policies that do not consider incentives and governance structures along the supply chain will likely result in adverse effects. Thus, the purpose of this study is to analyze the incentive structures in current marketing channels and understand their impact on coffee quality. We further apply economic theory (Principal-Agent theory) to explain the empirical results. Specifically, we consider two market channels, which include the farmer-middleman-exporter market channel (referred to as the middlemen channel), and the farmer-farmers' group-exporter market channel (referred to as the famers' group channel). The specific objectives of the study are: (1) to characterize coffee supply chain actors according to their transaction characteristics; and (2) to determine the impact of marketing channels on coffee quality. We hypothesize that the middleman channel negatively impacts quality of the coffee beans. The objectives are answered using primary data collected from farmers, middlemen and exporters through in person surveys and interviews. Results will help inform policy makers on the possible ways of improving coffee quality and welfare of actors along the supply chain.

3.2 Literature Review

3.2.1. Determinants of coffee quality

Pre-harvest, harvest, and post-harvest management activities play a unique role in determining coffee quality. The cupping quality is determined by each step starting from coffee variety selection to the final coffee drink preparation. Haile & Kang (2019a) stated that post-harvest processing activities such as pulping, processing, drying, hulling, cleaning, sorting, grading, storage, roasting, grinding, and cupping contribute about 60% of the quality of green coffee. Post-harvest processing changes the chemical composition of green coffee beans that can directly or indirectly affect coffee quality (Bhumiratana *et al.*, 2011; Wintgens, 2009).

3.2.1.1. Impact of harvesting on coffee quality

Proper timing of harvest is an important task of quality management. As the coffee cherries mature, they acquire suitable chemical compositions such as volatile compounds which are responsible for aroma and flavor properties of the coffee (Pimenta *et al.*, 2008). Such compounds are very low in immature coffee and if harvested can negatively affect cup quality. The greatest challenge in harvesting coffee is obtaining uniform maturity. Climatic conditions affect flowering, which prevents uniform maturity of the cherries (Pimenta *et al.*, 2018). There are mainly two mechanisms that can be used in coffee harvesting including strip and selective harvesting. Under strip harvesting, all coffee cherries are harvested at once (Haile & Kang, 2019a). In this kind of harvesting both ripe and unripe cherries are harvested which can greatly affect coffee quality. Selective harvesting on the other hand is where only the ripe mature cherries are harvested. This is important for quality management as it ensures consistency of the coffee. However, the downside of this method is that it is more labor-intensive.

3.2.1.2. Impact of post-harvest activities on coffee quality

Processing: After harvesting, the cherries undergo processing to obtain the green beans. There are mainly three processing methods including dry (natural) processing, semi-dry processing and wet (washed) processing (Haile & Kang, 2019b). In Uganda, Robusta coffee is mostly dry processed and Arabica coffee is mostly wet processed. Generally wet processing produces better quality coffee than dry processing. A report by (UCDA, 2019a) noted that wet processed coffee receives a higher price compared to dry processed coffee. Figure 3.1 briefly describes the processing methods.

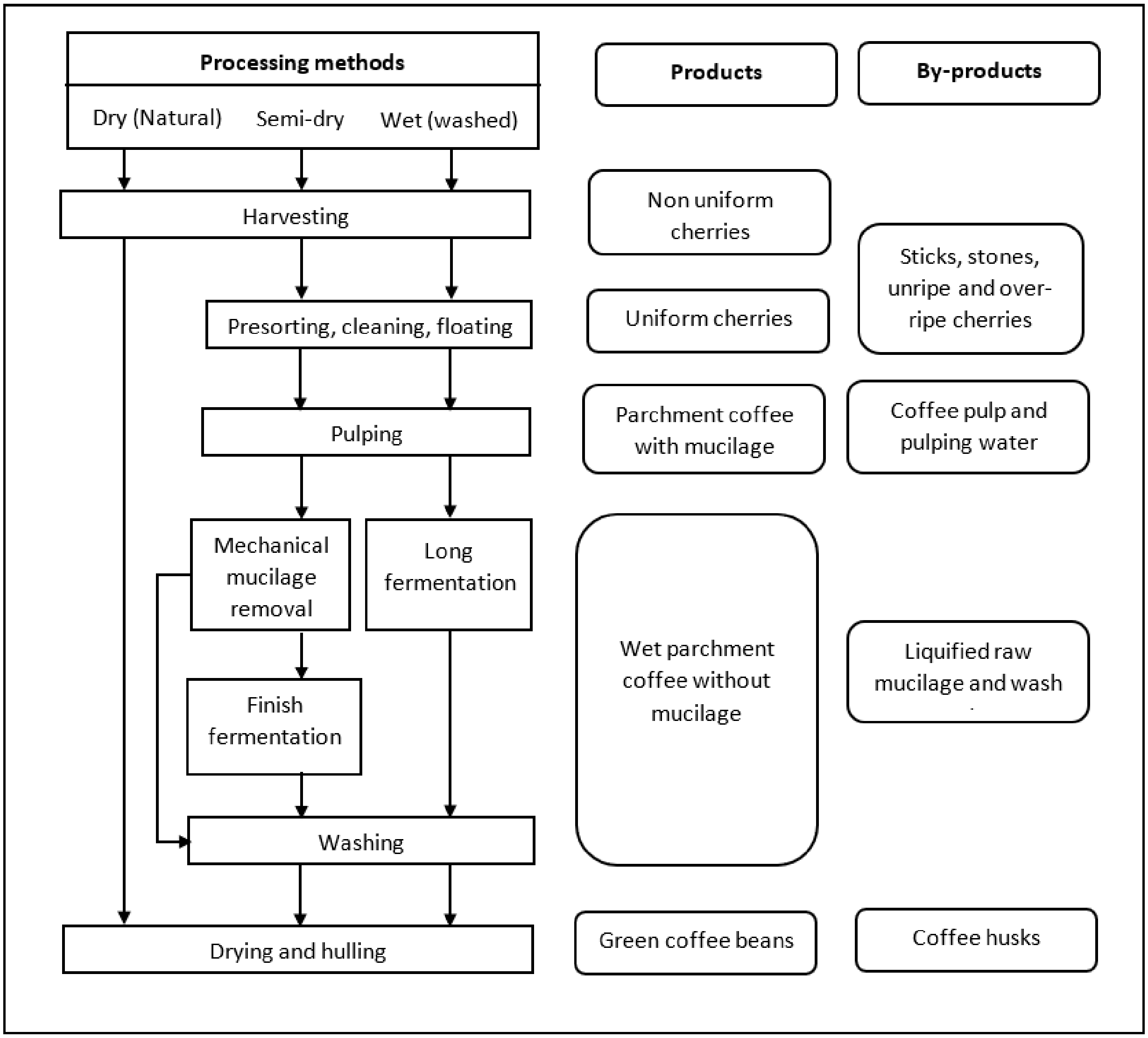

Figure 3.1. Description of coffee processing mechanism (Haile & Kang, 2019a)

In the wet processing method, the cherries are washed with water immediately after harvesting. This allows presorting, cleaning, and removal of floaters (bad or unripe cherries) (Haile & Kang, 2019b). The cherries are then de-pulped, mucilage is mechanically removed, and beans are allowed to ferment. Fermentation allows formation of organic acids which enhances the coffee bean quality (Massawe & Lifa, 2010; Silva *et al.*, 2013). At the end of this process, parchment or washed coffee is obtained. The final step is to dry the parchment and separate it from the bean (hulling) using machines or local materials like a motor. The semi-dry processing method is an intermediate process between wet and dry processing (Haile & Kang, 2019b). This method differs from the wet processing method in that the mucilage is not removed from the parchment before complete fermentation and drying. The dry processing method is the simplest, cheapest, and oldest method of processing (Haile & Kang, 2019a). In this method, the cherries are dried immediately after harvesting either by sun or mechanical driers. Sun drying is the most common method used in Uganda and takes between 10 to 15 days to complete the drying process. The dry method of processing poses a high risk of secondary fermentation, which may result from not removing the mucilage. The dried outer parts are separated from the bean in a hulling process (Da Rosa *et al.*, 2015).

Drying: Drying is the most important step in coffee processing (Haile & Kang, 2019a). It facilitates removal of excess water from the fresh cherries and simplifies the hulling process. The acceptable moisture level is between 9 and 12% (Subedi, 2011), according to the International Coffee Organization. Drying controls the growth of molds that are responsible for quality deterioration. Drying can be done merchantly by driers or sun-dried. Sun drying is the most common and cheapest method of drying. It is highly dependent on weather conditions. In Uganda, drying is often done on cement floors, tarpaulins or raised surfaces to reduce foreign matter contamination. Constant raking is done to ensure uniform distribution of heat during the drying process. When the temperatures are very high, it is advisable to cover the coffee beans to avoid cracking. Parchment coffee requires more attention, the cherries are more susceptible to heat damage. Mechanical driers on the other hand use hot air to dry the coffee. Less heat damage is reported for mechanical drying since it is much easier to control the temperature compared to sun drying.

Hulling and sorting: Hulling follows drying and involves the extraction of the coffee bean from its covering (parchment for wet processed or cherry for dry processed). This can be done mechanically or locally using a wooden mortar and pestle. Quality can be greatly affected if coffee is not properly dried before hulling. The hulled coffee beans are then sorted by either machine and/or hand. Hand sorting is the most common technique; however, it is very labor intensive. Coffee beans are sorted based on size, color, and density. Sorting enables removal of defects, which can lower the quality of the coffee cup.

Storage: Graded coffee beans are packed and stored until they are shipped and sold in the market. The storage house should have controlled temperature and humidity to maintain the quality of the coffee beans and to increase shelf-life. Alfonso (2001) noted that if coffee beans are stored for a longer period at a relative humidity of 60%, cellular degradation occurs, which results in oil leaking, affecting the chemical composition of the coffee beans. According to (NTCDB, 2009), oil becomes more acidic when coffee beans are stored for a long period of time, affecting quality.

Roasting and grinding: This is a critical step in coffee bean processing. Roasting affects the formation of aroma and flavor characteristics of the final cup. Development of flavor compounds is determined by the duration of roasting and the final temperature of the coffee beans (Huschke, 2007). Similar coffee beans may produce different flavors when roasting conditions are varied (Schenker *et al.*, 2002). Applying the optimal roasting conditions, such as at optimal temperatures and times, helps in maintaining a high-quality cup (Buffo & Cardelli-Freire, 2004). The roasting profile, conditions and degree depend on the specific roast type. The common roasting types include light roast, medium roast, medium-dark roast, and dark roast. After roasting, the coffee beans are ground (crushed) into powder. This can be done using an electric machine or a mortar and the particle size depends on the intended use and personal preference.

3.2.1.3 Transaction characteristics affecting the quality of coffee

Transactions between coffee supply chain actors can be characterized by frequency and uncertainty (e.g. price uncertainty, quantity/volume uncertainty, seasonality, variety, among others) (van Wagenberg *et al.*, 2009). Transaction characteristics and the market channels through which coffee moves from the farmer to the exporter can affect the quality of coffee purchased in each transaction.

Market channel: Coffee moves to the exporter through either farmer's groups/cooperatives of middlemen (USAID, 2010). High-quality is more probable through a farmers' group, because it is easier for exporters to monitor quality through farmers' groups than middlemen (USAID, 2010). Farmers who participated in farmers' organizations often have a lower defect level in their delivered coffee beans, which is a key quality indicator (Susila, 2005). Tolessa and others (Tolessa *et al.*, 2018) had similar findings from research conducted in Ethiopia, where coffee beans sampled from cooperatives had higher quality compared to those sampled from private traders (middlemen). This implies that farmers' organizations could play a significant role in improving coffee quality.

An export agent can easily inspect bulk coffee from a farmers' group. Moreover, farmers' groups can monitor farmers to ensure that only ripe cherries are harvested, and proper drying is attained. Through groups, farmers have access to extension services focused on high quality management, which improves farmers' knowledge and skills. Farmers' associations contribute to dissemination of and educate farmers in quality enhancing practices (Hernandez-Aguilera *et al.*, 2015). Farmers' groups also allow farmers access to inputs such as pesticides and fertilizers, which contribute to production of high-quality coffee. For instance, resource poor farmers can get inputs from the group on credit and payback the group after harvesting. Farmers' groups are more concerned about their reputation and thus work hard to provide the required quality, which enhances traceability and repeat transactions. It is the duty of every member in a farmers' organization to ensure that their produce is of good quality (Longo, 2016). The farmers' groups have a constitution that allows them to penalize any member who does not meet their standards, which further allows them to enforce and maintain higher quality coffee.

Premium price: A premium price is a special price (usually higher than the ordinary price) offered to the seller by the buyer when high-quality coffee is delivered. It therefore acts as a financial incentive for the seller to deliver higher quality coffee. It is more costly to produce (farmers) or purchase (middlemen) high-quality coffee compared to low quality. Such costs associated with higher quality coffee include investments in good production systems, drying facilities, processing equipment and proper handling. Therefore, high-quality coffee will only be sold to exporters if its value exceeds the associated marginal costs. Insufficient price incentives for high-quality coffee can limit production of high-quality coffee at the farm level, which has been evidenced in coffee production in Lampung, Indonesia (Susila, 2005). Susila (2005) further noted that the incentives were not sufficient to compensate for the costs and risks involved in producing high-quality coffee, since buyers only considered weight due to moisture content and foreign matter. A study by Murekezi (2003) also reveals that price premiums associated with high-quality coffee provide incentives for farmers to maintain coffee trees and increase their productivity. Coffee preparation (pre-harvest, harvest, and post-harvest) activities require a lot of human intervention whose motivation is key in determining the end quality of coffee. Efforts to promote quality are affected by world prices and buyers' willingness to reward coffee quality improvement with adequate premiums for better than average quality.

Variety of the coffee: Uganda grows two varieties of coffee; Robusta (*Coffea canephora*) and Arabica (*Coffea arabica*) (UCDA, 2019a). The two varieties produce different flavor profiles and are grown for different reasons. There is a big trade-off in quality and flavor between Arabica and Robusta (Bicho *et al.*, 2013). Arabica is rated much higher in terms of quality and price compared to Robusta (Dias & Benassi, 2015). Most of the "specialty" coffees that are graded as high quality are Arabica and often earn a higher price (UCDA, 2019b). Table 3.1 shows the differences between Arabica and Robusta coffee.

Table 3.1 Differences between Robusta and Arabica coffee (Dias & Benassi, 2015; UCDA, 2019b)

Robusta	Arabica
Grown in the low altitude areas of Uganda, ranging from about 900-1,200 meters above sea level	Grown in high altitude areas between 1000- 2200 meters
Yields fruits after 2 years	Yields fruits after 4 years
High productivity	Low productivity
General quality-low	General quality-high
Robusta coffee has a greater yield	Arabica coffee has a lower yield
Contains 2.7% caffeine	Contains 1.5% caffeine
Contains 3-7% sugar	Contains 6-9% sugar and almost 60% more lipids
Less susceptible to pests and diseases, thus, needs less fungicides and pesticides	More susceptible to pests and diseases, thus, needs more fungicides and pesticides

Seasonality: Uganda has two rainy seasons, from March through May and from October through December (Bunn *et al.*, 2019). Seasonal variation is characterized by differences in rainfall and temperatures. A majority of small holder farms in Uganda rely on rainfall for crop production, including coffee (Gottschalk, 2020). Fluctuations in rainfall and temperatures result in decreases in quantity and quality of the crop (Jassogne *et al.*, 2013).

3.2.2. The importance and welfare implications of coffee quality

Efforts to improve quality involve costs which rational individuals will bear if the benefits that accrue to them outweigh such costs (Barham & Weber, 2012). This implies that a certain level of quality loss is unavoidable depending on the level of technology available to suppliers. For example, farmers can reduce the foreign matter content in the coffee by drying on raised surfaces, but if the costs of putting up such structures exceed the value of high-quality coffee, farmers are unlikely to adopt the technology. Economic incentives are thus very important in enhancing coffee quality. Studies have shown that larger operators are more likely to adopt technologies than small operations. For the case of Uganda, where 80% of the farmers are smallholders, this poses a potential constraint on technology adoption of practices that can help enhance coffee quality. However, if farmers organize themselves into groups and pool resources, they could spread the cost of the technology investments, likely making it more profitable and attractive.

According to theory, actors in the coffee supply chain make rational decisions that allow them to maximize their profits (suppliers) or well-being (consumers) (FAO, 2019), including decisions on the level of quality reduction they find acceptable. Coffee quality improvements can have a positive impact upon suppliers and consumers' well-being. Coffee suppliers, for example farmers, middlemen and exporters can increase their revenue and income by reducing losses due to quality deterioration. If quality deterioration is minimized, suppliers would have more high-quality coffee to sell using the same amount of inputs. Suppliers who ensure high-quality are likely to improve their reputation and strengthen their customer base, as well. Consumers' happiness (utility) from drinking a high-quality cup is also likely to increase. However, this may slightly increase the price of a cup of coffee.

The quality of coffee affects supply chain actors in various ways. Low quality coffee commands a lower price than high quality coffee, thus resulting in revenue losses for the actors (Varangis *et al.*, 2003). Downstream actors (producers) usually get the lowest price in the coffee supply chain; however, the prices are reduced further when quality is jeopardized, potentially significantly reducing margins. According to the International Trade Center (ITC) (2020), for any producer or exporter who wishes to improve their welfare through the coffee business, quality should always be the priority when preparing a shipment (ITC, 2020). When contract obligations are always strictly adhered to, strong reputations are created, which attracts good buyers that are willing to pay the price for higher quality. Strong reputations lead to repeat business and raises the level of interaction between the buyer and the seller from just price to price and quality. For exporters, quality is often the most important aspect in their marketing strategies. Since importers (roasters) only make payments subject to approval on arrival, rejects turn out to be very costly to the exporter in terms of revenue and market reputation.

Good quality management contributes to reducing poverty by enhancing income earning opportunities for coffee supply chain actors including poorer and small holder farmers. Reduced wastage due to bad quality rejects reduces income losses and high-quality improves supply chain actors' ability to bargain for price premiums (Varangis *et al.*, 2003). Proper pre- and post-harvest handling of coffee contributes to food security and health in various ways, as well. Production of high-quality coffee reduces food waste and losses arising from pest and disease damages. Harvesting mature coffee and proper storage reduces losses due to molding, increasing the amount of coffee available for consumption.

3.3. Methodology

3.3.1. Study area

The study was conducted in two major coffee growing regions of Uganda (eastern and central). The eastern region is highly known for Arabica coffee, while the central region grows mostly Robusta coffee. The two regions helped to capture differences across varieties and location. In the central region, traders from Masaka and Lwengo districts were selected for interview since they are among the major Robusta coffee producers, while in the eastern region, traders from Mbale district were selected for interviews since it is among the major Arabica coffee producers. Figure 3.2 shows the location of the study area on the Uganda map.

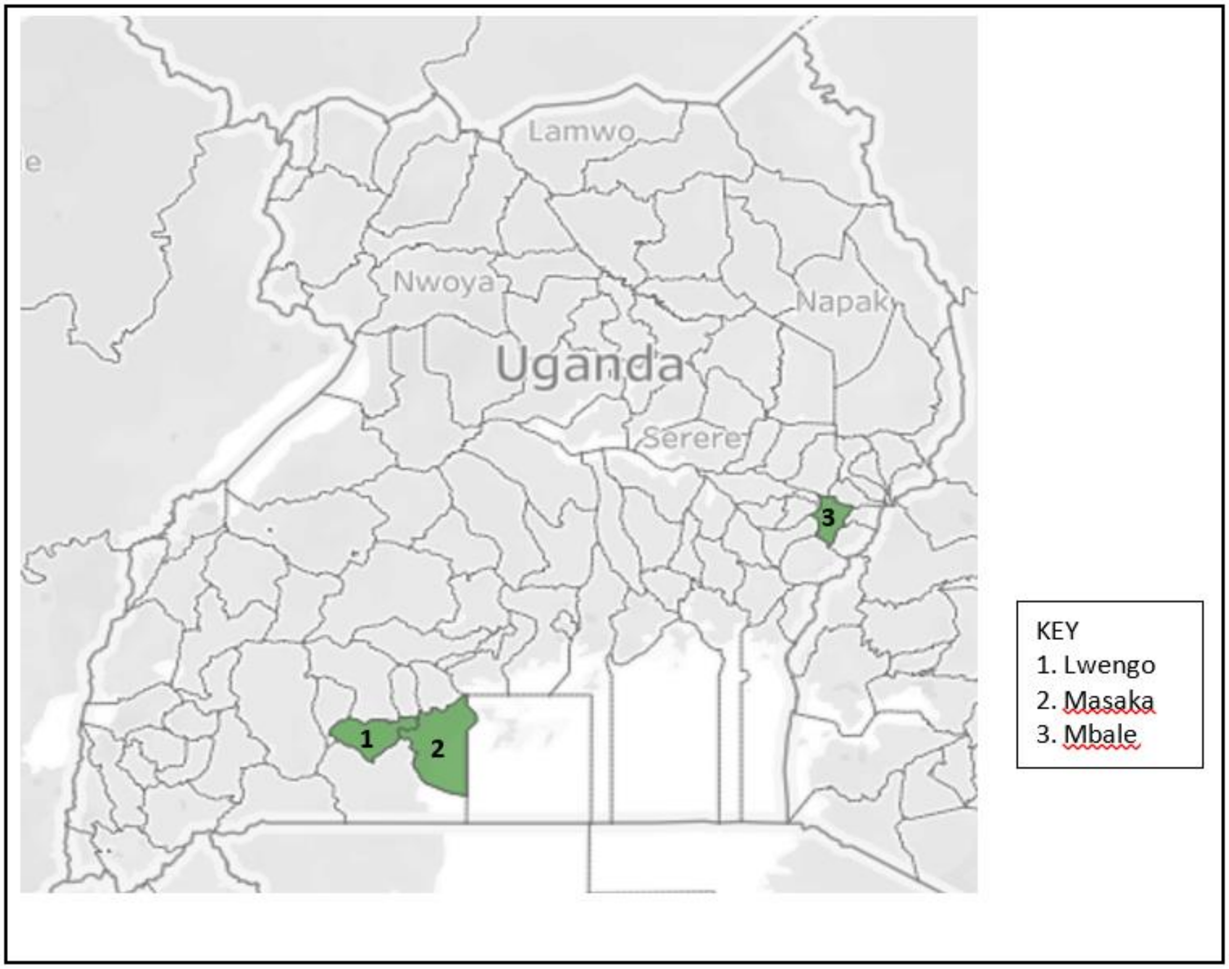

Figure 3.2. Map of Uganda showing the study area

3.3.2. Survey sampling

A survey questionnaire was pretested in Kiboga, one of the coffee-growing and trading regions in central Uganda. Using snowball sampling, a sample of 120 middlemen were interviewed from two major coffee producing regions in the country, 60 respondents from the eastern and central regions. The snowballing was initiated with a base of 15 middlemen provided by Uganda Coffee Development Authority (UCDA) personnel in the two regions. About 10 middlemen were interviewed from the base list. Each middleman interviewed was asked to suggest names and contacts of other middlemen they knew. This methodology provided a new set of middlemen for the interview. This process continued until 60 middlemen in each region were obtained summing up to the sample size of 120 middlemen.

For the exporters, a list of all registered exporters in the country was provided by UCDA. From this list, only exporters that were marked as active for the year 2019 were included in the study. A total of 30 exporters out of 35 active exporters were interviewed. The unit of analysis at the export level was a transaction. Based on the pretest, exporters purchased through two channels, farmers' groups and middlemen. Exporters were therefore asked to provide data on the two most recent transactions, this included one most recent transaction through the farmers' group and one most recent transaction through the middlemen channel for exporters that purchased through both channels. For exporters who only transacted through either farmers' group or middlemen channel, the two most recent transactions for that channel were considered. This therefore resulted in 60 observations in total.

To gain insights at the farm level, focus group discussions (FGDs) were conducted. We conducted four FGDs (two from each region). Participants for the FGDs were selected purposively. They included male and female farmers that were actively growing and selling coffee for the past 12 months. We included farmers that were selling individually and those that sold through famers' groups and cooperatives. Each group consisted of 12 members.

3.3.3. Survey Questionnaire

The data collected provides comprehensive information about key supply chain actors (farmers, middlemen and exporters) in the Uganda coffee industry. Data were collected using a structured survey questionnaire. The questionnaire was divided into three main sections including socio-economic, buying, and selling. The socio characteristics were collected for only middlemen and farmers and they included age, education level, and sex. Data on economic aspects were collected for all the actors including the exporters. Data collected included information on main sources of income, business experience, and market share. The buying and selling sections focused on business experience (e.g. how long the person has been involved in coffee trade), information on coffee suppliers and buyers (sellers' and buyers' profile including market needs), volumes transacted (quantities bought and sold), seasonality (fluctuations in volume and quality of coffee beans), quality aspects (characterizing high- and low-quality coffee, quality type purchased and handled by all actors (high or low), rewarding quality (premium price)), contractual arrangements in making transactions (type of contract; written or oral or no contract; and the specifications of the contracts) and finally the challenges faced in these transactions (buying and selling).

3.3.4. Data collection

Data were collected by a mix of face-to-face interviews and telephone interviews between January and February 2020. This was successfully conducted before the novel COVID-19 was declared as a pandemic in March 2020 by the World Health Organization. The face-to-face interviews enabled rigorous discussions with the respondents and field observations, which highly complemented the research. Telephone interviews were very useful in collecting data from the exporters as most of the exporters were very busy and hard to schedule for a face-to-face interview. The telephone provided the flexibility of discussion after work hours and on weekends.

Five enumerators were recruited and trained for two days to undertake the data collection exercise. The training included ethical conducts of research and the technicalities of the subject research. To ensure high quality of the data, only bachelor's degree and masters' degree holders with at least two years' experience were recruited. Tablets, notebooks, and audio recordings were used in data gathering. The data collection process was supervised by the researcher and the researcher conducted random interviews to ensure consistency of the data.

3.3.5 Data Analysis

Data were coded and analyzed using STATA version 16. The study is designed with two specific objectives, to characterize coffee supply chain actors and identify characteristics of coffee transactions at different nodes of the supply chain; and to determine the impact of market channels on coffee quality.

3.3.5.1 Descriptive Analyses

Coffee supply chain actors are characterized based on transaction relationships between buyers and sellers. For instance, this relationship could be the middlemen relationship between suppliers (sellers) and buyers (those they sell to). The characteristics of coffee transactions at various supply chain nodes are identified by asking the supply chain actors questions that captured data on, quality (attributes and measurement), frequency of the transactions, volume per transaction, contractual arrangements involved in the transactions, seasonal variations, prices, and varieties handled per transaction. The data retrieved are analyzed using descriptive statistics such as percentages, means, and standard deviations.

3.3.5.2 Regressions analyses of transaction characteristics on coffee quality

To determine the impact of market channels on coffee quality based on market transactions at the export level, we used regression models. We use data collected at the export level since we observe the final quality of coffee at the end of the supply chain (export level for Uganda's case).

Quality is measured based on attributes (characteristics) established by the international market and the International Coffee Organization[7]. The quality attributes include bean size, moisture content, percentage of defects and cup score. Table 3.2 shows the recommended quality attributes for high-quality coffee beans. Moisture content refers to the amount of water contained in the coffee beans; defects refer to the number of unsound beans (e.g., discolored beans, insect damaged beans, etc.); cup score refers to the score given after cup tastings; and bean size refers to the size of the beans. Bean size is determined by passing the coffee over a perforated screen, which retains beans of a certain size while letting smaller beans pass through. According to ICO (2018), the screen size is given in terms of 1/64 of an inch, where screen size 15 is equivalent to 15/64 of one inch (6.00mm), screen 17 is equivalent to 17/64 of one inch (6.70mm) and 18 is equivalent to 18/64 of one inch (7.10mm).

Table 3.2 Standard high-quality coffee bean attributes commercially accepted and recommended by the International Coffee Organization

Quality characteristic	**Standard High-quality requirement**
Moisture content	< 12%
Bean size	Screens 15, 17, and 18
Defects	<5%
Cup score	>= 85%

[7] http://www.ico.org/documents/cy2017-18/icc-122-12e-national-quality-standards.pdf

The dependent variable for the regression models is coffee quality, Y, which was observed as a binary variable representing the quality type at the export level – high or low. The question posed to the exporter is: “What was the quality of coffee in the recent transaction?” Exporters’ responses were coded as 1 if “high-quality” and 0 if “low-quality” based on the attributes presented in Table 3.2.

The impact of market channels on quality were identified by testing if there was a difference in the quality of coffee purchased by exporters through the farmers’ groups and that purchased through the middlemen channel (i.e., identified through the parameter α in equation (3.1)). The difference in coffee quality provides evidence of the channel through which high- and low-quality coffee arrives at the exporters.

Given the binary nature of the dependent variable, a binary Probit model was chosen to be estimated. We consider a simple univariate model with only market channel as a regressor and then add further controls (i.e., characteristics of the market transactions) to see if they further impact the effect of the market channel. The regression model with controls is specified as:

$$Y = \alpha M + \beta X + \varepsilon \tag{3.1}$$

where $$Y = quality\ type\ at\ export \begin{cases} 1\ if\ high - quality \\ 0\ if\ otherwise \end{cases},$$

$$M = marketing\ channel \begin{cases} 1\ if famers\ groups \\ 0\ if\ middlemen \end{cases},$$

$\varepsilon \sim N(0,1)$, and $\boldsymbol{X}$ is a vector of control (explanatory) variables.

Table 3.3 Descriptive statistics and description of explanatory variables to be used in the Probit model

Variable name	Variable Type	Description	Percentage
		Dependent Variable	
Quality type	Binary	Coded as 1 if high-quality, 0 if low-quality	High-quality = 43.33 Low-quality = 56.67
		Independent Variables	
Market channel	Binary	Coded as 1 if Farmers' group, 0 if middlemen	Farmers' group = 48.33 Middlemen = 51.67
Premium price	Binary	Additional payment associated with high-quality coffee. Coded as 1 if paid premium, 0 if did not pay a premium	Paid premium price = 50 Did not pay premium price = 50
Season	Binary	The period in which the transaction was made Coded as 1 if low season, 0 if high season	High season = 56.67 Low = 43.33
Variety	Binary	The variety of coffee purchased in a particular transaction. Coded as 1 if Robusta, 0 if Arabica	Arabica = 40.00 Robusta = 60.00
Frequency	Binary	Coded as 1 if it is a repeat transaction, 0 if it is a one-time transaction	One-time = 43.33 Repeat = 56.67
		Mean	**Standard deviation**
Volume per transaction (60-Kg bags)	Continuous	227	343.10

Table 3.3 presents the descriptive statistics and description of control variables used in the model (factors affecting the quality of a coffee transaction). As controls, we included transaction characteristics likely to affect the quality of coffee purchased in a given transaction such as premium price, variety of the coffee purchased, the season in which the transaction is made, the frequency of the transaction, and the volume of coffee purchased in a transaction (Dias & Benassi, 2015; Jassogne *et al.*, 2013; Susila, 2005).

The average volume of coffee purchased by exporters was 227 60-Kg bags per transaction. Table 3.3 shows that about 43% of the transactions made by exporters are for high quality coffee, 51% of the transactions are made through the middlemen channel, about half of the exporters pay a premium price to their sellers, 60% of the transactions are for Robusta coffee, and about 43% of the transactions are just one-time transactions with the sellers (farmers' groups or middlemen).

3.3.5.3 Why do market channels matter in determining the quality of coffee received by exporters in a transaction?

Economic theory such as the Principal-Agent framework is used to explain the empirical results and provide directions for future research. The Principal-Agent framework is used to explain the impact of market channels and transaction characteristics on coffee bean quality received by exporters. Quality variation in the coffee supply chain arises likely due to information asymmetry between actors at different interfaces of the supply chain. For example, information asymmetry between farmers and middlemen and/or middlemen and exporters. The quality variation could also be due to the current incentive structures at these interfaces.

3.4 Results and Discussion

3.4.1 Characterization of coffee transactions and supply chain actors

This section presents a description of coffee transactions and the supply chain actors involved in these transactions. We discuss the coffee quality attributes and measurements at each stage of the supply chain (we focus on the export level since it is the final stage where quality is observed), coffee bean price, output and quality variations, the contractual arrangements under which the transactions are made and the characteristics of such contracts, and the challenges faced by each actor in making coffee bean transactions.

3.4.1.1 Quality attributes and measurement at Farm level

Quality of a coffee bean starts right from the garden. Pre- and post-harvest practices play a great role in ensuring high-quality coffee production. Pre-harvest practices such as best agronomic practices (e.g., timely planting, pest, and disease control among others) and post-harvest practices such as selective harvesting, proper drying and hulling can significantly enhance the quality of coffee beans. Farmers considered several attributes (Table 3.4) in their measurement of coffee quality based on what their buyers considered as high-quality coffee. These included ripeness of the cherries, moisture content, size of the bean, and absence of molds. Table 3.4 shows the percentage of farmers (individual farmers and farmers' groups) that considered the quality attributes demanded by coffee buyers.

Table 3.4. Quality attributes considered by farmers

Attribute	Percentage of individual farmers	Percentage of farmers in farmers' groups
Harvest only ripe cherries	80	100
Dry on tarpaulin	90	100
Moisture content	100	100
Bean color	40	100
Absence of molds	100	100

When the coffee is mature, selective harvesting should be done to allow harvesting of only ripe cherries. All farmers selling through farmers' groups considered the ripeness of the cherry when harvesting. A ripe cherry is one that appears red while an immature one appears green. Farmers' groups were stricter about quality because they sell directly to export companies. Farmers selling through farmers' groups reported that they received a higher payment when they sold directly to exporters compared to what they earned when they sold to middlemen. Given that most export companies pay a premium price for quality, farmers are more incentivized to invest in high-quality. On the other hand, a majority of the farmers working individually (80%) ensure that they harvest ripe cherries (selective harvesting), though several of them also practice coffee stripping where unripe cherries are also harvested. Small holder individual farmers mostly sold dry cherries (kiboko) to the middlemen and at this stage it is not easy to tell the difference between a cherry that was harvested red and one that was harvested green by visual inspection. Thus, middlemen pay a uniform price for all dry cherries, which discourages the farmers that practice selective harvesting. Individual farmers reported that sometimes they did not have control over the cherries harvested since they employed people to do the harvesting on their behalf. Harvest labor payment was based on the number of bags harvested; therefore, harvesters ended up harvesting everything (both ripe and unripe) to fill as many bags as possible.

About 90% of the individual small holder farmers dried the cherries on tarpaulin. This ensured that coffee was kept clean and minimized foreign matter content. Farmers reported that timely drying was sometimes limited by the availability of enough tarpaulin given the high cost to purchase them. Middlemen offered the same price irrespective of whether dried on tarpaulin or not. During peak harvest, when farmers have limited tarpaulin, they transferred the cherries onto the ground to create space for the freshly harvested cherries, which adversely affects quality. The Uganda Coffee Development Authority discouraged this practice and sometimes penalizes farmers who do not comply.

Moisture content is a quality attribute that was fully considered by all farmers irrespective of their buyers. Middlemen took moisture measurements using their moisture meters before a transaction was completed. The standard moisture level at export level was 12% or less. When farmers presented coffees that had higher moisture levels, price discounts were applied depending on the moisture level. Middlemen sometimes bought coffee which was not fully dry at a lower price to compensate for weight loss after complete drying. Some farmers sold half dried coffee due to lack of enough drying materials. Since farmers did not own moisture meters, they relied on middlemen's measurements which were not always accurate. The inaccuracies demotivated farmers from fully drying their coffee beans.

Absence of molds is also an important quality attribute at the farm level. Molds usually formed when the cherries were not properly dried (e.g., nonuniform turning, which limits some cherries from getting enough sunlight, and frequent rainy days and long delays between harvesting and drying). Molded cherries were easily identified by the white color coating on the cherry and were often rejected by buyers. Molding is detrimental to quality as it affects the aroma and flavor of the coffee cup.

A small number of individual farmers (40%) cared about bean color because a majority of them sold unshelled beans, while farmers' groups sold hulled beans and thus cared more about bean color. The color of high-quality hulled beans depends on coffee variety. Hulled Arabica coffee beans are expected to have a green color. The color of hulled Robusta coffee on the other hand depends on the processing method, where a golden-brown color is required for dry processed beans and green for wet processed beans (ICO, 2018).

3.4.1.2 Quality attributes and measurement at the middlemen level

Middlemen measured quality based on attributes considered by their buyers (exporters). Table 3.5 shows the ranking of attributes considered in quality assessments of coffee beans at the middleman level based on importance.

Table 3.5. Quality attributes considered by middlemen (n=120)

Attribute	Rank #1(%)	Rank #2(%)
Color	57.98	22.11
Moisture content	28.57	20.00
Out-turn	6.72	13.68
Bean size	4.20	30.53
Viable cherry	1.68	11.58
No molds	0.84	2.11

Color was the highest (58%) ranked quality attribute. Middlemen considered color as a quality attribute regardless of the form in which the coffee was being purchased. When coffee was purchased in fresh cherry form, middlemen considered red cherries as high quality. The red color of cherries is an indicator that the cherries were mature at the time of harvest. When hulled coffee was purchased, they considered golden brown color for Robusta beans and green color for Arabica beans as high quality. This matches what the exporters considered as the right color of high-quality coffee.

Moisture content was ranked as the most important aspect by about 29% of the middlemen. Middlemen reported that they purchased coffee beans that were below 15% moisture level. The ideal moisture content required for export is below 12.5%. Deductions in terms of weight were made to account for losses after complete drying depending on the moisture level at the time of purchase. Some exporters bought coffee which was not completely dry and dried it mechanically after a price reduction from the middlemen. Most of the middlemen had easy access to moisture meters, which made it easy for them to take moisture level measurements.

Bean size was mostly (31%) ranked number two in terms of quality attributes. This implies that most middlemen considered bean size after considering bean color and moisture content. Bean sizes of screen 15 (6mm), 17 (6.7mm) and 18 (7.1mm) were considered as high-quality.

3.4.1.3 Quality attributes and measurement at export level

The final quality of coffee beans in Uganda is observed at the export level since quality is likely to change along the supply chain from the farmer to the exporter. We therefore consider quality at the export level for the rest of the analysis. At farm and middleman level, quality measurement is mainly based on physical characteristics such as bean size and color. However, at export level, cup tasting is done to measure the intrinsic quality attributes in addition to the physical attributes. Table 3.6 shows exporters' ranking of quality attributes based on importance.

Table 3.6. Ranking of quality aspects at the Export level (n=60)

Quality characteristic	Standard High-quality requirement	Rank #1 (%)	Rank #2 (%)	Rank#3 (%)
Moisture content	< 12%	53.57	15.38	0
Bean size	Screens 15, 17, and 18	25.00	38.46	15.38
Defects	<5%	17.86	26.92	23.08
Cup score	>= 85%	3.57	19.23	61.54

The four most important parameters considered in measuring coffee quality at the export level include moisture content of the bean, bean size, level of defects and cup score. Moisture content refers to the amount of water contained in the beans at the time of purchase. Moisture content is an important quality parameter because it has a great impact on the shelf life of the beans. High moisture content facilitates molding, which affects the intrinsic quality of the final coffee cup. The standard moisture content for export was reported to be less than 12%. This matches the findings by Hameed *et al*. (2018) who reported that to prevent undesired fermentation, green coffee beans should have a moisture content of between 10 and 12%. Moisture content was ranked as the number one aspect to be considered when assessing bean quality by about 53% of the export companies.

About 38% of the export companies ranked bean size as the second aspect to be considered in assessing bean quality. Export companies have standard measurement for bean sizes organized in terms of screen sizes (12, 15, 17 and 18), with screen 18 being the biggest. Beans which are smaller than a given screen measure will pass through the screen. High-quality beans were reported to have a retention capacity of at least 95% for screen 18, 90% for screen 17 and 85% for screen 15. The beans were usually packed based on their screen grades. Bean size measurements are important because they guide the roasting process by giving an indication of how to apply energy in the roasting process.

The level of defects was ranked second by about 27% of the companies and ranked third by about 23% of the companies. There are two types of defects namely, primary defects and secondary defects. Primary defects include foreign matter (such as stones, husks, sticks, and other substances rather than coffee), insect damaged beans (slight and severe) and discolored beans (for example full black, dark brown and white beans). Exporters reported that you need five severe insect damage beans to make one full defect. This implies that insect damage is less of a problem compared to foreign matter. One full black bean equals one full defect and likewise one dark brown bean equals one full defect. Full black beans affect the flavor and dark brown beans make the coffee cup sour. Secondary defects mainly included broken beans. Generally secondary defects are less problematic compared to primary defects. High quality coffee requires an out-turn[8] of above 85% after removal of defects. Specifically, high-quality coffee should not exceed 5% foreign matter and 35% black beans. Specialty coffee has a much stricter standard and only 5 secondary defects are allowed for coffee to qualify as a specialty coffee.

[8] Out-turn refers to the percentage of high-quality beans (beans with good physical characteristics) from the sample of coffee beans.

Cup score was ranked third by about 61% of the companies in terms of coffee quality measurement. A cup score is achieved through cup tasting. A sample of coffee is roasted, cupped and sensory tasted by several experts each awarding their score (guided by a standard cupping sheet) based on how the coffee feels. Coffee is scored based on fragrance/aroma, flavor, aftertaste, acidity, body, uniformity, balance, sweetness, clean cup, and overall quality. Each of these attributes is rated on a scale of 1-10 based on the attribute considered. For instance, a fragrance score of 6 is good and 9 is outstanding. Generally high-quality coffee is expected to obtain a cup score of 85% (85 points total) or above.

3.4.1.4 Characterization of farmers and farmer transactions

There are two categories of famers namely, farmers organized in groups commonly referred to as famers' groups and farmers working individually (individual farmers). Farmers groups mainly transact directly with export companies, while individual famers transact most often with middlemen. Individual farmers dry fresh cherries (referred to as kiboko) and sell them to middlemen or sometimes sell the fresh cherries directly to middlemen.

3.4.1.5 Characterization of middlemen and middlemen transactions

Middlemen act as a linkage between the producers (farmers) and the processors (exporters). Many of the middlemen (90%) were male with an average age of 34.8 years and 8.4 years of schooling. On average, middlemen had 9.9 years of trading experience. Most of the middlemen (90.83%) purchased their coffee from individual smallholder farmers. Middlemen ranked individual farmers as their most preferred source of coffee cherries, primarily due to low prices at farmgate, high quality cherries, and availability. However, individual farmers can only offer small volumes, which requires middlemen to collect from multiple farmers. Middlemen mostly bought dry cherries commonly referred to as ‘Kiboko’. The dry cherries were then hulled and sold to processors (exporters) as green beans referred to as FAQ (Fair Average Quality). About 68% of middlemen stated that 87% of the coffee from individual farmers was of high quality. Over 63% of the middlemen reported they paid a premium to farmers that supplied high quality coffee.

Most (59%) of the middlemen did not buy coffee under any contractual arrangements, while 33% bought coffee under oral contracts. Similarly, about 65% of middlemen did not sell under any contractual arrangements with only 7.5% selling under written contracts. About 55% of the middlemen reported that it was difficult to break a written contract compared to an oral contract, due to the penalties involved. Table 3.7 presents the specifications of the written and oral contracts for middlemen. The contracts specified price, quantity, minimum quality requirements, mode and speed of payment, quality premium and penalties. Over 80% of the middlemen who transacted under contracts reported that price was specified in written contracts and over 70% reported that price was specified in oral contracts. This indicates the importance of price in coffee transactions. The written contracts also mostly specified the speed and mode of payment, quantity, and quality requirements. However, fewer oral contracts specified the minimum quality requirements and quality premiums compared to written contracts.

Table 3.7. Specifications of the contracts between middlemen and their suppliers

Specifications	**Contract type with suppliers (middlemen buying side)**		**Contract type with buyers (middlemen selling side)**
	Written (%)	Oral (%)	Written contract (%)
Price	83.33	73.68	88.89
Quantity	58.33	73.68	77.78
Minimum quality requirement	58.33	34.21	88.89
Mode and speed of payment	75	34.21	66.67
Premium	25	5.26	33.33
Penalties	33.33	5.26	44.44

3.4.1.6 Characterization of exporters and exporter transactions

Table 3.8 Shows the descriptive statistics of export companies and related transactions. The average business experience of export companies was 14.7 years with an average market share of 3.3%. The average volume transacted was 227 60-Kg bags per transaction. The volume transacted is likely to affect quality received by the exporters either negatively or positively. When high volume is purchased in one transaction, it is more likely to get low quality due to high demand in terms of labor and technology for screening. On the other hand, companies that purchase large volumes are likely to attract high quality sellers based on their reputation.

Table 3.8. Descriptive statistics for exporters and exporter transactions (n=60)

Variable	Mean	Std. Dev.	Min	Max
Market share (%)	3.33	5.05	0.01	20.31
Volume transacted (tons)	227.00	343.99	0.33	1384.33
Business experience (years)	14.70	9.63	2.00	36.00

The majority of the exporters (87%) stated that the coffee business was their main source of income (figure 3.3). This sheds light on the value of coffee to these companies as a primary source of income.

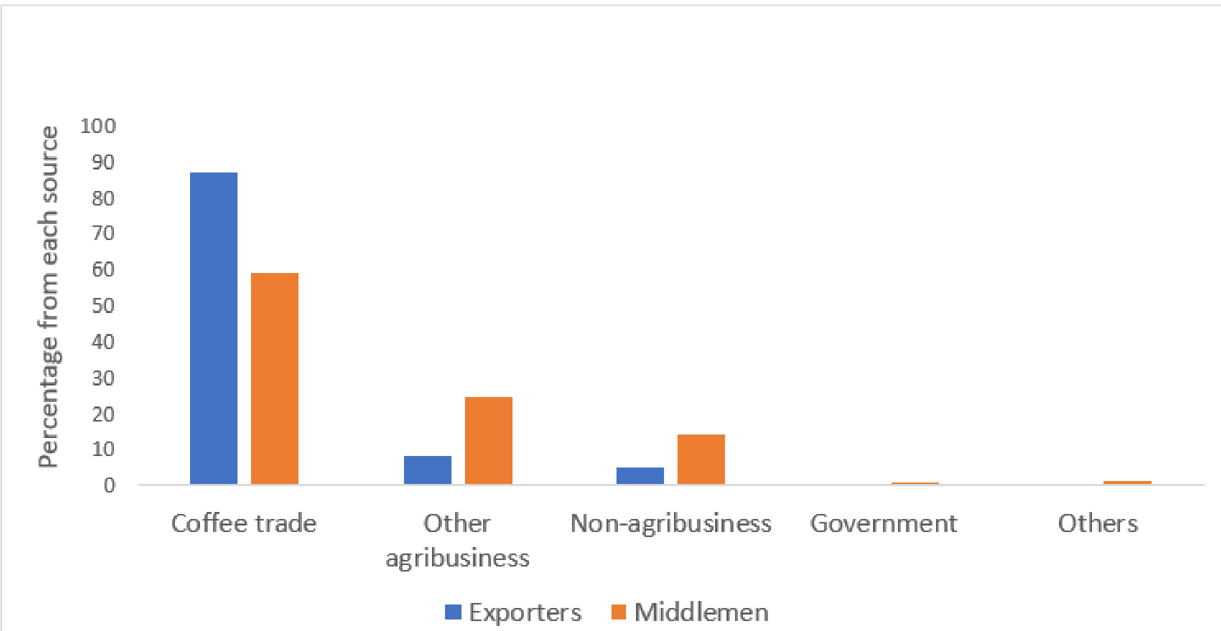

Figure 3.3 Sources of income for exporters and middlemen

There are two major sources of coffee for exporters: farmers' groups, and middlemen. About 90% of the exporters contracted with farmers organized in groups as this made it easy to monitor coffee quality and makes traceability more efficient. However, the few operational farmers' groups can not satisfy exporters' demand in terms of volume. Middlemen therefore played a role in bridging this gap. Given the large number and mobility of middlemen, it was difficult for exporters to monitor quality of the coffee beans since middlemen gathered their coffee from different regions. Exporters therefore preferred to contract more with farmers' groups. Exporters transacted through both middlemen and farmers' groups. About 52% of the transactions where through middlemen, while about 48% of the transactions came through the farmers' group channel (figure 3.4). This indicates the importance of middlemen in the coffee supply chain.

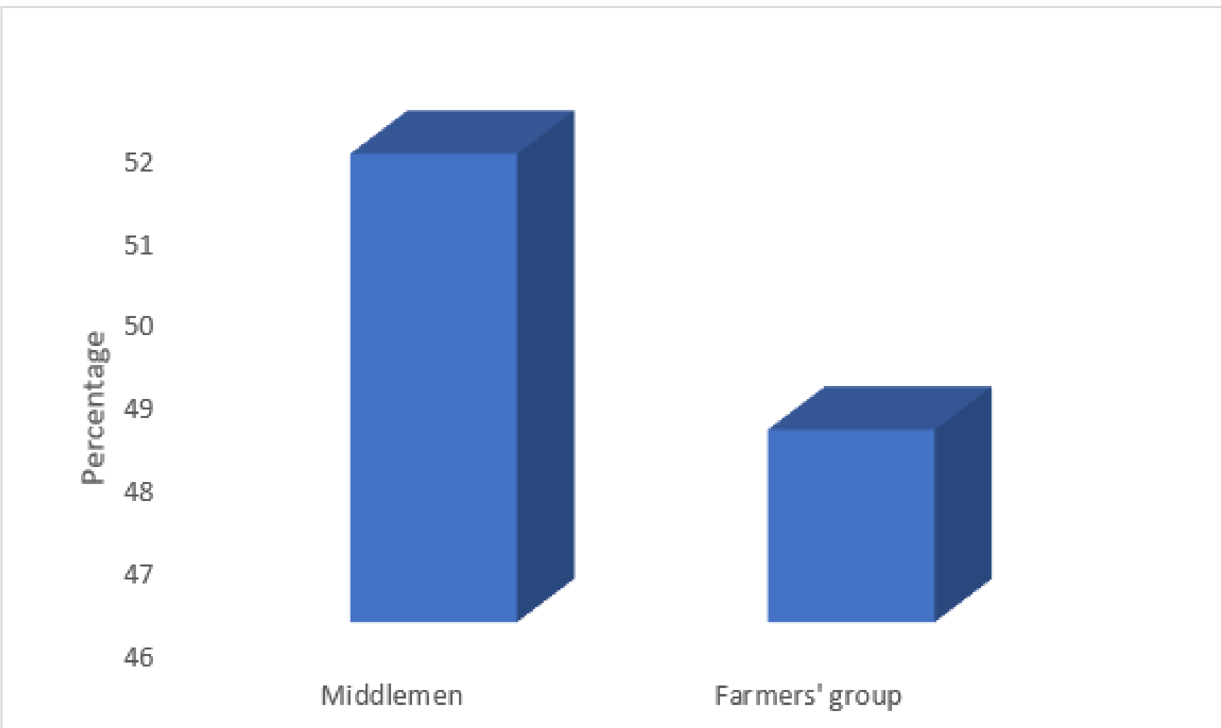

Figure 3.4 Percentage of transactions through middlemen and farmers' groups.

Generally, about 57% of the coffee received by exporters was graded as high-quality (figure 3.5).

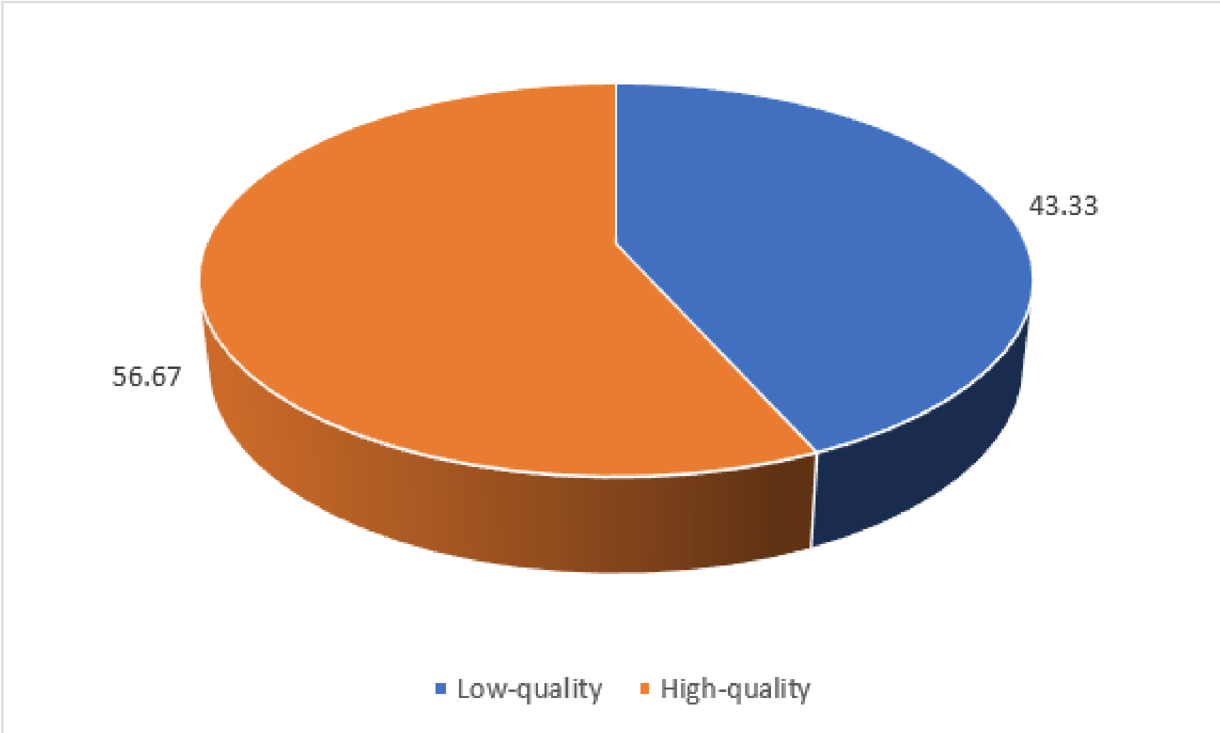

Figure 3.5 Quality of coffee beans received by exporters.

Results show that about 80% of the transactions through farmers' groups were graded as high quality compared to only 43% of transactions through middlemen (figure 3.6). This further explains why exporters preferred transacting with farmer's groups more than middlemen.

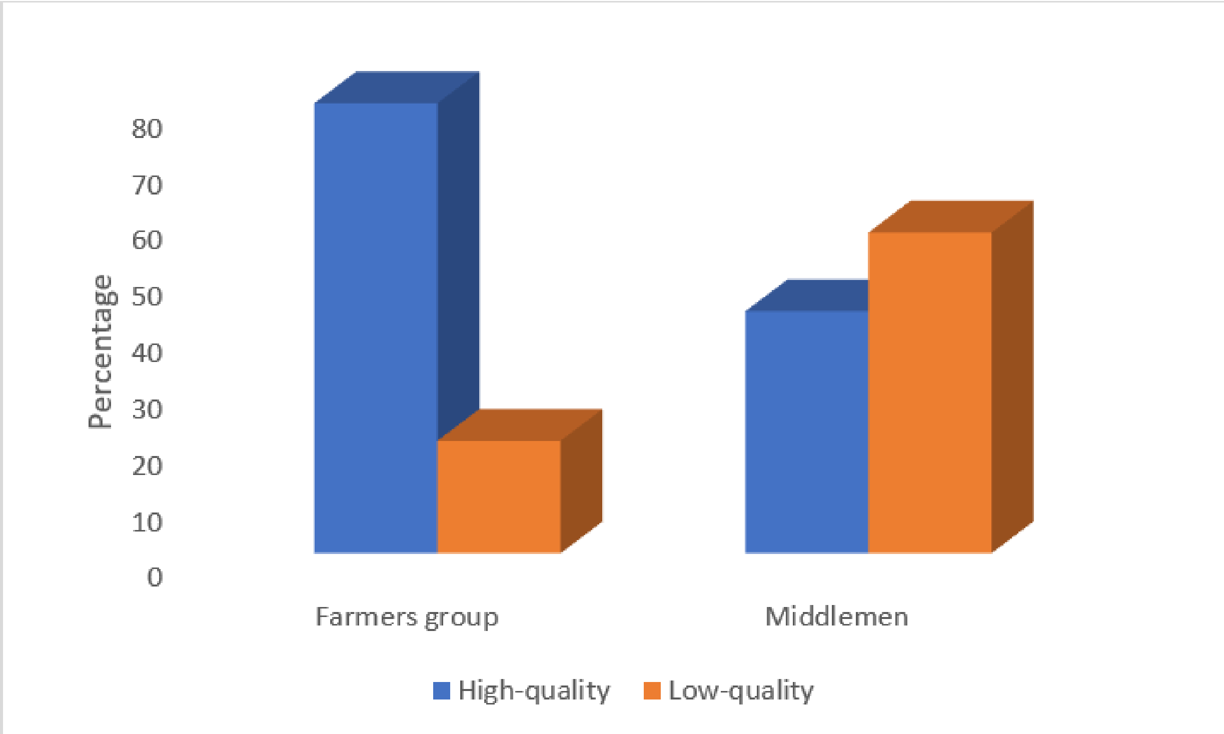

Figure 3.6 Ranking of coffee bean quality transacted by exporters through middlemen and farmers' groups

About 50% of the transactions recorded payment of a premium price to suppliers when high quality was delivered. The average premium payment was about 104[9] (UGX) per Kg of high-quality coffee. This implies that a farmers' group or middleman who delivers 1000Kg of high-quality coffee receives 100,400 UGX more compared to average quality. Low quality was penalized with a price discount. On average, a reduction of 181 UGX per Kg is applied when low quality coffee was delivered.

About 60% of the transactions were made during off-season (low season) periods. This is because the survey was conducted at the beginning of the off-season period. Off-season refers to

[9] 1 USD = 3600 UGX (February 2019)

the period where no harvesting is done. During off-season, the transacted coffee is mainly stock from the previous season. The seasonal variations are discussed further in the following sections.

In terms of contractual arrangements, only 40% of exporters had written contracts with their suppliers, these were mainly farmers' groups. Exporters mainly transacted under oral contracts or spot markets (no contract) with middlemen. The contracts specifications are reported in Table 3.9. About 25% of the exporters reported that their suppliers failed to respect the terms of a written contract and about 50% reported suppliers failing to fulfill the terms of an oral contract. Fifty percent of the exporters operating under oral contracts indicated that it was possible to breach the contract with the seller.

Table 3.9. Specifications of the contract between exporters and their suppliers and buyers.

Specifications	**Contract type with suppliers (exporter buying side)**		**Contract type with buyers (exporter selling side)**
	Written (%)	Oral (%)	Written contract (%)
Price	83.33	50	96.30
Quantity	91.67	100	100
Minimum quality requirement	91.6	62.50	100
Mode and speed of payment	83.33	62.5	70
Premium	66.67	75	55.56
Penalties	66.67	37.5	77.78

Exporters mainly (80%) sold their coffee to international roasters. A few (about 19%) sold to local roasters or did the roasting at their own factories mainly for local consumption. International roasters were preferred due to their fair prices and market reliability relative to local markets. All exporters selling to international roasters transacted under written contracts, which were very difficult and almost impossible to breach. These contracts had strict quality and quantity specifications.

3.4.1.7 Coffee quality, output, and price variation (seasonality)

Coffee quality and output varies depending on the season of the year. There are two coffee harvesting seasons (high and low). The high harvest season for Robusta coffee is between April and July and for Arabica is between December and January. The off-season months were February to March and August to September, respectively, as presented in Table 3.10. It is much easier to get high-quality coffee during the harvest season compared to off-season months. Towards the end of the season, farmers need money and thus harvest immature coffee beans, which affects quality. The chances of getting low quality coffee are higher during off-season periods than peak season periods.

Table 3.10. Seasonal variation in output and quality of coffee

<table>
<tr><th>Type</th><th></th><th>Oct.</th><th>Nov.</th><th>Dec.</th><th>Jan.</th><th>Feb.</th><th>Mar.</th><th>April.</th><th>May</th><th>Jun.</th><th>Jul.</th><th>Aug.</th><th>Sep.</th></tr>
<tr><td rowspan="2">Robusta</td><td>Output variation</td><td colspan="4">Low harvest</td><td></td><td></td><td colspan="4">High harvest</td><td></td><td></td></tr>
<tr><td>Quality variation</td><td colspan="4">Medium quality</td><td colspan="2">Low quality</td><td colspan="4">High quality</td><td colspan="2">Low quality</td></tr>
<tr><td rowspan="2">Arabica</td><td>Output variation</td><td colspan="2"></td><td colspan="2">High harvest</td><td></td><td></td><td colspan="4">Low harvest</td><td></td><td></td></tr>
<tr><td>Quality variation</td><td colspan="2">Low quality</td><td colspan="2">High quality</td><td colspan="2">Low quality</td><td colspan="4">Medium quality</td><td colspan="2">Low quality</td></tr>
</table>

The buying and selling prices are determined by the season in which the transaction was made, the quality of coffee, and the prevailing international coffee market price. Most traders received price information from the UCDA website which is updated daily. The disadvantage of this system was that some farmers did not have access to firsthand price information and thus took the prices set by the middlemen traders. This prevented premium payments for quality as traders were not willing to pay beyond the prevailing market price. The traders therefore used the price discount system of penalizing for low quality where farmers were paid below the market price whenever their coffee was of low quality. The discounts were mainly related to moisture content and number of defects. The discounts were given to safeguard against loss in weight due to moisture loss after complete drying and removal of impurities.

Generally, coffee export was done all year long with some monthly variation in volumes. Table 3.11 presents the monthly variation in coffee export volumes, prices, and quality. Coffee prices varied based on the season and the international coffee price. Actors reported that the price varied much with changes in exchange rates. The price also varied depending on the market where the coffee was sold, for example the London stock market vs Starbucks.

Table 3.11. Monthly variation in price, export volumes and quality

Month	**Coffee type**	**Price (UGX)**		**Total volume (60 Kg bags)**		**Quality**
		Mean	Standard deviation	Mean	Standard deviation	High quality (%)
January	Arabica	5968.42	2013.78	2093.77	4902.71	45.00
	Robusta	5247.43	843.10	9352.27	13575.83	
February	Arabica	6186.67	2329.45	1833.87	4960.84	47.62
	Robusta	5280.57	693.83	7540.57	11826.45	
March	Arabica	6189.50	2463.79	2202.17	4480.95	57.14
	Robusta	5361.00	717.45	7620.90	13108.63	
April	Arabica	6482.27	220.53	2304.73	5368.17	47.37
	Robusta	5236.00	683.25	6775.73	14141.90	
May	Arabica	5932.00	1851.93	2909.47	6548.56	55.00
	Robusta	4869.20	768.91	7321.10	12382.88	
June	Arabica	5775.73	1980.96	2617.50	6743.96	80.77
	Robusta	5228.36	1048.49	6999.53	10868.60	
July	Arabica	5277.05	1821.46	2486.50	5409.41	76.00
	Robusta	5071.27	710.64	10567.37	17002.01	
August	Arabica	5971.00	2443.23	2351.77	5240.26	64.71
	Robusta	5293.71	485.43	11671.93	16211.79	
September	Arabica	5361.26	2015.10	1303.07	2564.37	59.09
	Robusta	5155.56	681.38	9080.83	14241.16	
October	Arabica	7880.50	10750.94	2223.83	4518.41	57.14
	Robusta	4979.33	1081.44	9238.23	15969.76	
November	Arabica	5823.55	2103.97	3048.63	6505.85	76.92
	Robusta	5052.00	841.59	10269.73	17520.94	
December	Arabica	5787.55	2058.36	1391.20	2975.27	80.00
	Robusta	5397.50	1401.34	7679.47	12318.64	

In general, Robusta coffee export volumes were higher than Arabica volumes. Robusta coffee accounts for about 80% of total production. The highest average volume of Robusta coffee (11,672 60-Kg bags) was registered in August. Average export volumes for Robusta increased gradually from July through November. The export volume increment is consistent with the high harvest season which starts in April and goes through July. The percentage of high-quality coffee beans purchased was reported to be higher in the peak harvest period. For the year 2019, Robusta coffee exports were higher between July and November compared to February to June.

For Arabica coffee, the higher export volumes (3,049 60-Kg bags) were recorded in November, which also coincides with the peak harvest season. High export volumes were also recorded from May to August, which matches with the second (low harvest) season.

3.4.1.8 Challenges faced by middlemen in buying and selling coffee

Price volatility was reported as a key challenge to middlemen both when buying and selling coffee beans (Table 3.12). When making purchases, it was difficult for the middlemen to convince farmers about price changes, affecting their business relationships. Sometimes middlemen bought coffee beans at high prices from the farmers and by the time they delivered to the exporters', prices had dropped, negatively affecting them. Since there were few buyers, middlemen did not have many options for selling their coffee, having to accept the price offered by the exporter. Most of the large export companies in Uganda had shares with international buyers. Since the price is set by international buyers, they always set the price to their own advantage. Middlemen (28%)

reported that the prices offered by the exporters were very low and sometimes they operated under losses.

Table 3.12. Challenges faced by middlemen in buying and selling coffee

Challenge	Buying (%)	Selling (%)
Volatile prices	35.00	27.50
Transport	10.00	3.33
Quality	35.83	17.50
Trust	19.17	24.17
Low prices	0.00	27.50

Quality is also a challenge that middlemen face while buying and selling coffee beans. Middlemen reported that it was difficult to get 100% high-quality coffee demanded by exporters. Since middlemen purchased from farmers, they had little control over quality management at the farm level. Information asymmetry between the middlemen and the farmers affected quality. Some farmers did not follow the guidelines of harvest and post-harvest management that promote high-quality of the coffee beans. When selling to exporters, middlemen were penalized for low quality much of the time. Exporters applied weight penalties by reducing the quantity that they would pay for, depending on the quality. For example, a 10% reduction would be applied if the coffee were above a 12% moisture level.

There was a high level of distrust between the middlemen and their business partners (farmers and exporters) which affected their transactions. The information asymmetry regarding the quality of coffee led to distrust where exporters did not trust the quality of coffee delivered by the middlemen and the middlemen did not trust the quality assessment done by the exporters.

Because middlemen believed that no matter what quality they delivered, the exporters always applied a certain penalty, this discouraged the middlemen from applying maximum effort in gathering only high-quality coffee. Moreover, low quality coffee was bought at a lower price and exported to countries that needed to make instant coffees. Middlemen also reported that sometimes exporters bought their products on credit and did not make prompt payments as agreed. Similarly, some middlemen did not meet the quality requirements as described in the contract. For instance, they mixed fully dry and partially dry coffee to increase the weight of their bags.

Poor transport systems in the production regions affected middlemen, especially when buying coffee, since some farmers were in hard-to-reach areas. This sometimes affected the quality of coffee, especially when drying was delayed. During the rainy season, some roads were inaccessible especially in mountainous regions, which complicated purchases. Thus, middlemen were not always able to meet the timeliness requirements of their contracts.

3.4.1.9 Challenges faced by exporters in buying and selling coffee

Exporters reported several challenges in buying and selling coffee as presented in Table 3.13. The biggest challenge faced by most exporters (70%) was inconsistent quality. Exporters usually signed contracts with specific quality requirements as described in the previous sections; however, it was hard for them to get the exact quality from their suppliers. Since middlemen gathered coffee beans from many different locations, quality was heterogenous and traceability was highly complex. As a result, it became more costly for exporters to sort and grade the coffee. Exporters working with farmers' groups reported that when low quality coffee was rejected from farmers' groups, it was sold to middlemen who mixed it up with the high-quality coffee and later sold it to the exporters.

Table 3.13. Challenges faced by exporters in buying and selling coffee

Challenge	Rank #1 (%)	Rank#2 (%)
Buying		
Inconsistent quality	70,00	0.00
Volatile prices	6.67	25.00
Quantity/Volume	10	12.00
Bad roads	3.33	12.50
Trust	10.00	50.00
Selling		
Volatile prices	33.33	21.74
High transport cost	10.00	43.48
Delay in payment	6.67	30.43
Market search cost	50.00	4.35

The second biggest challenge in buying coffee as ranked by (50%) of the exporters was lack of trust between the exporters and the middlemen. Exporters reported that they did not trust the quality of coffee beans delivered by the middlemen. For instance, some middlemen presented a high-quality sample for analysis even though the actual product was not of equal quality. The middlemen also demanded quick payment which made it difficult for the exporters to fully assess all the coffee before making a payment. This increased the risk to exporters getting low quality coffee.

About 10% of the exporters mentioned difficulty in raising the required volumes, especially for Arabica coffee during off season periods. This is exacerbated by the fact that there are few farmers growing Arabica coffee in the country. About 13% of the exporters ranked bad roads as a second challenge in purchasing coffee. Some farms were in the mountainous parts of the country, which were difficult to reach. Transportation, such as use of donkeys, must be used to transport coffee from the fields to drying facilities in these regions, which is slow and tedious. To achieve the timeliness condition of the contract, some exporters who worked directly with farmers' groups facilitated the transportation of the harvested cherries.

In terms of selling coffee, exporters were mainly challenged by high transaction costs. The most pressing challenge as reported by 50% of the exporters was high market search costs. Before international buyers (importers) approved a contract, they required samples to be shipped to their premises (labs) for analysis, which was costly for the exporters. Based on their satisfaction, the contract could be approved or declined. In case of a decline, the exporter must ship his/her samples to other buyers for approval, which made contracting processes costly and time consuming. Mostly Arabica exporters mentioned that it was difficult to find a good buyer for their coffee as Uganda was not known for specialty coffee, making it difficult to earn a premium price for specialty Arabica coffee.

Price volatility was ranked number one by about 33% of the exporters. Like any other agricultural commodity, coffee is highly affected by price movements, being an international commodity. Prices fluctuate with changes in exchange rates (the US dollar specifically), as well. Exporters reported that most of the time they made their price negotiations under high price uncertainty, which at times turned out unfavorable for them. Price volatility made it difficult to set a price during purchases from middlemen and farmers as they sometimes believed that exporters took advantage of the situation.

High transport cost was ranked second by about 43% of the exporters. The high transport cost stems from the fact that Uganda is a landlocked country, therefore exporters were required to transport their coffee to the nearest port (mostly Mombasa) for shipping. In addition to high transport cost, exporters reported delayed payments by importers. Payment delay was due to the lengthy procedures for analyzing coffee before a payment is made, which is exacerbated by delays in shipping.

3.4.2 Impact of market channels on coffee quality in Uganda

Regression model results are presented in Table 3.14 and 3.15. The univariate model (Table 3.14) converged after 4 iterations with a log likelihood value of -27.35 while the model with controls (Table 3.15) converged after five iterations with a log likelihood value of -20.99. Both models were generally significant (Prob>chi2 = 0.000). Marginal effects were estimated at their means and the respective asymptotic standard errors were estimated using the delta method.

Results from Table 3.14 show a statistically significant positive marginal effect of the market channel on coffee quality. If the market channel changes from middlemen to farmers' group, the probability of the exporter buying high quality coffee increases by 63.8 percentage points.

Table 3.14. Effect of market channel on the quality of a coffee transaction at the export level (model without controls)

	Coefficient	**Standard error**	**Marginal effect**	**Standard error**	**P>z**
Market channel					
Farmers' Group	1.91	0.39	0.64	0.10	0.00
Constant	-0.65	0.24			
Log likelihood	-27.35				
Prob > chi2	0.00				
Pseudo R2	0.33				

Table 3.15 presents the Probit regression model estimates and marginal effects of factors affecting quality of coffee transactions at the export level (controlling for factors affecting quality of coffee transactions other than market channel). The marginal effect of market channel does not change significantly, even after controlling for other factors affecting the quality of a coffee transaction at the export level. The results confirm the impact of market channels on the quality of coffee received by an exporter in a transaction. Holding other factors constant, changing the market channel from middlemen to farmers' group increases the probability of buying high quality coffee by 55 percentage points.

Table 3.15 Factors affecting the quality of a coffee transaction at the export level (model with controls)

	Coefficients	**Marginal Effect**
Market channel	1.65	0.55***
1=Farmers' group	(0.48)	(0.13)
Variety	-0.530	-0.19
1=Robusta	(0.57)	(0.19)
Premium price	1.12	0.40**
1=Paid premium	(0.53)	(0.17)
Volume	-0.01	-0.01
	(0.01)	(0.01)
Transaction season	-1.07	-0.37**
1=Low season	(0.49)	(0.15)
Frequency	0.83	0.31*
1=Repeat	(0.51)	(0.18)
Constant	-0.38	
	(0.65)	
Log likelihood		-20.99
Prob>chi2		0.00
Pseudo R2		0.49
N		60

Standard Errors in parentheses
* P<0.10, ** P<0.05, *** P<0.01

The results in Table 3.15 show that other than market channel; premium price, frequency, and the season in which the transaction is made significantly affect the quality of coffee received by an exporter in a transaction. Paying a premium price for high quality coffee increases the probability of receiving high quality coffee by an exporter by 39.5 percentage points compared to not paying a premium price holding other factors constant. Thus, it would seem a premium price acts as an incentive for higher quality coffee. When the season changes from high to low, the chances of an exporter receiving high quality coffee decreases by 37.1 percentage points holding other factors constant. Seasonal variation is accompanied by fluctuations in quantity and quality. Changing the frequency of the transaction from one-time to repeat increases the probability of an exporter receiving high quality coffee in a transaction holding other factors constant. Repeat transactions are built on reputations, which lead to higher quality of coffee. These results are primarily exploratory and to help further explain them you a Principal Agent framework is used to provide additional context in helping to explain why the market channel impacts coffee quality. This then leads to other testable research hypotheses for future research.

3.4.3 Why are exporters more likely to receive high quality coffee when they transact with farmers' groups?

We explain why market channels have a significant impact on the quality of coffee received by an exporter in a transaction using a Principal-Agent framework. Based on the Principal-Agent framework, transactions between actors in the coffee supply chain can be analyzed as a bilateral relationship in which the principal contracts the agent to carry out a given action (Dewatripont & Bolton, 2005). We analyze the transactions between actors at each interface of the market channels. The interfaces considered include the farmer-middleman interface, middleman-exporter interface, farmer-farmer's group interface and the farmers' group-exporter interface. Figure 3.7 summarizes the quality at different market channels based on empirical evidence (significant effect of market channel on quality) and descriptive analysis (about 80% of the transactions with farmers' groups result in high quality coffee, while only 43% of the transactions through middlemen result in high quality), where the red arrow routes represent high quality coffee, and the black arrow routes represent low-quality coffee.

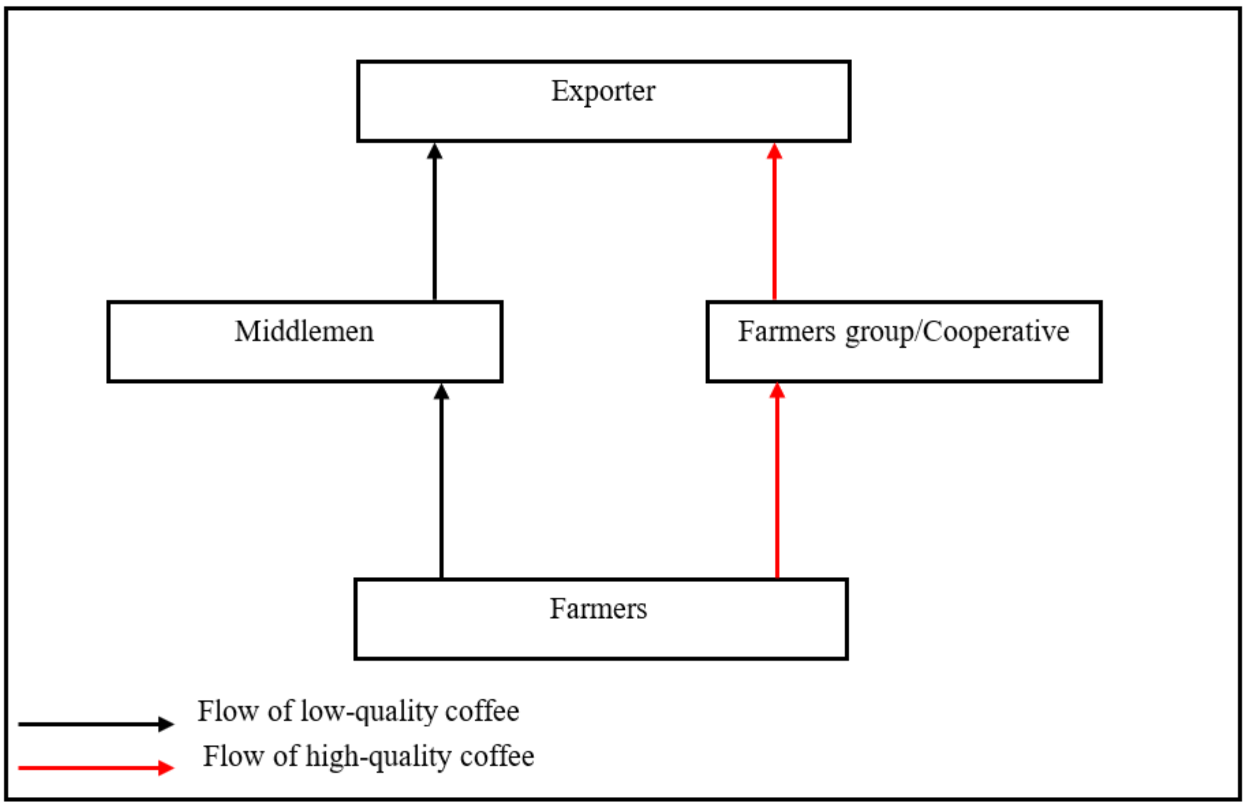

Figure 3.7 Flow of coffee quality from farmer to exporter

We analyze the coffee quality and incentive structures by considering a bilateral relationship in which the principal contracts the agent, to produce (farmer) or procure (middlemen) coffee of a certain quality. This relationship allows a certain amount of coffee (output) to be produced or procured whose monetary value will be referred to as y. The final monetary value of coffee depends on quality (q) (the effort that the farmer dedicates to production and postharvest management and the middleman's effort to procure high quality) and the value of other random factors which are beyond the agent's control e.g. weather (Macho-Stadler & Pérez-Castrillo, 2009). The monetary value of coffee is thus a random variable. The probability of coffee value y_i conditional on the quality (q) can be written as: $Prob[y = y_i|q] = p_i(q), for\ i\epsilon\{1,2, \ldots, n\}$ (Shanoyan *et al.*, 2019). We assume that $p_i(q) > 0$ for all q, i. In the presence of uncertainty, it is important to consider how participants react to risk. Risk preferences are expressed by their utility functions and we assume that the utility functions are of the von Neumann-Morgenstern type.

Considering a single-shot game, we assume that the main objective of both the principal and the agent is to maximize their utility functions expressed below as:

Principal's utility function: $$B(y, w) = b(y - w) \quad (3.2)$$

Agent's utility function: $$U(w, q) = u(w) - v(q) \quad (3.3)$$

where $B(.)$ is the utility function representing the principal's preferences. y denotes the revenue from the sale of coffee, *w* represents the payment (wage) to the agent. The function $B(.)$ is assumed to be concave and increasing ($B' > 0, B'' \leq 0$), which indicates that the principal is either risk-neutral or risk-averse. We assume that the principal is risk neutral. On the other hand (equation 3.3) the agent receives a payment *w* for his participation in the relationship, and he supplies a given quality of coffee q which implies some cost to him. We assume that the utility function $U(.)$ is additively separable in components w and q. This implies that the agent's risk aversion does not vary with the quality he supplies. The function $u(w)$ represents the agent's utility from his wage and this function is concave in w. We assume that the agent is risk averse. The function $v(q)$ represents disutility of effort (quality of coffee) and greater effort (high quality) means greater disutility. We also assume that the marginal utility of quality is non decreasing, such that: $u'(w) > 0, u''(w) \leq 0, v'(q) > 0, v''(q) \geq 0$. There is assumed to be only two possible levels of quality: high and low: $(q^H, q^L)$and $v(q^H) \succ v(q^L)$. Equations (3.2) and (3.3) imply that the agent prefers a higher payment w (wage) which is a cost to the principal. Similarly, the principal prefers high quality coffee as it results in more marketable output that earns them more revenue. However high-quality coffee requires more effort and investment, which translates into higher disutility for the agent. This illustrates the source of conflict between the principal and the agent.

3.4.3.1. Incentive structure and coffee quality at the farmer-farmers' group interface (symmetric information (observable quality))

Farmers can sell coffee to exporters through farmers' groups/cooperatives instead of middlemen. At the farmer-farmers' group interface, the farmers' group is the principal, who contracts the farmer, the agent, to produce high quality coffee. The farmers' group describes the terms of the contract and supervises the harvest and post-harvest processes. This ensures that members harvest only mature coffee beans and drying is done properly. Hence producing high-quality coffee. In this kind of relationship, the farmer's coffee quality is verifiable by the farmers' group since the farmers' group supervises the process, eliminating information asymmetry. Under symmetric information, both the farmers' group and the farmer have the same information before the relationship and during it (Macho-Stadler & Pérez-Castrillo, 2009).

Following Macho-Stadler & Pérez-Castrillo (2009), under symmetric information the farmers' group decision can be modeled using the following maximization problem:

$$\underset{[q,\{w(y_i)\}_{i=1,\dots,n}]}{\text{Max}} \sum_{i=1}^{n} p_i(q)[b(y_i - w(y_i))]$$

$$s.t \sum_{i=1}^{n} p_i(q)u\big(w(y_i)\big) - v(q) \geq \underline{U}$$

where $\underline{U}$ is the farmer's reservation utility, y_i is the monetary value of coffee, q is coffee quality, and w is the farmer's wage. Assuming the farmers' group is risk-neutral, and the farmer is risk averse and solving the above maximization problem, the optimal contract can be expressed as:

$$w^H = U^{-1}\left(\underline{U} + v(q^H)\right)$$

The farmer's pay-off is determined by the optimal distribution of risk between the farmers' group and the farmer. In this case, the farmer receives a fixed payment depending on the quality level observed by the farmers' group. To incentivize the farmer to invest in high-quality coffee, the farmers' group offers offer w^H for high quality and w^L=0 (reject low quality) for low-quality coffee. Thus, farmers' groups can purchase high-quality coffee from farmers. Since farmer's groups offer a premium payment for high quality coffee that is higher than the payment offered by middlemen, this explains why farmers' groups obtained 90% high-quality coffee from the transactions with famers.

3.4.3.2. Incentive structure and coffee quality at the farmers' group-exporter interface

Export companies can purchase high-quality coffee from farmers' groups since farmers' groups invest in coffee quality through supervision. Farmers' groups have built reputations which makes supplying low-quality coffee very costly in terms of buyer-customer relationships. Therefore, this explains why exporters are more likely to purchase high quality coffee through the farmers' group channel than the middlemen channel. The descriptive analysis shows that exporters received high-quality coffee beans from about 80% of the transactions with farmers' groups.

3.4.3.3. Incentive structure and coffee quality at the farmer-middlemen interface (asymmetric information (unobservable quality))

The middleman (principal) contracts the farmer (agent) to produce coffee of high quality. In this kind of arrangement, there is likely asymmetric information. Information asymmetry occurs when one of the transacting parties has more information than the other either about themselves or the course of action they would take in a response to a situation (Pandey *et al.*, 2013). Information asymmetry between the middleman and the farmer arises because: (1) the farmer's effort to produce high-quality coffee is not verifiable by the middleman at the time of purchase (2) the type of the transacting parties (honest or dishonest) is not known to each other. This has resulted in opportunistic behavior from farmers. Farmers have been reported to be harvesting immature coffee beans and mixing them with mature beans, improper drying, and storage after harvest. Therefore, middlemen make payments based on the low-quality end, which takes away any incentive to invest in high-quality production. These actions have resulted in mistrust between farmers and middlemen and have also led to adverse-selection of low-quality producers in the middleman-farmer interface.

With a fixed payment, the farmer will receive $\overline{w}_i(y_i) \leq w_i(y_i)$. The type of farmer is represented by subscripts H(Honest) and D(Dishonest) where y_D represents the farmer not drying and storing appropriately after harvest and mixing mature and immature coffee together to make the middleman believe that the quality of the coffee is high such that $\overline{w}_D(y_D) \geq \overline{w}_H(y_H)$. Figure 3.8 shows the payoff functions of the farmer and middleman where EF and EM represent the expected utilities of the farmer and middleman, respectively. The superscripts denote the effort level (investment in quality) and the subscripts represent the type of the farmer (Honest or Dishonest).

		Farmer's effort level (investment in quality)	
		High	Low
Farmer type	Honest	$EF_H^H = u(\overline{w}_H) - v(q^H)$ $EM_H^H = \sum_{i=1}^{n} p_i^H\, b(y_i - \overline{w}_H)$	$EF_H^L = u(\overline{w}_H) - v(q^L)$ $EM_H^L = \sum_{i=1}^{n} p_i^L\, b(y_i - \overline{w}_H)$
	Dishonest	$EF_D^H = u(\overline{w}_D + s) - v(q^H)$ $EM_D^H = \sum_{i=1}^{n} p_i^H\, b((y_i - s) - \overline{w}_D)$	$EF_D^L = u(\overline{w}_D + s) - v(q^L)$ $EM_D^L = \sum_{i=1}^{n} p_i^L\, b((y_i - s) - \overline{w}_D)$

Figure 3.8 Farmer and Middleman payoff under asymmetric information (status quo)

The payoffs indicate that $EM_H^H > EM_H^L$ and $EM_H^H > EM_D^H$ which implies that the middleman prefers to contract with an honest farmer who provides high quality coffee. It can also be shown that $EF_H^H < EF_H^L$ which implies that the honest farmer has no incentive to provide high quality coffee. The dishonest farmers have an incentive to adversely-select into selling to middlemen since they have a higher payoff than the honest farmer: $EF_D^L > EF_H^L$ and $EF_D^H > EF_H^H$. Therefore, this explains why it is more likely for middlemen to purchase low-quality coffee. This result is also evidenced by the descriptive analysis where 13% of the transactions from farmers were graded as low quality.

3.4.3.4 Incentive structure and coffee quality at the middleman-exporter interface (asymmetric information (unobserved quality))

In this arrangement, the exporter is the principal who contracts the agent, the middleman to procure high quality coffee. We make similar assumptions as in the middleman-farmer interface and the utility functions take the same functional form. Exporters purchase from both farmers and middlemen because they only work directly with a few farmers registered under a certain group or cooperative, which limits the volumes accessed through this channel. On the other hand, exporters cannot move from farm to farm to purchase the small volumes from individual farmers as this significantly increases transaction costs (Henning & Henningsen, 2007). Buying from scattered individual farmers would induce high transport costs and search fees, moreover the quality differs across regions. Working with middlemen reduces transaction costs but involves a lot of challenges in terms of coffee quality management, because of asymmetric information.

Information asymmetry between exporters and middleman arises because the middleman's effort to procure high quality coffee is not verifiable by the exporter at the time of purchase. This has resulted in opportunistic behavior from both the exporter and the middleman. The middlemen tend to blend high- and low-quality coffee for instance: mixing dry and under dry coffee; mixing green and discolored beans; and mixing small and good size beans in the same bag. When the price of Arabica increases, they tend to mix Arabica type coffee beans with Robusta type coffee beans to increase volume so that they can get higher margins. Middlemen are also known to sometimes add foreign materials like stones in coffee bags to increase their weight. Given the large volumes delivered by the middlemen, it is difficult for the exporters to examine all the bags before making a payment. Thus, they can only base their quality judgement on selected or random samples. Exporters have been reported to under report the moisture content of the coffee beans delivered by the middlemen. Moreover, exporters make payments based on receiving low-quality beans, which takes away incentives for investments in high quality procurement. These actions have resulted in mistrust between exporters and middlemen and have also led to adverse-selection of dishonest middlemen (those who lower the quality of coffee) in the exporter-middleman interface.

If the exporter offers a fixed payment ($\overline{w}$) to the middleman, the following payoff functions would arise:

$$EU^H = u(\overline{w}) - v(q^H)$$

$$EU^L = u(\overline{w}) - v(q^L)$$

It is evident that the middleman will choose the lower effort (produce low-quality coffee) since $EU^L > EU^H$. This is true since $v(q^H) > v(q^L)$, which implies that the middleman does not have the incentive to procure only high-quality coffee. The lack of incentives explains why the exporters are likely to purchase more low-quality coffee when they transact with middlemen. Therefore, there is a potential moral hazard problem at the middleman-exporter interface. The relationship between coffee quality and market channel is also shown by the descriptive analysis where only 43% of the transactions through middlemen were graded as high-quality compared to 80% of the transactions made through farmers' groups.

3.5 Summary, conclusions, and policy recommendations

There is growing global demand for high-quality coffee (McCluskey, 2015) and yet Uganda continues to observe some low-quality coffee. Post liberalization policies in Uganda resulted in low coffee quality. The quality of a coffee cup is determined by decisions made along the supply chain including planting, harvesting, processing, and marketing (Wintgens, 2009). There is limited empirical evidence of how incentive structures along different market channels impact coffee quality in Uganda. Public policies that do not consider incentives and governance structures along the supply chain will likely result in adverse effects. This paper analyzes the incentive structures in current marketing channels to understand their impact on coffee quality.

The market channel through which the transactions are made plays a significant role in the quality of coffee. Coffee procured by exporters through a farmers' group channel is 55% more likely to be of high quality than coffee procured through a middleman channel. The farmers' group channel (cooperative governance structure) is incentive compatible for high-quality coffee procurement. The middleman channel (spot market governance structure) likely leads to adverse selection and moral hazard resulting in low-quality coffee. Other factors that significantly affect coffee quality include premium price, coffee variety, and the frequency of the transactions. The premium price for quality positively influences coffee quality since it is used as a basis for economic evaluation of the benefit of high-quality coffee versus low-quality coffee. Robusta coffee variety negatively affects quality, while frequency of the transactions has positive impacts.

Quality of coffee can be improved by providing incentives to farmers (e.g., premium prices for high quality coffee) to invest in coffee quality. This will ensure that middlemen can purchase high quality coffee. Therefore, the exporter will purchase high quality coffee through both market channels. Thus, all actors may improve their livelihoods as a result of higher quality and price.

Uganda can enhance the flow of high-quality coffee beans through the supply chain by supporting the formation of more farmers' groups. Farmers' groups have the capacity to provide extension services to its members such as quality focused training (Hernandez-Aguilera *et al.*, 2015). A study from Ethiopia revealed that coffee beans sampled from farmers' groups presented higher quality compared to beans sampled from private traders including middlemen (Tolessa *et al.*, 2018). Much as the findings from our study are focused on the coffee supply chain, they can be used to improve quality flow in other agricultural supply chains with asymmetric information problems such as the beef supply chain.

3.5.1 Further research

Based on empirical results and theoretical analysis, incentive structures are important determinants of coffee quality in the supply chain and can lead to moral hazard problems and adverse selection if actors are not properly incentivized. Further research is necessary to test hypotheses based on proposition from the Principal-Agent framework presented here: spot market governance structures lead to adverse selection of low-quality and dishonest (highly opportunistic) producers; spot market governance structures can lead to a moral hazard problem and are not incentive compatible with high-quality coffee production and wholesale; and farmers' group channels (cooperative governance structure) are incentive compatible for high-quality coffee procurement. Further research is also needed to test what drives the quality difference across marketing channels (e.g., incentive structure vs. access to resources vs. technical knowledge). The results from this further research will inform public policy initiatives designed to improve quality of coffee in Uganda.

3.5.2 Limitations to the study

The study was limited by time availability to collect data. The would be second phase of data collection was affected by COVID-19 pandemic since it was not safe then to conduct face to face interviews, yet mails could not be used as well due to the nature of Uganda system. As a result, we could not test some of the hypotheses hence referring them for further research. The small number of exporters in Uganda also limited the sample size of the study.

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Appendix A - Supplementary material for Chapter 3

A.1 Derivation of optimal solution under symmetric information

$$\max_{[q,\{w(y_i)\}_{i=1,\dots,n}]} \sum_{i=1}^{n} p_i(q)[b(y_i - w(y_i))]$$

$$s.t \sum_{i=1}^{n} p_i(q)u\big(w(y_i)\big) - v(q) \geq \underline{U}$$

$$L = \sum_{i=1}^{n} p_i(q)[b(y_i - w(y_i))] + \lambda\left(\underline{U} - \sum_{i=1}^{n} p_i(q)u\big(w(y_i)\big) - v(q)\right)$$

Let $p_i(q)$ =q^H

$$L = q^H[b(y - w^H)] + \lambda\left(\underline{U} - q^H U(w^H) + v(q^H)\right)$$

Kuhn-Tucker conditions

1.

$$\frac{dL}{dq^H} = b(y - w^H) - \lambda U(w^H) + \lambda v'(q^H) \leq 0\,, q^H \geq 0\,, q^H\big(b(y - w^H) - \lambda U(w^H) + \lambda v'(q^H)\big) = 0$$

2.

$$\frac{dL}{dw^H} = -q^H b'(w^H) - \lambda q^H U'(w^H) \leq 0\,, w^H \geq 0\,, w^H\big(-q^H b'(w^H) - \lambda q^H U'(w^H)\big) = 0$$

3.

$$\frac{dL}{d\lambda} = \underline{U} - q^H U(w^H) + v(q^H) \geq 0, \lambda \geq 0\,, \lambda\left(\underline{U} - q^H U(w^H) + v(q^H)\right) = 0$$

Case 1: $\lambda = 0\,, q^H > 0, w^H > 0$

From condition 3,

If q^H=1,

$$\underline{U} + v(q^H) = U(w^H)$$

$$w^H = U^{-1}\left(\underline{U} + v(q^H)\right)$$

Appendix B - Questionnaires

B.1 Middlemen questionnaire

EXAMINATION OF QUALITY DIFFERENCES IN COFFEE ALONG THE SUUPPLY CHAIN IN UGANDA. IMPLICATIONS FOR THE INDUSTRY AND THE ECONOMY

Research question

What incentives will motivate farmers and middlemen (traders) to invest in coffee quality?

Questionnaire for middlemen

Screening Question: Have you bought and sold coffee during last 12 months?

Yes ☐ **No** ☐

Section A: Socio-economic characteristics

1. District……………………………………………………………………………………...

2. Village………………...

3. Sex of respondent: Male ☐ Female ☐

4. Age of the respondent……………………………………………………………………...

5. Education level of respondent…………………………………………………………….

6.What is the percentage of your income from the following sources?

Source	**Proportion of total income (%)**
Coffee trade	
Business other than coffee	
Government pay	
Agribusiness	
Other source	

Section B: Coffee purchase

7. How long have you been in the coffee business?

……………………………………………………………………………………………………

8. From who do you buy the coffee and in what form?

	In what form? (e.g. fresh, dry)	% of purchase from each source (e.g. number between 0 and 100)	Rank suppliers based on your personal preference (1 most preferred, 3 least preferred)	Provide main reasons for your ranking
Individual farmers				
Farmer groups/cooperatives				
Other (please specify) __________				

10. Please specify average quantity per transaction from each source?

Supplier type	Amount	Unit	How often in days? (e.g. every 15 days)
Individual farmers			
Farmer group/coops			
Other (please specify ________________			

11. Please describe what you understand by coffee quality

Quality type	Characteristic description
High quality	
Medium quality	
Low quality	

12. Please specify the total volume, price per unit, and quality (e.g. high, medium, low) for each month.

Month	**Total volume (in kg)**	**Price**	**Unit**	**Quality (H, M, L)**
January				
February				
March				
April				
May				
June				
July				
August				
September				
October				
November				
December				

13. What are the main reasons for price fluctuations?

Reason for high price	Reason for low price

14. What are the reasons for fluctuation in quality

Reason for high quality	Reason for low quality

15. How do you rate the overall quality of coffee purchased from your suppliers?

	3 High: 2 Medium; 1 Low
Individual farmers	
Farmer groups/coops	
Other……………………………… …………………………………….	

16. What proportion of high, medium and low quality do you purchase?

	Individual farmers	Farmer groups/coops	Other
Proportion of High (%)			
Proportion of Medium (%)			
Proportion of Low (%)			

17. Do you consider any quality aspects before buying the coffee?

(a) Yes…………………………………………… (b) No……………………………………

18. If yes, what quality aspects do you consider before purchase?

What quality aspects do you consider	On a scale of 5, please rank the quality aspects with 5 the most important

19. If no in 17, explain why?

……………………………………………………………………………………………………

……………………………………………………………………………………………………

20. Do you pay a premium price to your suppliers who satisfy your quality needs?

(a) Yes ☐ (b) ☐

21. If yes how much do you pay?

Quality type	Price (UGX) record zero if bad quality coffee is rejected
High quality	
Medium quality	
Low quality	

22. If no in 20, explain why?

(a)……………………………………………………………………………………………...

(b)……………………………………………………………………………………………...

(c)……………………………………………………………………………………………...

(d)……………………………………………………………………………………………...

23. On what contractual basis do you buy your coffee?

(a) written contract

(b) oral contract

(c) no contract (please provide reasons for not using contract) ________________________

24. How long have you been buying under this contractual agreement?

………………………………………………………………………………………………

25. What is specified in this contract?

i) price of coffee

yes……………….. No…………..

ii)quantity of coffee that will be purchased

yes………………….. No………………………..

iii)minimum quality requirement

yes…………………. No……………………………..

iv)mode and speed of payment

yes………………………. No……………………………….

v) premium

yes……………………………..No…………………………..

vi)penalties for breaking the contact

yes………………………. No……………………………………..

vii)other specify

……………………………………………………………………………………………………

26. What is the main reason for signing a contract?

a) guaranteed market for coffee

b) extra services available only under contract arrangement

c) higher price than without contract

d) specify other

27. Has your seller ever failed to respect the terms of the contract?

a) yes, often b) yes, sometimes c) seldom, d) no, never

28. Would it be difficult for you to break the contract and buy your coffee to another seller if you wanted to?

a) impossible b) difficult c) possible d) easy

29. How much cost do you incur for an average transaction?

Please provide following information regarding your most recent transaction and a typical transaction

Cost type	**Most recent transaction**	**Typical transaction**
Communication and Search fee		
Distance to seller (Km)		
Distance to buyer (Km)		
Unit cost of coffee (Kg)		
Other cost		
Other cost		

30. What is the most important challenge you face while you are buying coffee?

……………………………………………………………………………………………………

……………………………………………………………………………………………………

Section C: Coffee sell

31. Whom do you sell your coffee to and what proportion?

Buyer	Form/type (e.g. fresh, dry)	Proportion (%)	Reason for choice of buyer
Processor/exporter			
Other 1			

Other 2			

32. On what contractual basis do you sell your coffee?

(a) written contract

(b) oral contract

(c) no contract

33. How long have you been selling under this contractual agreement?

……

34. What is specified in this contract?

i) price of coffee

yes……………….. No…………..

ii)quantity of coffee that will be delivered/purchased

yes………………….. No………………………..

iii)minimum quality requirement

yes…………………. No……………………………..

iv)mode and speed of payment

yes………………………. No……………………………….

v) premium

yes……………………………..No…………………………..

vi)penalties for breaking the contact

yes………………………. No……………………………………..

vii)other specify

……

35. What is the main reason for signing a contract?

a) guaranteed market for coffee

b) extra services available only under contract arrangement

c) higher price than without contract

d) specify other

36. Has your buyer ever failed to respect the terms of the contract?

a) yes, often b) yes, sometimes c) seldom, d) no, never

If yes, why?

……………………………………………………………………………………………………

37. Would it be difficult for you to break the contract and sell your coffee to another buyer if you wanted to?

a) impossible b) difficult c) possible d) easy

38. Please state what you believe high quality coffee is?

……………………………………………………………………………………………………

……………………………………………………………………………………………………

39. Does your buyer consider any quality aspects?

Yes……………………………No………………………………………………………..

40. If yes, what quality aspects does the buyer consider before purchasing your coffee?

What quality aspects does your buyer consider	Please rank the quality aspects with 5 the most important

41. Do you always meet the quality needs set by the processor/buyer?

(a) Yes……………………………(b)No…………………………

42. If yes, do you receive a premium for meeting all the quality needs required by the processor?

(a)

Yes…………………………………………………(b)No……………………………………

43. How much is the premium payment?

Quality type	Price (UGX) record zero if bad quality coffee is rejected
High quality	
Medium quality	
Low quality	

44. If no in question 42, give reasons why?

……………………………………………………………………………………………………

……………………………………………………………………………………………………

45. What is the basis of payment? Please mark all that apply

(a) weight of the bag

(b) bean color

(c) bean size

(d) bean moisture content

(e) specify other

……………………………………………………………………………………………………

……………………………………………………………………………………………………

46. What is the most important challenge in selling coffee?

……………………………………………………………………………………………………

……………………………………………………………………………………………………

47. Is there anything else you would like to share about coffee quality?

……………………………………………………………………………………………………

……………………………………………………………………………………………………

Thanks for your time

B.2 Exporter Questionnaire

EXAMINATION OF QUALITY DIFFERENCES IN COFFEE ALONG THE SUUPPLY CHAIN IN UGANDA. IMPLICATIONS FOR THE INDUSTRY AND THE ECONOMY

Research question

What incentives will motivate farmers and traders to invest in coffee quality?

Questionnaire for Exporters

Screening Question: Have you bought and sold coffee during last 12 months?

Yes ☐ **No** ☐

Section A

1.What is the percentage of your income from the following sources?

Source	**Proportion of total income (%)**
Coffee trade	
Business other than coffee	
Government pay	
Agribusiness	
Other source	

Section B: Coffee purchase

2. How long have you been in the coffee business?

……………………………………………………………………………………………………

3. From who do you buy the coffee and in what form?

	In what form? (e.g. fresh, dry)	% of purchase from each source (e.g. number between 0 and 100)	Rank suppliers based on your personal preference (1 most preferred, 3 least preferred)	Provide main reasons for your ranking
Individual farmers				

Farmer groups/cooperatives				
Other (please specify) __________				

4. Please specify average quantity per transaction from each source?

Supplier type	Amount	Unit	How often in days? (e.g. every 15 days)
Individual farmers			
Farmer group/coops			
Other (please specify __________________			

5. Please describe what you understand by coffee quality

Quality type	Characteristic description
High quality	
Medium quality	
Low quality	

6. Please specify the total volume, price per unit, and quality (e.g. high, medium, low) for each month.

Month	**Total volume (in kg)**	**Price**	**Unit**	**Quality (H, M, L)**
January				
February				
March				
April				

May				
June				
July				
August				
September				
October				
November				
December				

7. What are the main reasons for price fluctuations?

Reason for high price	Reason for low price

8. What are the reasons for fluctuation in quality

Reason for high quality	Reason for low quality

9. How do you rate the overall quality of coffee purchased from your suppliers?

	3 High: 2 Medium; 1 Low
Individual farmers	
Farmer groups/coops	
Other……………………………… …………………………………….	

10. What proportion of high, medium and low quality do you purchase?

	Individual farmers	Farmer groups/coops	Other
Proportion of High (%)			
Proportion of Medium (%)			
Proportion of Low (%)			

11. Do you consider any quality aspects before buying the coffee?

(a) Yes………………………………………… (b) No……………………………………

12. If yes, what quality aspects do you consider before purchase?

What quality aspects do you consider	On a scale of 5, please rank the quality aspects with 5 the most important

13. If no in 11, explain why?

………………………………………………………………………………………………………

14. Do you pay a premium price to your suppliers who satisfy your quality needs?

(a) Yes ☐ (b) ☐

15. If yes how much do you pay?

Quality type	Price (UGX) record zero if bad quality coffee is rejected
High quality	
Medium quality	
Low quality	

16. If no in 14, explain why?

(a)……………………………………………………………………………………………

(b)……………………………………………………………………………………………

(c)……………………………………………………………………………………………………
(d)……………………………………………………………………………………………………

17. On what contractual basis do you buy your coffee?

(a) written contract

(b) oral contract

(c) no contract (please provide reasons for not using contract) ______________________

18. How long have you been buying under this contractual agreement?

………………………………………………………………………………………………………

19. What is specified in this contract?

i) price of coffee

yes……………….. No…………..

ii)quantity of coffee that will be purchased

yes………………….. No………………………..

iii)minimum quality requirement

yes…………………. No……………………………..

iv)mode and speed of payment

yes………………………. No……………………………….

v) premium

yes……………………………..No…………………………..

vi)penalties for breaking the contact

yes………………………. No……………………………………..

vii)other specify

………………………………………………………………………………………………………

20. What is the main reason for signing a contract?

a) guaranteed market for coffee

b) extra services available only under contract arrangement

c) higher price than without contract

d) specify other

21. Has your seller ever failed to respect the terms of the contract?

a) yes, often b) yes, sometimes c) seldom, d) no, never

22. Would it be difficult for you to break the contract and buy your coffee to another seller if you wanted to?

a) impossible b) difficult c) possible d) easy

23. How much cost do you incur for an average transaction?

Please provide following information regarding your most recent transaction and a typical transaction

Cost type	**Most recent transaction**	**Typical transaction**
Communication and Search fee		
Distance to seller (Km)		
Distance to buyer (Km)		
Unit cost of coffee (Kg)		
Other cost		
Other cost		

24. What is the most important challenge you face while you are buying coffee?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

Section C: Coffee sell

25. Whom do you sell your coffee to and what proportion?

Buyer	Form/type (e.g. fresh, dry)	Proportion (%)	Reason for choice of buyer
Processor/exporter			
Other 1			
Other 2			

26. On what contractual basis do you sell your coffee?

(a) written contract

(b) oral contract

(c) no contract

27. How long have you been selling under this contractual agreement?

…………………………………………………………………………………………………

28. What is specified in this contract?

i) price of coffee

yes……………….. No…………..

ii)quantity of coffee that will be delivered/purchased

yes………………….. No………………………..

iii)minimum quality requirement

yes…………………. No……………………………..

iv)mode and speed of payment

yes………………………. No……………………………….

v) premium

yes……………………………..No…………………………..

vi)penalties for breaking the contact

yes………………………. No……………………………………..

vii)other specify

…………………………………………………………………………………………………

29. What is the main reason for signing a contract?

a) guaranteed market for coffee

b) extra services available only under contract arrangement

c) higher price than without contract

d) specify other

30. Has your buyer ever failed to respect the terms of the contract?

a) yes, often b) yes, sometimes c) seldom, d) no, never

If yes, why?

…………………………………………………………………………………………………

31. Would it be difficult for you to break the contract and sell your coffee to another buyer if you wanted to?

a) impossible b) difficult c) possible d) easy

32. Please state what you believe high quality coffee is?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

33. Does your buyer consider any quality aspects?

Yes……………………………No……………………………………………………..

34. If yes, what quality aspects does the buyer consider before purchasing your coffee?

What quality aspects does your buyer consider	Please rank the quality aspects with 5 the most important

35. Do you always meet the quality needs set by the processor/buyer?

(a) Yes……………………………(b)No…………………………

36. If yes, do you receive a premium for meeting all the quality needs required by the processor?

(a)

Yes………………………………………………….(b)No……………………………………

37. How much is the premium payment?

Quality type	Price (UGX) record zero if bad quality coffee is rejected
High quality	
Medium quality	
Low quality	

38. If no in question 35, give reasons why?

……………………………………………………………………………………………………

……………………………………………………………………………………………………

39. What is the basis of payment? Please mark all that apply

(a) weight of the bag

(b) bean color

(c) bean size

(d) bean moisture content

(e) specify other

……………………………………………………………………………………………………

……………………………………………………………………………………………………

40. What is the most important challenge in selling coffee?

……………………………………………………………………………………………………

……………………………………………………………………………………………………

41. Is there anything else you would like to share about coffee quality?

……………………………………………………………………………………………………

……………………………………………………………………………………………………

Thanks for your time