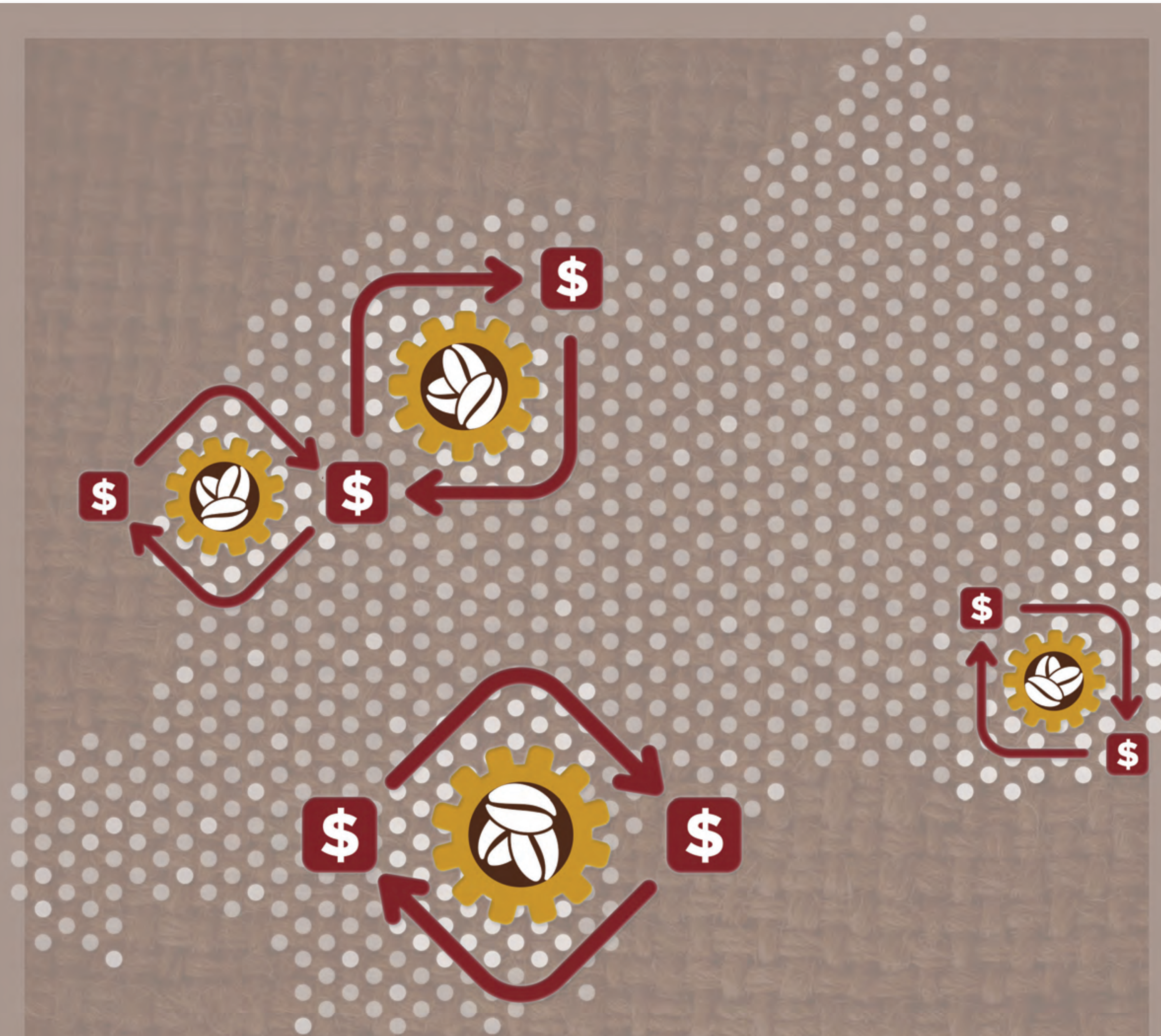


Estimating Farmer Cost of Production: Implications for Sustainable Growth in Rwanda's Coffee Sector

Ruth Ann Church: A Masters Project B Study in partial fulfillment of an
M.S. Community Sustainability, Michigan State University, August 2017

MICHIGAN STATE UNIVERSITY

Acknowledgements

Generous support for the research and writing of this report came from the Community Sustainability department, College of Agriculture and Natural Resources at Michigan State University. Special thanks to Dan Clay, Maria Claudia Lopez and Daniel NT Rukazambuga for their generosity, guidance and support. Thanks also to all the institutions and individuals in Rwanda who helped me during my nine month residency in Rwanda. There are certainly too many to name all of them here, but your contributions are acknowledged with heartfelt thanks. Gratitude also goes to the coffee farmers, a few of whom I was able to meet and interview. These times were definitely the highlights of this project for me. I hope that this project in some way creates improvements for your lives. Last, but not least, huge appreciation to my husband, John Kaczor, and children, Naomi, Isaac and Noah, for their unfailing support.

Contents

1. Executive Summary

A better understanding of costs of production (CoP) is essential to understanding the profitability, and therefore the sustainability, of coffee as a source of income at the farm level, and export revenue at the national level in Rwanda. Toward this end the present research seeks first to provide an analysis of the major components of producer cost of production in Rwanda's coffee sector. Further, the report describes a methodology and quantitative estimation process that can be used to collect the necessary data and generate CoP estimates in other coffee producing countries with predominantly smallholder production. Applied to Rwanda, the estimation procedures arrive at mean and median CoP values of 177 RWF/KG[1] and 122 RWF/KG cherry, respectively. These costs for many farmer groups are higher than the average cherry prices being paid in Rwanda. This has serious implications for Rwanda's long term production trend of specialty coffee.

In addition to satisfying the above dual objectives, (an analysis of components of CoP and an estimation methodology) a regression analysis finds that five variables are significant determinants of coffee cost of production. The report shows how number of trees, number of years of farmer experience, cooperative membership, gender of head of household and slope of the fields affect farmer costs in Rwanda.

The research shows that the number of trees in a farm plantation is significantly and inversely related to CoP (see Figure 1). It is recommended that this finding be used to guide both the design and the evaluation of farmer training programs. Programs should seek to target their resources to the size of farmer that will benefit most.

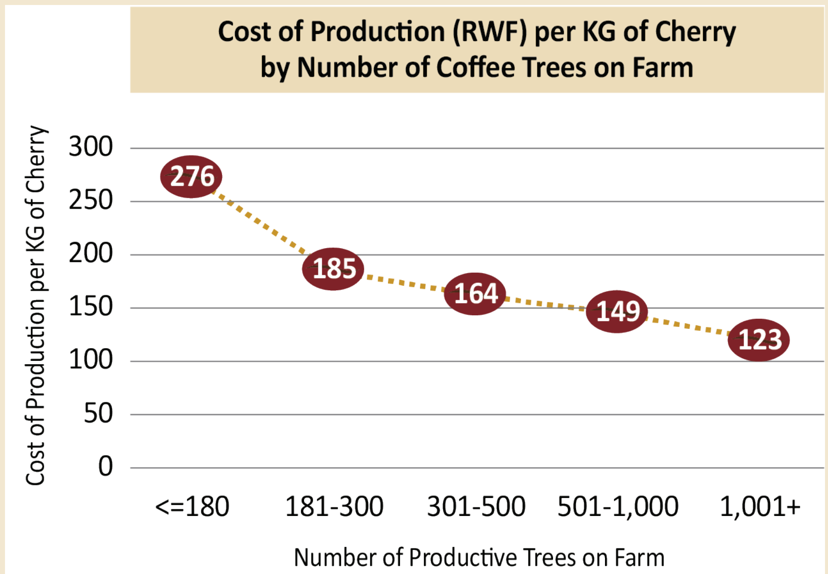


Figure 1: CoP/KG cherry is inversely related to number of trees

I also find that the number of years a farmer has been in coffee significantly reduces his/her CoP. This, too, has important implications for program design. Farmer field schools might seek to include input from farmers with many years of experience, and at the same time target the younger farmers as participants.

[1] 177 RWF/KG cherry converts to $.63/lb. green, a more universally comparable metric, using Fx rate of 814 Rwf/$ and cherry to green ratio of 6.4.

Cooperative membership also shows a significant impact on CoP. I find that cooperative membership reduces CoP slightly, and I attribute this effect to the training cooperatives offer and the motivation farmers receive from the second payment that cooperatives often pay.

The study further finds that female headed households have, on average, higher CoP than male headed households, all else equal. This result is contrary to what one might expect given the high score Rwanda received on IFPRI's Women's Empowerment in Agriculture Index (the WEAI). But the reasons for this empirical result are not clear. It could be that differences in strength due to physical build and higher average age mean that women work more hours doing the same tasks, which would raise their CoP, and they may also hire more costly labor for tasks requiring more strength, or those requiring the use of chemicals. I recommend further investigation to test these interpretations.

Finally, out of four additional exogenous variables included in the model (elevation, slope, free pesticide, and free fertilizer) only slope proves to be significantly related to CoP/KG. This is explained by the fact that measures for erosion control become essential on steep slopes and these are also costly, both in terms of time and cash outlays for mulch material. There is also some evidence that yields are lower on plants grown on very steep slopes.

With this research on costs of production, those who set cherry prices in Rwanda and those who purchase coffee anywhere in the coffee value chain are better able to change the incentive structure and better motivate Rwanda's coffee farmers. I recommend, for example, that this newly estimated cost of production in Rwanda (177 RWF/KG cherry) be incorporated into the formula and process for determining the floor price for cherry in Rwanda. I also see the need for steps to regularly update CoP estimates in the future. Tracking such information over time would be helpful to NAEB and washing stations in their strategic planning as well as day-to-day management decisions. Moreover, a more accurate formula for creating cherry floor prices based on multiple years of data will be an essential step towards ensuring Rwanda's "second sunrise" for coffee.

2. Introduction and Background

"The first and primordial step," is a term sometimes used to underscore the importance of understanding the cost of production (CoP) for smallholder coffee farmers (Kraft, 2016). The phrase is apropos because so many controversial topics and debates in the coffee industry boil down to understanding and accurately estimating this concept. For example, "fair" pricing, price risk management, incentives, quality premiums, pest control, national production levels and many in-depth coffee value chain studies rest on estimates of, and assumptions about, farmers' CoP. Often, the focus of the debates are about *small* farmers and their livelihoods, as throughout origin countries, smallholders produce most of the coffee (Fairtrade Foundation, 2016).

In Rwanda, the topic of CoP is particularly salient, and simultaneously problematic because of a lack of accurate data. Over 95 percent of Rwanda's coffee producers are smallholder producers. They typically farm 250 trees along with other crops on less than a half a hectare of land (NAEB, 2016). For many years coffee has been Rwanda's most important source of foreign exchange[2] and an important source of income among smallholder farmers (Schluter & Finney, 2001; AGLC, 2016e). Income from coffee sales can greatly influence rural household expenditure patterns and wellbeing, and in Rwanda about 70 percent of the population is rural.[3] Yet despite its multi-faceted importance, overall coffee production in Rwanda is still far below what it was prior to the conflict in 1994 (PTSA III, 2009; Nzeyimana, 2013; AGLC, 2016a). The PEARL and SPREAD[4] project years saw a burst of activity bringing production of fully-washed coffee up to a significant level (26,000 tonnes in 2004). But for the past five years, 2010 – 2015, volumes have largely plateaued, averaging only 15,300 tonnes per year. (See Figure 2 below.) Low producer prices and a lack of inputs are among the reasons for the decline/stagnation of coffee production in Rwanda (Loveridge, 2003; AGLCa and AGLCc, 2016).

[2] The PSTA III (Strategic Plan for the Transformation of Agriculture, Phase III) has prioritized coffee as Rwanda's primary export crop. The sector averaged USD 58 million in export revenues for the decade 2001 - 2011.

[3] World Banks statistics estimate the percent of Rwanda's population that is rural is dropping rapidly. Whereas it was 80% in 2005, it is now at 70%. http://data.worldbank.org/indicator/SP.RUR.TOTL.ZS?locations=RW

[4] PEARL (Partnership for Enhancing Agriculture in Rwanda through Linkages) was a USAID funded program running from 2000 – 2006. SPREAD (Sustaining Partnerships to enhance Rural Enterprise and Agribusiness Development) also USAID funded, ran from 2006 – 2012. More in Appendix 2.

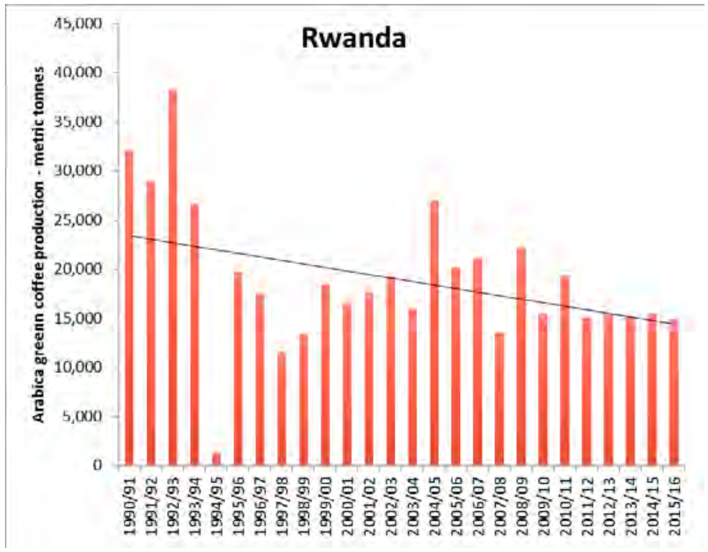
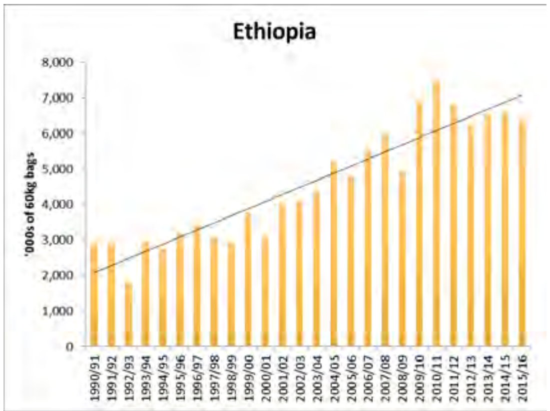
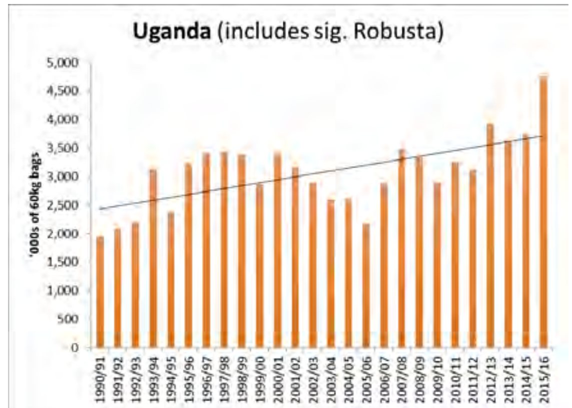


Figure 2: Rwanda's Arabica green coffee production trend is downward. Source: ICO

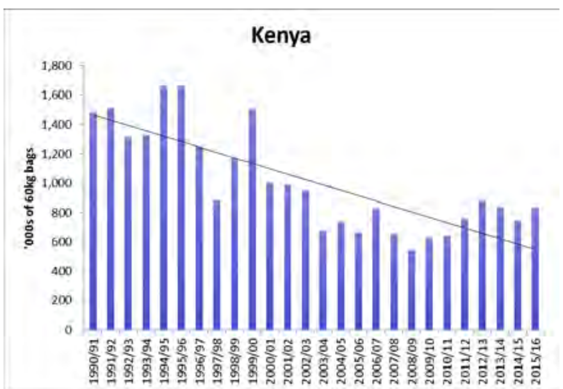
Rwanda's production decline is happening within the context of the broader East Africa Coffee community which seems to be producing both coffee "winners" and coffee "losers." Ethiopia is the big winner in the region due to its impressive and sustained increases in production. It is also a comparable case to Rwanda, in that it produces Arabica coffee. Uganda is also experiencing production gains, but these may be substantially due to the large share of Robusta coffee (~80%) in Uganda's production, which is a different, lower quality market. See Figure 3 and 4.

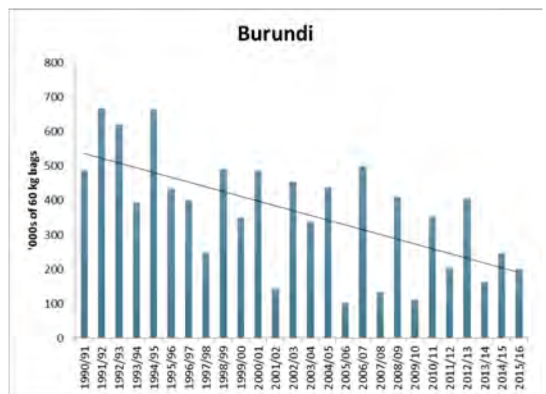


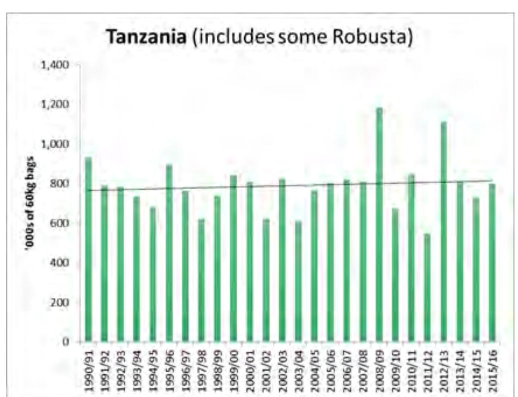


***Figures 3 and 4: East Africa Trends: Growth in coffee production in Ethiopia and Uganda. Source: ICO*.**

On the other hand, Rwanda's production trend looks more like Kenya and Burundi. Both of these countries are major producers of Arabica and they are experiencing the same kind of declines as Rwanda. The other major producer in East Africa is Tanzania, and its production appears to be flat over the 1992-2016 time period (see Figures 5, 6 and 7). Tanzania's production includes about 30% Robusta.[5]







Figures 5, 6, 7: East Africa Trends: Kenya and Burundi in decline; Tanzania has plateaued. Source: ICO

[5] http://www.coffeeboard.or.tz/tzcoffee_%20profile.php, accessed July 2017.

A review of the literature on what is causing production declines in East Africa over the past few decades points to a broad spectrum of factors. Everything from taxes to climate change, structural adjustment to licensing and low prices are found to be causes of the reduced volumes (Baffes, 2005; Baffes, 2006). Prices of inputs and price fluctuation on the international market are also cited (Ndayitwayeko, 2014; Technoserve, 2011; Ikeno, 2007). Liberalization, in general, is touted as improving prices for farmers, but the higher revenues are often offset by higher labor costs and limited access to credit, which restricts access to inputs (fertilizer or pesticide), in turn leading to declining yields (Winter-Nelson & Temu, 2002 and 2015). In Tanzania in the early 2000's, it appears that coffee "lost out" to maize and rice, as government policies abolished coffee cooperatives, making access to inputs more costly to farmers, while investments from foreigners to improve rice and maize were introduced (Maghimbi, 2007). In Kenya, also during this time period, low prices and competition from other crops and expanding human settlements were found to cause production declines (Karanja, 2002). More recently, reports have focused on the impacts of climate change. In Tanzania nighttime temperatures over the past 40 years for each of Tanzania's Arabica growing areas are found to have increased +0.30c per decade (Craparo, 2015).

As this review indicates, Rwanda is not alone in its challenges, historical and current. However, according to those leading Rwanda's industry now, Rwanda intends to be one of East Africa's future coffee "winners," not one of the losers, and it has captured their intention in their newly released brand, "Rwanda Coffee: A Second Sunrise." Rwanda's current goal is to reach 36,000 tonnes production by the year 2018.[6] This will be a challenge for a country where the 2015/2016 season produced 18,793 total tonnes.[7]

Figure 7: NAEB recently released a new brand for Rwandan coffee.

Layered onto the overall production challenge is a sub-challenge to transition from being primarily an exporter of commodity coffee, to being a recognized exporter of gourmet, specialty coffee.[8] As a land-locked country with high population density and limited coffee acreage, Rwanda must succeed in the quality-driven specialty coffee market as it is un-competitive on a global basis for commodity grade coffee, which competes largely on volume and price. NAEB has a strategic goal to increase to 80 percent the proportion of coffee produced through the fully-washed (FW) channel, significantly reducing the production of "ordinary" or "semi-washed" coffee. In 2015, about 50% was sold through the FW channel, up from 41% the year prior,[9] so reaching the 80 percent mark by 2018 is indeed a very challenging task.[10]

To successfully meet these production and quality challenges, understanding CoP for farmers will be essential, (Nguyen, 2015; Nyoro, Wanzala & Awuor, 2001). Fortunately, the government of Rwanda

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6 Gatarayiha, C, 2016, Presentation at AFCA, Feb. 5, 2016, Dar Es Salaam.
7 New Times, July 22, 2016, "Twin, TMEA move to make coffee sector a more lucrative business."
8 Gatarayiha, C, 2016, Presentation at AFCA, Feb. 5, 2016, Dar Es Salaam.
9 Ibid.
10 Ibid.

supported a partnership led by Michigan State University to help improve coffee productivity and to control antestia pest damage on Rwanda's coffee farms through the Africa Great Lakes Coffee (AGLC) project. An essential aspect of the work in both of these domains (productivity and antestia control) involves coming to grips with what it *costs* farmers to produce quality coffee in Rwanda and under what circumstances coffee can be profitable to farmers.

This study uses data from AGLC to bring greater understanding of CoP for coffee in Rwanda, and in turn to improve the livelihoods of Rwanda's coffee farming families. As another prominent research group has pointed out, "few countries actually know the cost of production for their small farmers; at best some countries have some expert estimates" (COSA, 2015). A major coffee producing country recently discovered the average cost assumptions they were using were substantially incorrect for some areas. Better data showed how "different policies were affecting farmers' costs and incomes. The evidence was so clear and credible that – within months - it resulted in a major turn-around in sustainability policies. The shift most likely affected the lives of many producers and their communities," (COSA, 2015).

The impact of income improvements for coffee farmers can also have a large multiplier effect. Cano, Vallejo and Caicedo (2012) show that a 10% increase in labor income in coffee areas in Colombia will increase GDP 43 base points, similar to the effect produced by a 10% increase in the wages of the *rest of the agriculture sector.* GDP will only increase 4 base points if the same adjustment is applied to workers in the oil sector. As stated by these authors, "[T]here is no other product which pulls GDP as strongly as coffee. Coffee production reduces poverty and distributes income among the rural population,"(Cano, Vallejo and Caicedo, 2012).

When countries are as dependent on an agricultural export as Rwanda is dependent on coffee, the importance of having information <u>systems</u> to consistently generate cost of production data becomes paramount. In Colombia, another country heavily dependent on its coffee exports, the situation is described this way:

> "This environment [of intense competition in agricultural markets] plus the purpose of the National Government … to make agriculture one of the engines of development in the country … by strengthening the competitiveness of the sector, means you have to improve and increase agricultural information systems, including production costs, so that agricultural producers and investors have better tools for efficient resource allocation." (Perfetti, 2012, p. I-1)

Rwanda has an estimated 355,000 households dependent on coffee for a significant part of their income.[11] New research shows the income from coffee is used for everything from basic survival-levels of food and shelter, to school fees and community obligations, to starting small businesses and investing in coffee.[12] So the economic impact of coffee is large at both the national and the household levels and multiplies far beyond the physical 'cash in hand' of the farmer. This is why the Rwandan government

[11] NAEB – National Coffee Census. 2016, p. 14.
[12] AGLC working paper, Farmer Investments….

must also put a high priority on the activities of the coffee sector, and this study seeks to support that prioritization.

This report seeks therefore to serve two main purposes. First and foremost, it is designed to provide data and insights on costs of production that enable evidence-based decision-making for all stakeholders in Rwanda coffee. In particular, I envision this analysis will support: 1) policy-making at the national level and 2) coffee producers at the farm level, to reach their goals for coffee production. A second goal of this report is to provide a benchmark cost of production estimate for coffee in Rwanda and a methodology for its calculation.

To achieve this dual purpose, the remainder of this report is organized as follows. Section 3 reviews the literature on CoP in coffee, noting ways the report is similar to other works, and some important ways in which it departs from the literature. Next, it describes the methodology of the AGLC Baseline Survey which generated the data from which the estimates of CoP are derived. In section 5 the process for estimating CoP is described in detail. This section also examines the relative importance (size) of the various CoP components. We also look at CoP when certain optional components are included, such as fertilizer distributed for free and transport costs.

Section 6 presents the analysis and findings of several external factors known to impact CoP/KG. We present our hypotheses about these determinants and how farmers can potentially lower their CoP. We model 17 variables which fall into three broad groups: farm characteristics, washing station variables and agro-ecological variables. With this unique dataset from Rwanda, we are able to test our hypotheses and identify some of the primary determinants of differences in CoP at the farm level. These results are presented and discussed.

Finally, conclusions and implications for further policy and research are discussed. We believe the research meets the objectives of sharing a CoP methodology for use by the coffee industry and of deepening understanding of CoP in Rwanda to aid its progress towards its “Second Sunrise.”

3. Review of Literature - Cost of Production in Coffee

The research literature on cost of production in coffee is unanimous in substantiating the importance of understanding the costs and the profitability of smallholder farmers. The profitability of smallholder farmers is a cornerstone to the sustainability of the specialty coffee industry, as well as the larger global coffee industry. In general, costs of production need to be better understood so that they can be managed effectively. Nguyen (2015) and Nyoro (2001) working in Vietnam and Kenya respectively have published two studies on different continents with very different coffee “contexts” and their studies are even conducted 15 years apart. Yet their conclusions are similar: costs of production must be lowered in order to improve profit margins to make quality coffee possible, and also to ensure continuation of any coffee production at all.

Other authors like Wilson (2010), study CoP in the context of high debt rates of farmers in Nicaragua, and find that the squeeze between increasing costs and declining prices is the main cause for the high debt levels of smallholders. He claims the slimmer margins are directly causing productivity declines from a lack of labor (time) investment and depletion of soil nutrients due to reduced inputs. This is in line with findings from the AGLC working paper, "Farmer Investments…" where investments per tree in Rwanda are shown to be the lowest for farmers who are withdrawing their time and cash due to lack of motivation and lack of monetary incentives.

So the relationship of CoP to farmer investments and profitability is fairly well described in the literature in a variety of contexts and timeframes. What is surprisingly less well understood, are the methods used to estimate CoP and empirical analyses of factors that impact CoP. We summarize 20 examples here of studies that have estimated CoP for coffee. We compare them on units of measure, CoP results, major components of CoP and their methodologies for measuring costs. (The 20 sources are listed in Appendix 1, Table 1). With this background, several important aspects of the CoP data from the AGLC project are noted below.

Unit of Measure and the Definition of CoP

As one reviews the literature on cost of production, one of the first observations is the wide variety of units of measure for cost of production used. Papers and reports use a broad mix of currencies and coffee "units." Table 1 in Appendix 1 lists these various units of measure. We note that **US$/lb. green coffee** or **US$/KG green coffee** appear to be the most common metric for CoP results. But for many contexts, including this study, these units involve several conversions from the original data, each of which can add distortions. First a conversion factor for the currency (in our case from RWF to US$) must be chosen and then for the coffee unit, (from KG cherry to lb. or KG green). So throughout our analysis we use the local currency, RWF, and the unit of production at the farm level in Rwanda, which is KG of cherry, and only occasionally use conversions to the more common US$/lb. green coffee.

The units of measure, in effect, define "cost of production," so they take on great importance. In the Rwandan context, for example, the cost required to produce one KG of exportable green coffee actually involves the work of at least three different organizations: the farmer, the washing station and the dry mill. Thus when speaking about the *farmer's* cost of production, it makes the most sense to use the unit that is the "final product" that the farmer sells. In Rwanda farmers sell both cherry and parchment which they process at home. (The home-processed parchment is called "ordinary" or "semi-washed" coffee.) However for this study, we focus on farmers selling cherry to washing stations, so the unit for CoP is RWF per KG cherry.

An important distinction should also be made between the costs per unit of <u>product</u> (like KG cherry or KG parchment or lb. green) and expenses per production <u>asset</u>, such as a tree or a hectare of land. With the former as the denominator, we are estimating CoP. With the latter, the production asset as the denominator, we can have a discussion of expenses, investment levels and productivity, which is an important difference. We note that practitioners are not always clear about this distinction, but the proper definition of "cost of production" is **the value of a set of costs divided by the units produced**. Typically a unit of weight (KG or lb. or arroba) is the best denominator unit for CoP of agricultural products.

In which direction should CoP/KG go?

Related to the definition of CoP is the question of, at the farm level and at the national level, should one hope to see CoP declining or increasing? In general, the answer is that CoP should decline, as this implies improving margins. However, the question often brings up the relationship between costs per asset and costs of production (per product unit). Namely it can be a positive for the value of the investments per asset to increase (the term "productivity" refers to this metric), but all other things being equal, the value of costs of production per product need to always decrease. In other words, in a thriving coffee business, one would expect to see the US$ costs/hectare (investments and productivity) increasing and US$ costs/KG (CoP) cherry decreasing. But there are exceptions. The concept of "a lower CoP is a better CoP" does not hold true, for instance, when comparing across regions where input costs are very different. For example, we expect farms in Hawaii and Panama to have higher CoP/KG than farms in Rwanda, primarily because they have higher costs of labor. They have also developed a customer base that expects quality and adequately compensates their higher costs. I advocate for Rwanda to pursue customers in this gourmet coffee category also, but to get there in the short term, the direction of average CoP/KG cherry both at the farm level and nationally, should be decreasing, not increasing.

CoP Results

With the distinction between overall costs and CoP/KG in mind, we can review the results from the studies found in the literature. Ten of the twenty or so papers we reviewed give clear estimates of CoP, and these are summarized in Table 2 below. Using US$/lb green as a unit of measure to enable comparison, the range of values for Rwanda is $.05 to $.64.[13] Integrity's milestone study for Burundi estimated $.75/lb green for 2012. COSA's estimate for Kenya converts to $1.52/lb green in 2015 and Nyoro found $.68/lb green for Kenya in 2001. Estimates for Colombia range from $.68 - $2.38/lb green. This wide range of values can be attributed to both the underlying differences in costs across time and across regions and countries, as well as the variety of methodologies used in the estimation formulas.

[13] We use $1 = 790 RWF. The rate as of July 2016.

Table 2: Ten CoP studies with country and CoP result

Sorted by country, then highest to lowest CoP			**CoP Result**
Study #	**Study (Author - year)**	**Country**	US$ per lb. green coffee
1	**USAID - AGLC - 2016**	**Rwanda**	**$0.64**
2	Technoserve, 2011-2013	Rwanda	$0.26
3	NAEB - 1990s	Rwanda	$0.05
4	TMEA - Integrity - 2014	Burundi	$0.75
5b	COSA - 2015b	Costa Rica	$1.96
5c	COSA - 2015c	Guatemala	$1.32
5e	COSA - 2015e	Nicaragua	$0.92
5f	COSA - 2015f	India	$0.72
5g	COSA - 2015g	Vietnam	$0.52
5a	COSA - 2015a	Kenya	$1.52
6	Nyoro, Wanzala &Awuor 2001	Kenya	$0.68
8a	CIAT/CRS - 2015	Colombia - Narino - Off-farm	$2.38
9	IDH - Technoserve 2014	Colombia	$1.66
8b	CIAT/CRS - 2015	Colombia - Narino - specialist	$1.58
8c	CIAT/CRS - 2015	Colombia - Narino - diversified	$1.40
5d	COSA - 2015d	Colombia	$1.12
8d	CIAT/CRS - 2015	Colombia - nat'l avg.	$0.92
7a	Committee on Coffee Competitiveness, 2015	Colombia - state A	$0.83
10	CRECE- UTZ, 2014	Colombia	$0.78 - $0.95
7b	Committee on Coffee Competitiveness, 2015	Colombia - state B	$0.72
7c	Committee on Coffee Competitiveness, 2015	Colombia - state C	$0.68

Components of CoP – the largest is labor

A wide variety of components are included in the estimates of CoP in Table 2, but we notice two components are consistently included – labor (especially hired workers) and inputs such as fertilizer and pesticide. All other items appear to be optional as to whether they are included in the CoP formula. This is appropriate, also, as coffee is grown in very different contexts with different sets of costs. One notes that the largest component of CoP, for all the papers that disclose some granularity of their estimates, is labor. The labor component ranges from 30 – 80 percent of total costs. We also note that there is not consistency in how household (unpaid) labor is valued. Many studies appear to ignore unpaid labor as a cost, and many others make an effort to give that labor a value and include it in CoP. The AGLC data here includes a value for unpaid labor, as will be discussed later in this section.

Methodologies for Estimating CoP

Cost of production can be measured in numerous ways. Some studies conduct primary research using farmer surveys and/or focus groups discussions with farmers. This type of study is expensive, however, so it is not surprising that we also see many studies using focus groups with industry experts and secondary data. The largest sample of the six reviewed studies that used survey research was 1540 in Kenya (Nyoro, 2001). The others ranged from 120 – 857 household surveys. In one study, the entire sample is drawn from one cooperative in the country. In other studies, the sample is taken from several selected coffee growing districts or states. Some of the studies are multi-country studies, but most are focused on a single country or a single region within a country.

The CIAT/CRS study stands out in a number of ways. First, it is a focused effort to understand CoP in a single region in Colombia. Estimating a national value for CoP is not part of the study's purpose. Second, they use multiple "lenses" to "triangulate" the value of CoP. They use: 1) a baseline survey, 2) farmer record books filled out by farmers over a period of time, and 3) focus groups with a carefully selected group of industry stakeholders, including green coffee buyers. Finally, they are the only study we reviewed where the authors estimate CoP over an extended period, seven years in this case. The objective was to estimate investment costs over this period of time. Finally, the CIAT/CRS team gives their own definition of CoP components. Lundy suggests CoP is a function of three main "sets" of variables:

Genetics X **E**nvironment X **M**anagement[14]

They add that these variables are greatly impacted by two other key factors: market channel (the coffee buyer) and farmer livelihood strategies. The latter includes a group of variables including coffee as a percentage of total income, a measure of the size of the coffee plantation and the amount of income from non-coffee wage labor.

The Integrity/TMEA study is the second study that has exceptional quality deserving further attention, and it is more relevant to the present analysis, because the context in Burundi is very similar to Rwanda. The study gathered data from 400 farmers for two years (2011 and 2012). The data are well organized and presented to show variation by region and farm size. The authors carefully walk through the differences in yield and tree spacing that can impact assumptions about costs when aggregating to costs per tree or per hectare. The study rightly focuses, however, on estimations of cost of production per KG cherry and breaks down the results by year, by region and by size of plantation. The average CoP is estimated at 383 FBU/KG cherry in 2012 ($.75/lb green). But the authors keep the disaggregations by

[14] Lundy, Mark. 2015 presentation at SCAA, Seattle, WA.

region and plantation size as they look at prices and gross margins, providing rich context for their conclusions that the “grille” or framework for calculating floor prices for cherry must be reformed.

In general, research and industry efforts to quantify and understand cost of production of coffee seem at best to create a robust methodology that works in a specific context, and at worst, the efforts are poorly executed and severely underfunded. Even when studies are well done, public accessibility can be a true challenge. Thus, the methodology of the baseline study (described in section 4) and the estimation process for CoP (described in section 5) should be especially helpful and can be used as a benchmark and a model for others seeking to quantify and understand cost of production among smallholder coffee farmers.

4. Methodology of the AGLC Baseline Survey

Cost of production in Rwanda is derived from data collected by the Africa Great Lakes Coffee (AGLC) project Baseline Survey. The AGLC Baseline Survey was conducted from December 2015 to March 2016 with 1024 farmers in four of Rwanda’s coffee-growing districts: Gakenke, Rutsiro, Huye and Kirehe.

Sample Frame

The sampling frame used in the survey is as follows:

- 1024 farmers were interviewed:
    - 256 in Gakenke (North)
    - 256 in Huye (South)
    - 256 in Rutsiro (West)
    - 256 in Kirehe (East)
        - 4 washing stations were selected in each of these districts
        - 64 farmers were randomly selected from the list of farmers delivering to each washing station.

4 districts x 4 washing stations x 64 farmers = 1024 total farmers interviewed.

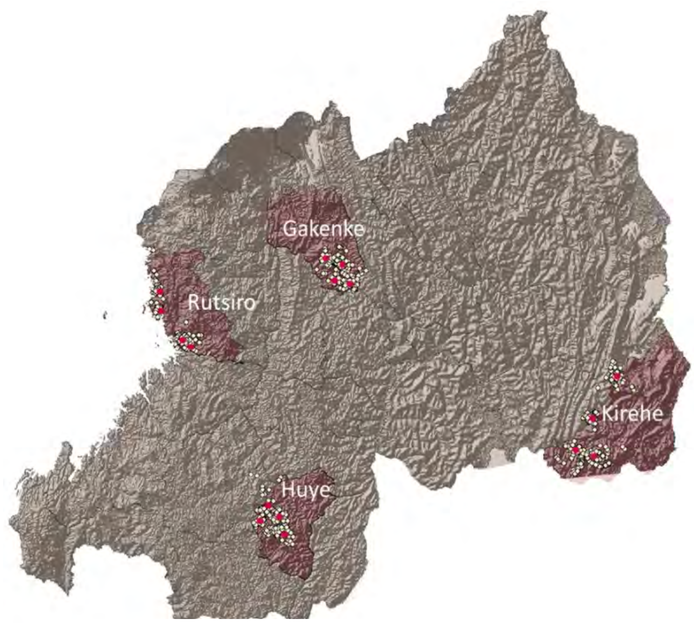

Figure 8: Four regions of Rwanda included in field research. The sampled CWSs and coffee producer

Although the sample is not representative of the entire population of Rwanda’s coffee farmers,[15] it is large enough and diverse enough to give reliable metrics like cost of production for farmers actively engaged

[15] The sample does not include farmers who exclusively produce semi-washed coffee. These are farmers who either live very far from a washing station (probably > 5km) or they simply choose for other reasons to process their coffee at home and sell parchment. Estimates of how many of Rwanda’s farmers are in this category could not be obtained. The volume of semi-washed coffee in Rwanda was about 50% of the total in 2015.

in the production of cherry for fully-washed coffee. This is an especially important segment of coffee growers in Rwanda.

The Baseline Survey includes a large set of variables gathered at the field level and the household (or farm) level. All the variables for the CoP estimation come from the farm level data. The CoP variables include: labor for seven cultivation tasks, harvesting and sorting. After labor, there are variables for the inputs, like fertilizer, pesticide and mulch, and equipment.

The baseline data were loaded into SPSS for analysis. SPSS was used to compute CoP, then analyze descriptive statistics on the components of CoP and other variables such as the number of trees on the farm, gender, cooperative membership and agro- environmental factors.

See conceptual model (Figure 10 in section 6) for a visual diagram of the variables and research questions.

The literature review of twenty other studies of CoP (provided in the previous section) highlights the uniqueness of the dataset of the AGLC project.

- **Sample size:** The AGLC project uses a structured approach to surveying 1024 farmers in Rwanda. (Detail on the sample frame is included in the Methodology section below.) The largest sample found in the literature is 1540. So much of what can be gathered from farmers is based on recall. Recall can be weak (Arthi, 2015). But the weaknesses of recall can be statistically minimized when averaged across a large number of sampled households.
- **Robustness of the data:** the robustness, or the reliability, of the data is directly linked to the sample size, but it must be noted as a distinguishing and important aspect of the AGLC work. The importance of strict design methodology and quality data collection is emphasized by the authors of other cost of production analyses (Perfetti, 2012). The AGLC project produces CoP estimates that are robust at a national level. The data credibly represents the segment of Rwanda's coffee industry producing fully-washed coffee, which is the segment that supplies the specialty coffee industry and is the focus for Rwanda's future.[16]
- Representation of the situation in the field is what all researchers want, but data gathering from farmers is extremely time consuming. The work by other groups reviewed here is sometimes limited to one cooperative (FairTradeUSA, 2015) or one concentrated region (Burtica, 2013). Limiting geographic area and farmer 'types' is understandable because of the expense and huge amounts of time it takes to do face to face interviews with a carefully selected list of farmers. One must travel to the coffee producing regions, which in Rwanda are one to four hours' drive from the capital. Then one must meet the individual who knows where the farmers are, and then, if interviews are conducted at the household or at the fields, one walks by foot to these locations. This last leg is sometimes another 30 minutes to an hour. The AGLC project was able

[16] The AGLC sample does not include a representation of the producers who sell primarily "semi-washed" or "ordinary" coffee. These producers in Rwanda still primarily de-pulp and dry their coffee at home using stones and drying mats. See details in the methodology section below.

to do this work by hiring 10 enumerators who worked daily for 10 weeks to complete the required 1024 surveys, (i.e., 500 person-days total, or .48 days per survey).[17]

- **The high granularity of the data** compiled in the AGLC Baseline Survey offers the ability to uncover insights that are otherwise not possible. For example, the CoP data can be disaggregated by region, size of farm, number of trees, household demographics, cooperative membership and dozens of other variables. This makes it possible to determine the effects of these characteristics on the production costs, which is useful for understanding the competitiveness of the sector. It also facilitates simulation analyses, which are useful for designing policy instruments. Only a handful of the twenty CoP studies we reviewed seemed to have this level of granularity (TMEA/Integrity, 2014; CIAT/CRS, 2015; IDH-Technoserve; 2014; Fedessarollo, 2012].
- **Public availability:** The work by AGLC is already putting results in the public domain through this report and others. Results and the AGLC methodology will continue to be made public during and after the project ends in 2018.
- **Quality of enumerators:** A few of the studies reviewed here discussed the research program in enough detail to learn that the fieldwork is sometimes completed by expatriate grad students assisted by translators, or cooperative staff who are trained for a short-term field research effort. The AGLC Rwanda project was fortunate to have at its disposal 10 Rwandan young professionals with college degrees and prior field research experience. They received a week of training on the instrument including a field test. After the field test with farmers in an area not included in our sample, feedback was discussed and adjustments to the instrument were made. They worked in two teams of five, each supervised by a senior Rwandan researcher. This part of the research was organized and conducted by the project's local partner, the Institute for Policy Analysis and Research (IPAR-Rwanda).
- **Quality of the data collection instrument and its application:** The instrument included 400 questions created by a team of experienced researchers. Data collection occurred at the farmers' households and at a minimum of one of each farmer's fields. In other words, the enumerators went to where the farmer was most comfortable, where he/she had records available about the farm and where details such as the geo-coordinates of the home and the slope of the fields could be collected first-hand. Enumerators also could observe details such as amount of mulch applied to the fields. The instrument was translated into Kinyarwanda and enumerators had both English and Kinyarwanda versions available on their Samsung 7" tablets used for the survey. All questions, prompts and sequencing for the enumerators were programmed into the tablets using CSPro Mobile, a public domain software package made available by the US Census Bureau.[18] The Samsung tablet combined with the CSPro Mobile software enabled regular uploads of data through the internet to a Dropbox folder for safekeeping (back-ups), quality control purposes and early analysis by researchers in Kigali and East Lansing, Michigan.

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[17] The issue of time often brings up the topic of research by cell phones. We note that in Rwanda, only 36% of the coffee farmers own mobile phones in 2015 [NAEB, 2016].

[18] http://www.census.gov/population/international/software/cspro/

- **Timeliness of data and research results:** the data were collected in Jan – Mar 2016, which is less than six months from the time of writing this report. Other research efforts in this field can take years to move from data collection to publicly available reports and results.

5. Estimation of CoP/KG Cherry

5.1 Estimation of Cost of Production per KG Cherry

With an understanding of the methodology used to collect the data in mind, this section will describe the steps used to create my CoP estimate. In some ways, this is 'part 2' of the methodology. My estimation of CoP has three major components: tasks requiring labor, equipment costs and purchased inputs. The details of the estimation process for each major component follow. As this section will show, I have estimated the mean value of CoP per KG cherry in Rwanda to be 177 RWF/KG cherry, which converts to $US .22/KG cherry, or $US .10/lb cherry.

It is also helpful to look at the median CoP/KG cherry, as the median is less affected by the extremes of the distribution and thus better characterizes the "typical farmer." The median is a lower figure at RWF 122/KG. I have this result because a significant number of farmers with CoP at the upper levels skew the distribution and yield a mean that is measurably higher than the median. Figure 2 shows a histogram of the CoP/KG for our sample.

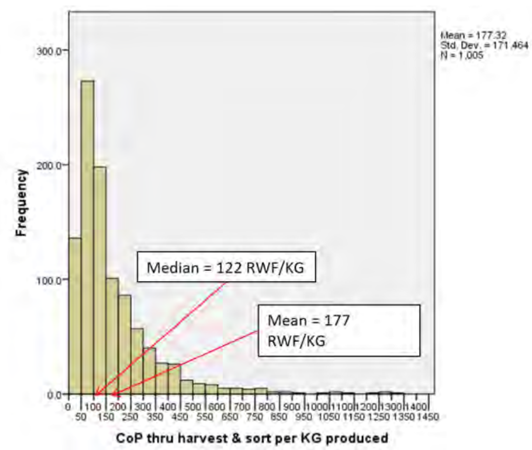


Figure 9: Histogram of CoP showing the median is less than the mean.

While the 177 RWF/KG cherry estimate is a useful average number, it is important to bear in mind that each farmer's cost of production is different, depending on the number of trees, access to processing facilities, availability of inputs, agro-ecology of the farm, family size and other factors that are explored more fully in this report and other analyses sponsored by AGLC.

I exclude the cost of land since in Rwanda because very few coffee farmers have recently purchased land for coffee production. Moreover, for nearly all farmers, land is not an incurred cost. Most land is inherited. Also, unlike equipment or buildings, land generally does not amortize, i.e. decline in value. So even in instances where farmers purchase land for coffee production, that land can be sold at some future point, generally at higher price than what they paid for it.

The 177 RWF/KG mean CoP/KG includes unpaid household labor, but excludes the value of free inputs such as fertilizer and pesticide provided by the government. Values for fertilizer and pesticide are added later in this paper, but other costs are simply excluded from consideration in this report as they are not costs incurred by the farmer. Excluded items are listed and discussed in Appendix 3.

Value of Labor Tasks
The value of labor tasks are estimated first by creating a sum of all the household labor and all the wage labor farms used to produce coffee in 2015. This is the most expedient way to estimate a total value of labor, and the comparison of household and wage (paid) labor is an important one. However, many analysts prefer to view the labor requirements by task, so we break out labor using task variables, also.

Value of Household Labor
Each major component is derived from a set of variables included the baseline survey. For example, the value of household labor is compiled using farmers' own estimates of the time they spend on cultivation and harvesting tasks.[19]

The labor categories included in the survey questions were seven cultivation tasks, plus harvest tasks (lumped together), and sorting tasks (also lumped as one).

- Cultivation tasks
    1. Weeding
    2. Mulching
    3. Fertilizer application
    4. Pesticide application
    5. Pruning
    6. Stumping
    7. Planting seedlings
- Harvest tasks
- Sorting tasks

For each cultivation task, farmers were asked a series of questions to enable estimation of a value of their time. For example for weeding they were asked, "Last season, on how many days did members of your household work on weeding coffee?" Then the survey asks, "On those days, how many hours per day (on average) were dedicated to weeding by members of your household?" This allowed researchers to calculate the number of "household labor days" spent on weeding. I divide the total hours of each household by 5.5, the average number of hours worked per day in rural areas.[20]

Finally, the total number of days spent weeding must be given a value in RWF. Analysts applied the median daily wage paid by the sampled farmers to hire labor for all tasks (excluding sorting, which was significantly lower). This wage is 700 RWF/day, ($US .89). So for weeding, the mean value of household labor is 11,084 RWF per household.

The same method was applied to all seven cultivation tasks, the harvest and sort tasks, (see list of tasks above) to create a single variable of the <u>household time</u> spent on cultivation, harvest and sorting in

[19] Farmer recall is not 100%. However, statistically, as the sample grows, the sampled mean more reliably estimates the population mean. It is also important to note that farmer recall is greatly aided when the data are collected task by task.
[20] This was the consensus of the AGLC project agronomists. The average agricultural laborer works from 7:00am – 1:30pm. The number of days/week was part of the question to the farmer. We asked "how many days/week do you do weeding?"

2015. This mean value of household labor in the baseline is RWF 35,868 ($US 45.40)[21] per household per season.

Value of wage labor

In the AGLC baseline survey farmers were asked about wages paid to hired workers, and for how many days, for the same seven cultivation tasks listed above for household labor. For example, they were asked, "Did you hire anyone to help you weed?", "In total, for how many days did you hire them?", and then, "How much did you pay them per day?" The answers allowed researchers to calculate the total value of wages paid to workers for all tasks. The mean value for total wages paid per household is RWF 44,313 ($US 56.09) for the 2015 season.

Table 5 below summarizes the major CoP components, including household and wage labor, highlighting the fact that wage labor is the larger of the two labor components at 55 percent of total labor costs. In Appendix 1, see "Table 3: Detail on Cultivation Tasks" for a breakdown of each of the nine production tasks by value of household and wage labor. For harvesting, the value of wage labor is larger than household labor, but for weeding and mulching the value of wage labor and household labor is approximately equal. This may be due to the fact that during harvest, the work is urgent, as the cherries must be picked the day they are ripe. Weeding and mulching, on the other hand, have more flexible timing and can be integrated more easily into the household's other tasks.

Value of Labor by Task

The same variables used to estimate the total value of household labor and total value of wage labor can be combined in a different order to arrive at the total value of labor per task. For example, by combining the value of household labor and wage labor for weeding, we have an estimate of the total labor value for weeding. The mean value of labor for weeding for all households in the sample was 22,097 RWF, (see Table 4 below). All nine production tasks included in the survey are shown in rank order in Table 4. Not surprisingly, we see that harvest tasks are the largest, most "expensive" category for farmers. Other researchers in Burundi, Rwanda and Colombia have also found that labor costs at harvest are the highest single cost not only on the farm, but sometimes in the entire coffee value chain (USAID Burundi, 2008; Aithal and Pinard, 2008; Lundy, 2015).

Regardless of how it is estimated, by type of labor or by task, the mean value for all labor for the households in our sample was 81,151 RWF, (USD 103), (see Tables 4 and 5).

[21] Using $US 1 = 790 RWF. The rate as of July 2016.

Table 4: Labor Value by Task – Sorted by Value (in RWF and USD)

N=1024	Total Labor Value (mean RWF)	Total Labor Value (mean $US)	%
Harvesting	29,137	36.88	36%
Weeding	22,097	27.97	27%
Mulching	16,549	20.95	20%
Pruning	5,726	7.25	7%
Fertilizer Application	3,232	4.09	4%
Pesticide Application	1,625	2.06	2%
Planting Seedlings	1,144	1.45	1%
Sorting	1,119	1.42	1%
Stumping	523	0.66	1%
TOTAL Cultivation Tasks	**81,151**	**102.72**	100%

Value of Purchased Equipment

We estimate the value of purchased equipment[22] used on the farm by asking the farmers whether they own seven different types of equipment and then also asking them to name any "other" equipment they own for coffee production.

1. Sprayer
2. Mask
3. Drying mat
4. Drying table
5. Barrel (for soaking)
6. Bucket (for harvesting)
7. Sacks
8. Other

"Other" equipment mentioned by farmers frequently were ropes, pruning shears, saws and hoes. So these were added to the equipment inventory. The most common tools owned by farmers in the sample were:

- Sacks
- Baskets
- Pruning shears
- Drying mats
- Ropes (for bending trees for harvest and pruning)

For each equipment item they said they owned, we also asked how much it cost them. For example, "How much did you spend for one sprayer?" To obtain an annual value for each piece of equipment, we

[22] Did not ask about rented or borrowed equipment.

went back to a small sample of farmers and asked them to estimate how many seasons each of these pieces of equipment typically lasts. This helped us calculate an annual cost for each tool.

By creating a total of the annual cost of each piece of equipment owned, an estimate of the value of the farmer's equipment for a single season was created, and the mean for all households in the sample was RWF 7,506 ($US 9.50). This amount includes only purchased equipment and excludes the value of any equipment the farmers received at no cost, which sometimes happens through local development projects.

Value of Purchased Consumable Inputs

The key consumable inputs for coffee are fertilizers and pesticides. In the AGLC baseline survey, we also asked whether they purchased mulch, manure, coffee plant seedlings or shade trees. For fertilizer and pesticide, we ask the farmers whether they used any last season, and then, if they said "yes," we asked them how much they actually purchased and how much was given to them by the government or others.

For the initial CoP calculation, we only include the inputs *paid for* by the farmers. We leave out inputs that are given to them free of charge (even though we know these have a high value) because we are interested in estimating the actual costs incurred by farmers. In Rwanda, a certain amount of fertilizer and pesticides are distributed by CEPAR/NAEB to farmers every year for free. We have the farmers' report on those amounts, but they are not included as a cost to the farmer.

The purchased input most commonly identified by farmers in 2015 is mulch (53%), followed by manure (14%). Interestingly, fertilizer and pesticide *purchases* by farmers are small – almost insignificant, presumably due to the "free" distributions from the government and the high cost of these items. The mean value of all purchased inputs reported by farmers was RWF 19,838 ($US 25) per household.

Total CoP for costs through harvest and sorting

The sums of the means of the three main categories above comes to RWF 107,527, ($US 136) per household. Table 5 below shows each category, with a breakout of labor by type, and thus the final sum in absolute value.

Table 5: Cost of Production (with Labor by Type of Labor) per household

CoP Component	RWF Value	$US Value	%
Value of All Labor by Type of Labor:	**81,151**	**102.72**	**76%**
Value of wage labor:	44,313	56.09	55%
Value of household labor:	35,868	45.40	44%
Value of equipment used:	**7,506**	**9.5**	**7%**
Value of purchased inputs:	**19,838**	**25**	**18%**
Total (2014/15 season):	**107,527**	**136**	**100%**

Costs per KG and per hectare
Our interest is in the cost of production at the farm level and comparisons of different farmer groups, for example those with many trees vs those with few trees, or female headed households vs male headed households. To do this we create a *household level* cost of production *per KG* of coffee cherry produced, then compare their means. We know the KGs produced by household, because in the survey we ask, "During the last harvest season (2015), what is your estimate of your total cherry harvest? (in KGs)" The mean of this variable is 1,025 KG. The resulting CoP per KG value for our sample of 1024 coffee households in Rwanda is 177.32 RWF/KG cherry, which is $US .22/KG cherry, or $US .10/lb cherry.

In some cases it is helpful to understand the costs per hectare of land. To estimate costs per ha is a similar process to the one described above. For each household, the value of labor for all tasks is totaled and the value of equipment and *purchased* inputs (fertilizer and pesticide) is added. Then this value is divided by the household's hectares of land cultivated in coffee.[23] The mean value of CoP/Ha is 564,385 RWF, (US$ 715). To summarize the above, Table 6 shows the three main components of CoP along with the per KG cherry and per Ha estimations.

Table 6: 2015 CoP Main Components – Absolute value, per Ha and per KG

CoP Component	RWF Value	Total RFW/Ha	Total RWF/KG Cherry
Value of All Labor:	81,151	438,552	137
Value of purchased inputs:	19,838	82,986	27
Value of equipment used:	7,506	43,181	15
Total CoP:	**107,527**	**564,385**	**177**

Clarification of the sample comprising this CoP/KG estimate
These CoP/KG estimates (mean 177/KG; median 122 CoP/KG) constitute accurate average estimates of CoP for four of Rwanda's major coffee-growing districts (Gakenke, Huye, Kirehe and Rutsiro) and farmers growing coffee for the fully-washed channel in those districts. The focus of the AGLC program is on the fully-washed channels as those are the farmers who comprise the target group for NAEB and the Ministry of Agriculture, as well as the major stakeholder groups in the coffee value chain. One of NAEB's strategic goals is to transition to 80% fully washed coffee within the next 4-5 years.

We also note that the 177 RWF/KG average estimate is based on 2015 data. The value would likely be incrementally higher or lower for the year prior and for future years depending on climate variations affecting production as well as changes in the composite costs such as wage rates, equipment costs, etc.

[23] The mean value of Ha^2 cultivated for coffee is .32.

The 177 RWF/KG estimate is not intended to serve as an "ideal" CoP/KG in Rwanda. It is a carefully constructed measure of the mean cost that producer households actually incur to produce one KG of cherry for the fully-washed channel in four important coffee growing districts in Rwanda in 2015. In general, we know that yields per tree in East Africa, and Rwanda specifically, are very low by world standards. One experienced agronomist maintains that Rwanda's CoP of $US .10/lb[24] is "poverty coffee farming." Per KG and per LB costs in regions like Panama, Colombia and Hawaii will be much higher. In addition, further analysis will show whether many or few of the farmers in the AGLC sample were using best practices, what kind of prices they received the year prior and whether they were profitable last year. Any of these factors could be far from the ideal and can also heavily impact the CoP/KG for a given year.

5.2 Analysis of Largest Component of CoP/KG

5.2.1 Major components of the CoP figure

For a summary of the major components of CoP, including values per hectare and per KG cherry, see Table 7 below.

Table 7: CoP major components, per Ha and per KGcherry

N=1024	Total (mean RWF)	RFW/Ha	RWF/KG Cherry	%
Labor	**81,151**	**438,552**	**137**	**75%**
Harvesting	**29,137**	173,862	51	27%
Weeding	**22,097**	106,428	35	21%
Mulching	**16,549**	90,273	31	15%
Other tasks*	**13,368**	31,709	22	12%
Input Costs (Fertilizer & Pesticide)	**19,838**	**82,986**	**27**	**18%**
Equipment	**7,506**	**7,449**	**15**	**7%**
Total	**107,527**	**528,988**	**177**	**100%**
*Application of fertilizer, pesticide, pruning, stumping, planting seedlings.				

In Table 7 it is important to note:

- Labor comprises 75percent of the CoP.
- Labor costs (including unpaid labor) for harvest and weeding are the largest labor costs.
- Inputs, such as fertilizer and pesticide, are the next biggest category of expense. This category includes any cash purchases the farmer made for fertilizer, pesticide, mulch, manure, seedlings or shade trees. (It does not include a value for inputs received for free or from the government.) See section 5.3.1 for a discussion of free inputs.

[24] 177 RWF/KG = $.10/lb. This metric is used here as $/lb. is a more common unit used to compare across countries.

- NOTE: Table 3 in the Appendix 1 has a more detailed breakdown of the nine production tasks and the value of household vs. wage labor for each.

5.2.2 Analysis of Household Labor Component

Household labor is 45% of the labor component and 33% of the overall CoP. Since household labor is unpaid and it is such an important component, we want to also understand who does what for the nine tasks for which labor was measured.

Table 8: Responsibilities for Coffee Production Tasks in the Household

(Pink = predominantly female HH member does task; blue = predominantly both perform this task; yellow = predominantly male HH member does the task)

	1	2	3	4	5	6	7	8	9
HH Type	Weeding	Mulching	Fert. Application	Pesticide Application	Pruning	Stumping	Plant coffee seedlings	Harvesting	Sorting
Male HHH, no spouse present	M	M	M	M	M	M	M	F	M
Male HHH, spouse present	F	F	M	M	M	M	M	M/F	F
Female HHH (spouse not pres)	F	F	M	M	M	M	M	F	M

Table 8 above shows there are important gender-specific roles in Rwanda's coffee production:

- Women tend to be more involved in work done "by hand": weeding, mulching, harvesting, sorting.
- Men are most likely to do work involving tools, such as pruning, stumping and applying chemicals.

The impact of these insights on cost of production relate to questions like, what choice will a female head of household make, when she has no spouse and pruning should be done? Does she do it herself, or hire someone (probably a male) to do it for her, or just not do it? Further research in this area might be justified if we find that cost of production is higher for female headed households, (see next section).

5.3 Optional Components

5.3.1 Free Fertilizer and Free Pesticide

Estimating the value of the free fertilizer and free pesticide delivered to farmers is challenging. First, the context of input distribution in Rwanda will be shared, and then estimations of the value of the fertilizer and pesticides distributed in 2015. The National Agricultural Export Development Board (NAEB) in collaboration with industry stakeholders organizes the distribution of chemical inputs to coffee farmers and they have done this for many years, more recently in collaboration with CEPAR. Thus, coffee farmers in Rwanda have grown to expect to receive these critical inputs "for free." However, in reality there is an export tax paid by buyers that underwrites a "fertilizer fund."[25] This means farmers are paying this cost via a reduced cherry price. It is unclear how many farmers are aware of this tax. The distribution system has changed over the years, as almost every year there are problems. For example,

[25] NAEB taxes green coffee exports to pay for fertilizer, the logic being the government can buy the fertilizer in bulk at a lower rate than individual farmers could purchase it. Some argue this is a service and a subsidy the government is providing, but it is controversial.

there is difficulty getting a timely supply of the appropriate fertilizers, or inputs are sold on informal markets instead of being used on the farm. Some are reported to be eventually sold in Tanzania (IFDC, 2014). With this report we consider the extent to which fertilizer and pesticides are not reaching the farmers in the AGLC sample. This is important background to the effort to quantify the costs of inputs and the remarkably low amount spent by farmers, even the high-capacity largeholders, on purchased chemical inputs.

The government of Rwanda, via NAEB, directs farmers to apply 200g per tree in two doses over the course of one growing year.[26] They try to distribute this amount to farmers based on records of how many trees farmers have. This recommended amount falls short of the 300g per tree per year threshold of fertilizer which is an internationally accepted norm for coffee trees, (AGLC, 2016c). For pesticide, NAEB recommends what the manufacturer suggests for dilution. For example, the recommended dose for Confidor is 2.25 ml diluted with 15L of water. But then NAEB determines the number of trees they will recommend for the dose, in this case 40-45 trees, which equals .056 ml per tree.[27] Unfortunately, even the government recommended doses do not seem to reach the farmers' fields. The average application of free fertilizer in 2015 was 47g/tree for the farmers in the AGLC sample and the average application of free pesticide was 0.045ml/tree. The amount of fertilizer and pesticide purchased by farmers was nearly negligible. So the farmers, on average, are applying 24% of NAEB's recommended fertilizer dose and 80% of the recommended pesticide dose.

Table 9: Recommended and Actual Input Doses

Input	Internationally accepted standard dose[28]	NAEB Recommendation	Actual Avg. Application of Free Input *(AGLC baseline)*	Percent Actual vs. NAEB Recommended
Fertilizer	300g per tree in 3 doses	200g per tree in 2 doses	47g per tree in 1 dose	24%
Pesticide (Confidor)	2.25ml diluted in 15L water	**.056 ml per tree** 2.25ml diluted in 15L water, apply to 40 trees	**0.045ml per tree**	80%

The reason for less than 100% application of recommended doses of inputs may be related, in part, to the funds available to NAEB to purchase inputs. Exporters must collect the equivalent of 14 RWF per KG cherry for fertilizer if a 7:1 conversion ratio is used. Using purchase values from the AGLC baseline survey, the recommended dose of 200g per year per tree would cost 80 RWF or 46 RWF per KG cherry.[29] Therefore in "per KG cherry" terms, the tax of 14 RWF is only 30% of the amount needed for the recommended fertilizer dosage. For pesticides, on the other hand, it appears more than enough tax is

[26] Soruce: Celestin Gatarayiha, Director of Coffee Division, NAEB. He said the "ideal" is to apply 100gr for season A and another 100gr for season B. Season A is from Oct. – Dec, Season B is Feb.- to May.
[27] The manufacturer of Confidor, Bayer, indicates farmers should dilute the 2.25ml dose in 15L of water. The number of trees per 2.25ml is suggested by NAEB.
[28] Source: AGLC, 2016c.
[29] We assume productivity of 1.75 KG per tree.

collected, compared to what is needed. (See Table 10 below.) Yet the pesticide that farmers receive is still only two thirds of the recommended amount. Uncovering why there is a discrepancy in amount received versus amount needed is a worthy question, but beyond the scope of this report. These estimates should be treated as estimates, not precise values. But they point toward one of the biggest challenges in coffee production – how to finance and distribute the critical inputs.

Table 10: Input Taxes Compared to Input Costs

Input	A. Value of tax Rwf/KG cherry	B. Value of one unit in RWF (KG or ML)	C. Value of recommended dose per tree (Rwf)	D. Value of recommended dose per KG cherry (Rwf)	E. Percent tax vs. value of recommended dose, (A/D)
Fertilizer	14	400	80	45.71	30%
Pesticide	1.57	14.6	0.82	0.47	335%
Both	15		80.82	46.18	33%

See assumptions in Appendix 6.

Table 10 also helps explain the low values for inputs in Rwanda's CoP. As stated above, inputs received for free by farmers were measured in the AGLC baseline survey, but their value is not included in the average 177 RWF/kg cherry CoP number. This is because the CoP estimate is intended to be the value of a farmer's actual expenditures on coffee production today.[30]

However, from the perspective of purely understanding what it costs to produce coffee in Rwanda, it can be useful to give free inputs a value and include them as an adjusted CoP computation. I find that free fertilizer distributions increase COP by 14,689 RWF ($17) when valued at the average price surveyed farmers paid when they purchased fertilizers. When pesticides and all other free inputs (manure or mulch received at no cost) are included, CoP goes up by 14,434 RWF ($18.27).[31] Table 11 summarizes these results, including a per KG cherry estimate of +27.35 RWF for the free inputs (205 – 177 = 27 RWF/KG Cherry). This is low amount, equal to only 3 US cents, still represents a 15% increase over the "no free inputs" CoP/KG value of 177 RWF/KG.

[30] Also, the CoP estimate will be used to estimate farmers' gross margins, and if free inputs were included they would have to be subtracted out again to understand the farmer's disposable income and return on labor.
[31] The AGLC baseline survey did not ask farmers about how much free compost they received. However, more washing stations in Rwanda are composting the pulp waste and distributing it to farmers for free, so this may be an item to include in future research.

Table 11: Adjusted CoP when free inputs are valued

N=1021	Absolute Value (Rwf)	Rwf / KG
CoP All Coffee (no free inputs)	104,479	177.32
Value of free fertilizer rec'd	14,689	22.23
Value of free pesticide rec'd	438	0.58
CoP all coffee incl. **all free inputs**	118,914	204.67
Difference (value of all free inputs)	**14,434**	**27.35**

As noted above, the average farmer is not receiving enough fertilizer by either NAEB or international standards. The taxes are not high enough to cover the costs, but the farmers have grown to expect the government to arrange fertilizer purchases and distribution, and they have limited capacity to purchase it themselves. Sometimes, even if a farmer has the cash, the inputs are unavailable (AGLC, 2016c). In other words, the CoP numbers are showing the value of inputs that are by any standard, inadequate. Thus distribution of inputs are highly recommended as an area of focus for improvement that at relatively low cost, could bring about improved yields and lower CoP/KG for many farmers.

5.3.2 Transportation

Transportation was not included in the base calculation of CoP for the AGLC sample. Technically speaking, transport is not a direct cost of production in the way that labor for weeding or harvesting is. Also, in Rwanda, farmers actually have two coffee products, coffee cherry (generally sold to regional washing stations) and dry coffee parchment, typically sold in local markets to traders. While this study is focused on the costs of cherry production, we feel it is important to note that the rationale for not including transport in the base value of 177 RWF/KG cherry, is that it will make this figure a useable "base value" for future studies that may compare the costs of production of these two products. Other reputable organizations, such as the USDA, also include only those costs incurred in the production phase of an agricultural product and they exclude information related to the marketing and distribution of the harvested crop, (Perfetti, 2012).

Contrary to our expectations, survey findings show that even when household time and labor dedicated to transporting coffee is valued, the transport costs are almost negligible. The average amounts paid for transport, including unpaid help from household members, totals to 4,986 RWF/year ($6.31). When divided by the average KG of cherry produced, this amounts to 6 RWF/KG cherry, or $.01/KG cherry.

Small as it is, transport is still a cost and the AGLC project does include transportation costs when estimating gross margins to farmers.

Transport costs also play a key role in **cherry price negotiations**. Washing stations typically pay site collectors 10-20 RWF per KG cherry for their service of collecting and transporting cherry. There is usually an assumption that the site collector will perform a "quality control" role according to guidelines from the washing station. In effect, this 10–20 RWF/KG comes directly off the cherry price paid to the farmer. Therefore it sometimes becomes a hotly contested value as floor prices and other standard prices are negotiated. With the estimation above that farmers are able to transport their cherry for far less than 10 RWF/KG, it is not clear why the site-collectors' would charge more and further research in this area is recommended.

To understand gender differences in transport costs, we examined the average transport costs by household type and by sex of the "main person making decisions about income from coffee cherry." For the female headed households (with no spouse present), the costs are above the mean (of 6.6) slightly at 7.10 RWF/KG cherry, while the households with male heads and a spouse present (the predominant household type in our study) have an average slightly below the mean at 6.3 RWF/KG cherry (significant at $p<.05$). When I look at the females who are the decision-makers about coffee income, their transport costs are 7.03 RWF/KG cherry (significant at $p<.05$). So it appears there is a slight gender difference in transport costs.

I also examine the question of who in the household transports cherry to the washing station for sale, noting that, in general, males in the household have the responsibility for transport. We assume this is due to a verbalized cultural norm that males should do work that involves transporting heavy objects and long distances, but surmise that some portion of these trips also involve collecting cash and that this may also be a factor.[32] Only 11 percent of the respondents indicated a female alone takes responsibility for cherry transport. I find that 22 percent of the farmers report that a male alone takes responsibility for transport and 40% of the time it is a joint responsibility, between both the head of household and his spouse. The remaining 27 percent said "neither" is responsible. I assume 15 percent of these are the households that always hire out the transport of cherry. The reasons for another 12 percent stating no one in the HH is responsible for transport should be further investigated. Perhaps when traders move through rural areas collecting cherry, they come to the farm gate making "no one in the HH" responsible for transport, but this has not been confirmed.

One of the baseline questions asks who normally transports cherry. Of the households in our survey, 46 percent indicated that at least one time during the season they hire someone to help them with transportation of cherry (see Table 12). It appears households use a wide variety of people to transport cherry over the course of a season.

[32] This cultural norm was given as an explanation to the author, but there was no explanation for why then women and girls are often in charge of collecting water.

Table 12: Persons transporting cherry

(**Bold** indicates transportation was hired.)

Person/People Transporting Cherry	# of Responses	%
Head of HH only	111	11%
Head & spouse	95	9%
No hired (other)	559	34%
Hired Transporter	**158**	**15%**
Head, spouse, & hired	**101**	**10%**
Head & hired	**90**	**9%**
Hired (other combos)	**116**	**12%**
TOTAL	1024	100%
All hired	**465**	**46%**

Next we look at which modes of transportation are used for transporting cherry, finding that over 60 percent of cherry is transported on foot (See Table 13) as it leaves the farm gate. A visit to a washing station or collection site during peak season makes this clear. Between 1 and 5pm, one cannot help but notice along the roads and moving down paths on steep mountainsides, the bulging white sacks on top of heads moving towards the station.

Table 13: Mode of Transportation – Cherry to Sales Point

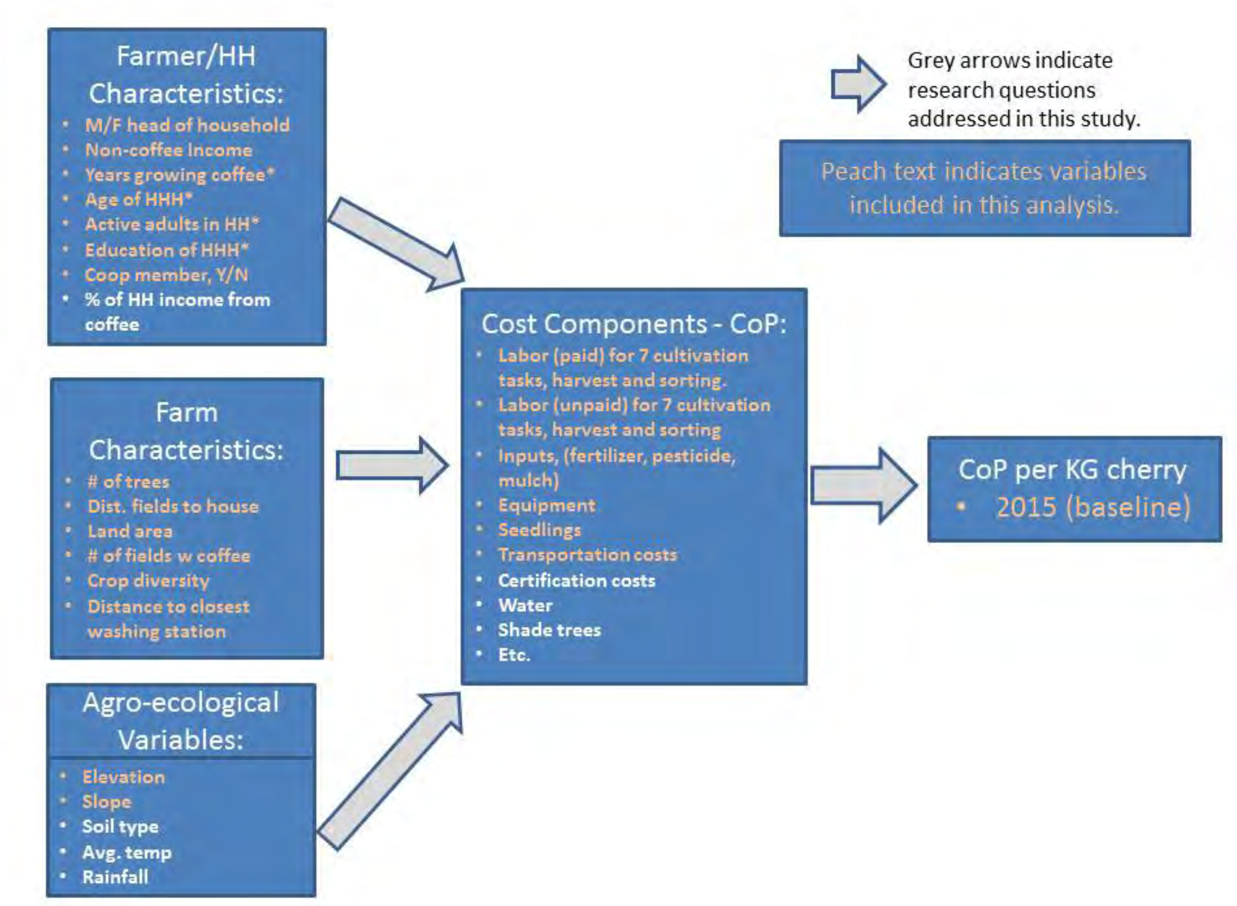
Mode of Transport	Frequency	%
No one in HH transports	280	27%
On foot	641	63%
Foot and Bike	51	5%
Bicycle	49	5%
Motorcycle	1	0%
Car/Truck	1	0%
Other	1	0%
Total	1024	100%

We also check the average distance that farmers are traveling to deliver cherry and find the average is 1.6 km, or 22 minutes (we ask farmers to estimate the distance both ways). When disaggregated by gender, there is virtually no difference between the sexes in terms of kilometers or time for transportation of cherry.

6. Analysis and Findings –What Impacts CoP?

So far we have examined the various components of CoP individually. Now we evaluate key external factors that relate to CoP. Referring to the research framework (Figure 10), I hypothesize that 17 variables will impact cost of production.

Figure 10: Research Framework showing areas of interest and relationships



The regressor variables fall into four groups: farmer/hh characteristics, farm characteristics, related to inputs, and agro-ecological factors, as shown in Table 14 below.

Table 14: Regression Variables

17 Variables of High Interest for Impact on CoP (included in regression)			
Farmer/HH Characteristics	Farm Characteristics	Related to Inputs	Agro-ecological
1. M/F head of household 2. Non-coffee Income* 3. Years growing coffee* 4. Age of HHH* 5. Active adults in HH* 6. Education of HHH* 7. Coop member, Y/N	8. # of trees* 9. Dist. fields to house 10. Land area* 11. # of fields w coffee* 12. Crop diversity 13. Dist. to closest washing station	14. Value of free fertilizer used 15. Value of free pesticide used	16. Elevation 17. Slope of coffee fields

*Partial indicator of farmer capacity.

Eight of the variables listed in the farmer/household and farm characteristics categories include factors which are considered **indicators of farmer capacity** (indicated with *). In the AGLC working paper "Determinants of Farmer Investments in Coffee Production" (AGLC, 2016a) *capacity* of farmers is highlighted as one determining factor of a farmer's ability to invest in his/her coffee trees. So I hypothesize that capacity variables like non-coffee income, years growing coffee, active adults in the household, education of head of household, # of trees, land area and # of fields with coffee are all negatively correlated to CoP. So for example, farms with <u>non-coffee income</u> will have lower (better) CoP because the non-coffee income helps them pay for things that help reduce overall costs, like pesticide, pruning shears or additional help at harvest time.

<u>Years growing coffee</u> and <u>education of head of household</u> are believed to be negatively correlated to CoP because with more years and/or education the farmer simply has more knowledge to draw from to help problem-solve everything from calculating the amount fertilizer he needs each season to deciding when to prune or renovate the trees.

<u>Active adults in the household</u> are believed to impact CoP directly, because each adult is assumed to be an efficient, motivated source of help for the farm. Husband and wife with grandma and live-in aunts and uncles are viewed as helping that household to be more productive than an average day-laborer could. The additional productivity may come from something as simple as lower transaction costs to "get to work" or better communication and understanding about the work to be done because they live under the same roof.

<u># of trees, land area and # of fields with coffee</u> are the final three capacity variables we include because I expect larger farms to have some efficiency from their size. I realize there are minimal economies of scale in coffee, but there may be some. For example, time spent hiring or organizing day laborers may be slightly lower for large farms. If these three variables all show significant and negative correlation, we will explore more deeply what, beyond 'economies of scale', could cause this relationship. For example, I hypothesize that having a larger farm simply brings more people into contact with the farm, thus multiplying the years of experience present. As mentioned above, I believe more years growing coffee will help problem-solving, reducing costs over time. Since larger farms will need more people to accomplish tasks, especially harvesting, at the right point in the season, the large farms may be getting more 'problem-solving attention' than others.

<u>Other farm and farmer variables, distance from field to house, gender of farm ownership, and number of crops grown (crop diversity) are factors</u> that other researchers and industry professionals have hypothesized can impact farm profitability, thus we want to test whether they are significantly related to CoP/KG in Rwanda.

We hypothesize that **distance to the closest washing station** is positively correlated to CoP, meaning the larger the distance, the more costs the farmer incurs. This is not only be due to the transportation costs, but higher costs due to less access to support, which theoretically, washing stations are giving to farmers in the area surrounding the station. "Support" includes inputs and training, and some farmers have mentioned occasional access to small loans. Harvest season in Rwanda is also the rainy season, and some collectors and farmers do not carry cherry during heavy rains. Instead, they wait until the next day. Closer proximity to the washing station may improve his/her willingness to deliver cherry even in bad weather, which may mean less of the farmer's fruit is damaged during overnight storage. Coffee cherry is very time-sensitive, the rule of thumb being to deliver it to the washing station within 8 hours. In other words, waiting 12+ hours, until the next day, increases the likelihood of damaged goods, unacceptable to the buyer.

Farmers who are a member cooperative have some similar hypothesized cost advantages. It is said that cooperatives that are managed well provide benefits in terms of shared profits, more access to inputs and training and better assurance of sales than what farmers usually get if they are not cooperative members. So we hypothesize a negative relationship, meaning farmers with cooperative membership will have lower CoP/KG.

Finally, **agro-ecological variables** are widely accepted to have important impacts on almost all aspects of coffee – flavor, plant productivity, and pest resistance to name a few. We hypothesize that these factors impact costs, also. For example, we assume that poor **soils** will increase costs for farmers, since they will either spend more during cultivation on *fertilizer* to add nutrients to the soil, or they will spend more time (*labor costs*) harvesting because tree yields are poor, i.e. harvest labor productivity will be reduced.[33] Unfortunately, we do not have soil analysis details for the households in the AGLC baseline survey at the time of this analysis.[34] **Elevation** and **slope** are two more ecological variables hypothesized to have a significant impact on costs. Higher elevations are conducive to coffee farming, but typically with higher elevation comes steeper slopes. The steeper slopes add difficulty and therefore cost.

Two variables related to **inputs**, **value of free fertilizer and value of free pesticide**, are included in the model as well. We hypothesize that farmers receiving and using the recommended amounts of inputs will have lower CoP/KG due to higher productivity per tree.

A regression model on the 17 variables selected shows that seven of them have a significant relationship to CoP/KG, (see Table 15 below).

[33] Thanks to soil scientist, Dr. Francois X. Naramabuye, for this insight.
[34] Soil data are expected soon for a sub-set of our sample and an analysis of CoP and soil types can be added, post hoc, to this report.

Table 15: Regression of 17 variables on dependent CoP variable

Cost of Production Regression					
#		Coeff. B	Std. Error	Beta	Sig.
1	Nbr of productive trees*	-0.026	0.007	-0.142	***
2	Total land owned*	-0.001	0.001	-0.077	**
3	Income 2015 (not including coffee)	0.000	0.000	0.028	
4	Value of free fertilizer used	0.000	0.000	0.001	
5	Value of free pesticide used	0.006	0.005	0.042	
6	Number of coffee fields*	-8.579	3.460	-0.084	**
7	Distance coffee fields to house	0.308	0.271	0.037	
8	Slope of coffee fields	1.070	0.549	0.065	*
9	Distance to buyer	-0.268	3.563	-0.002	
10	Member of coop	-28.582	11.204	-0.083	**
11	Gender of head of household	33.647	14.286	0.076	**
12	Age of head of household	0.859	0.578	0.071	
13	Active adults in household	1.149	3.535	0.011	
14	Education of head of household	4.611	5.277	0.030	
15	Years growing coffee*	-1.826	0.520	-0.162	***
16	Elevation of household (m)	0.055	0.034	0.052	
17	# of non-coffee crops grown	-4.285	2.922	-0.046	
	Constant	86.013	65.785		
	a Dependent Variable: CoP thru harvest & sort per KG produced				
	* = p < .10; ** = p < .05; *** = p < .01				

Four of the seven factors with a significant relationship to CoP/KG cherry are related to farmer capacity, and indicated by an asterisk (*) next to the variable label in Table 15 above. In the following sections I will examine in more detail the relationship of CoP to these four capacity variables, giving special attention to number of trees. Then I discuss the results from the other indicators such as cooperative membership, gender of head of household, and slope of fields.

6.1 Capacity Variables

Other research confirms the importance of capacity to profitable coffee farming, (AGLC, 2016a), thus one would expect things like the four capacity variables in the list above to be significant – number of productive trees, area of land owned, number of fields and years farming coffee. In Rwanda, the number of trees is a commonly used metric by farmers, the government, processing and exporting companies to understand a farm's size. So in my analysis, I look at the number of trees, the years the farmer has in coffee and how these impact CoP, and then briefly touch on number of fields and total land owned.

6.1.1 Number of Trees

Variability of CoP depending on farm size is an area of great importance in Rwanda and throughout the specialty coffee industry. Previous research has found a strong inverse relationship between farm size and productivity in Rwanda (Clay, 2014; Ansoms, 2009; Clay, 2002). Therefore estimates of the costs required to grow coffee in Rwanda should regularly take farm size into account. However, many estimates are based on a single estimate of a farm's expenses, which means a single "average size" farm must be used. Sometimes a lower CoP for large farms vs. small farms will be estimated without any data on which to base their assumptions. The consequences of using a single average CoP or an estimate of CoP that is scaled with no reference to empirical data can be severe in a country like Rwanda. Lack of understanding of the distribution of farm sizes and CoP values can lead to poorly designed policies for pricing, extension services, and planning for processing steps, which eventually leads to production declines or stagnation as we see in Rwanda.

For example, if policymakers want to ensure a floor price that covers the "average" costs for the "average" farmer, they might choose to use a CoP estimated on a 1 ha farm, or 2,500 trees, since this sounds like a standard unit size.[35] But this would vastly underestimate the reality for most of Rwanda's coffee farms. A histogram of the number of trees on the farms in our sample (Figure 12: below) illustrates how the majority (~ 62 percent) of farms in Rwanda have less than 500 trees.

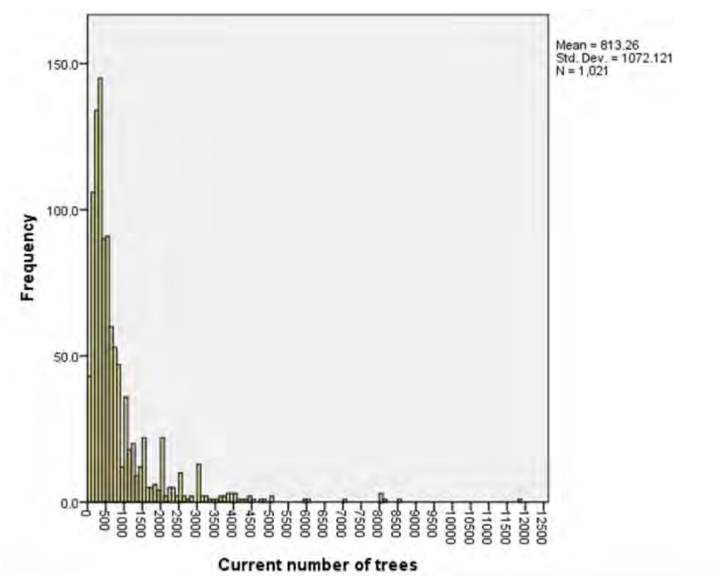


Figure 12: Histogram of Number of Trees in the AGLC sample (N=1024)

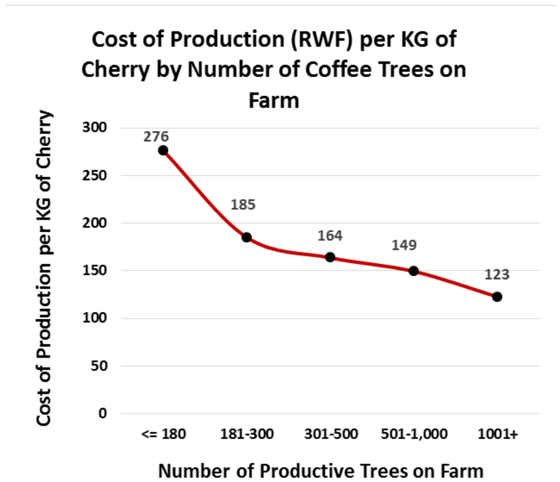
Thus, understanding the variability of CoP by farm size, and knowing the distribution of farm sizes in the country is critical. From the 15 studies of CoP of coffee reviewed for this report, it seems the concept of CoP varying due to farm size is not yet well researched or understood. Only a few reports, (Buritica, 2015; Integrity, 2013), include the relationship of CoP/KG to size of the coffee farm in the analysis. As in our study of Rwanda, the researchers in Colombia and Burundi found there is a correlation and farms

[35] In Rwanda, the rule of thumb is 2,500 trees per hectare. One hectare is considered a small farm in some producing countries. And in Colombia, for example, the rule of thumb is 5,000 trees per hectare, (Buritica, et. al., 2015).

with more trees had significantly lower CoP/KG. The Integrity research in Burundi also looked at effects of training split by size of farm, and compares yields across the spectrum of farm sizes in their study. Yields on the largest farms (>800 trees) are the lowest of the four farm size groups and the expected post-training increases in yields do not occur as often for the large farms as they do with the small farms. Yet, profits remain the strongest for the large farmers. The Burundi study shows that while all coffee farmers have slimmer margins when the NYBOT price is low, the margins of the large farms are on average still higher than the smaller farms. The Colombian study (Buritica, 2015) has a similar result. Margins are highest for the group of farmers with the largest farms.

Based on these studies it seems likely that "size matters" in coffee farming and it impacts key indicators, including CoP. Therefore, the relationship is explored here also. It would be an aid to many stakeholders to know whether assumptions about CoP, which is difficult to estimate, can be made based on knowledge of the number of trees, which is a much easier metric to assess. With a differentiated picture of CoP based on farm size, stakeholders are then more likely to find differentiated strategies that are responsive to the needs of farms of all sizes.

The regression model (Table 15 above) I tested confirms a significant, inverse relationship for trees and CoP for Rwanda, (β=-.026, p <.000). The relationship is fairly linear, (see Figure 13), meaning the rate at which CoP/KG decreases is about the same between the five groupings of farms by size. The only exception being the large difference between the smallest group, farms with < 180 trees, and the next group, farms with 181-300 trees. The mean CoP/KG cherry falls 91 RWF, from 276 RWF to 185 RWF, between these two groups, whereas the differences between the means of the other groups are 15 – 25 RWF.



Note: CoP does not include transport costs @ 6.6 RWF/Kg

Figure 13: CoP/KG Cherry decreases as Number of Trees Increases

A large difference like this between CoP for the smallest farms versus the others helps to clarify the reasons for differences in margins (AGLC, 2016a) and should lead to more strategic application of resources by policy-makers at origin, green coffee buyers across the globe, and NGOs implementing coffee farmer livelihood programs. Based on these data, for example, training programs designed to lower costs of production might target "smallest of the small" farmers since these farmers have higher costs than others. So I expect that training farmers in this category can contribute towards improved livelihoods (via better margins). In other words, the pay-off per individual trained should be better than with farmers with many trees. This may be due to the fact that the smallest farmers in our survey are also older and have less years of education.

More and more, the specialty coffee industry is realizing that programs and, importantly, pricing may need to be tailored by farm size to achieve sustainable margins in all size groups, (Trewick, 2015).

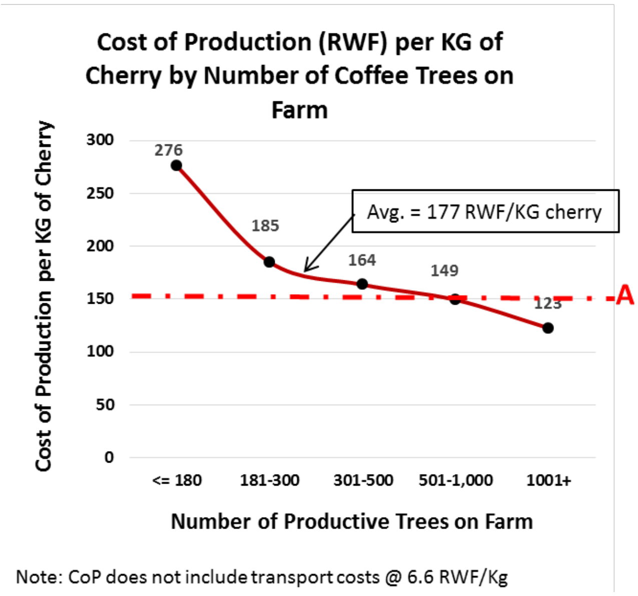


Figure 14: CoP/KG Cherry by Number of Trees with the 2016 cherry floor price

For example, the floor price for cherry in Rwanda was set at 150 RWF at the beginning of the 2016 season (see line A in figure 14). Based on the CoP data from 2015, one can easily see how the smaller farmers will lose money on coffee at this price, whereas large farmers with 1001+ trees (20% of the sample in this research) make a slim margin, because their cost of production is below the average and below the floor price.

Based on these findings, stakeholders in Rwanda might begin to look at other aspects of those with very few coffee trees, such as the inability to join cooperatives due to the fact that membership usually requires a minimum number of trees. A minimum tree requirement of 200 – 300 trees is common. On average, cooperative membership has been shown to significantly correlate with lower cost of production in Rwanda (see section 6.2 below), and this holds true even when isolating farms with less than 500 trees (AGLC, 2016b). With a holistic look at the situation of the "smallest of the small" farms, appropriate and specific interventions that would help create profitable scenarios for these farmers could be designed.

Similarly, these findings create the ability to more accurately understand the production cost situation of medium-sized and largeholder farmers. In the AGLC paper, "Determinants of Farmer Investments in Coffee Production", the differences in farmer groups based on size of plantation is developed into a new typology of Rwanda's coffee farmers. Each group has different capabilities and motivations.

The findings here also show the great variability that exists "behind" the curve shown above. As Table 16 shows, the standard deviations, especially for the group with the smallest number of trees, is quite high, meaning many farmers have a CoP that is quite far from the group mean of 276 RWF/KG. A scatterplot in Appendix 4 gives a visual graph of the distribution of the CoP data by number of trees.

Table 16: CoP/KG cherry by number of trees

Nbr of trees (5 groups)	CoP/KG cherry (mean RWF)	N	Std. Deviation
<= 180	276.1	178	244.7
181 - 300	185.1	200	144.2
301 - 500	163.0	200	144.2
501 - 1,000	149.5	209	142.2
1001+	122.7	186	124.2

The industry is also calling for more sophistication in evaluating the impact of schemes and programs designed to help the environment or lift communities out of poverty (COSA, 2015). Since these programs often affect the costs of production for a coffee farmer, our findings would support an emphasis on disaggregating by number of trees both when designing programs and when assessing impacts in coffee-growing regions.

6.1.2 Capacity – Farmer Experience

"Years growing coffee" is one of the eight 'capacity' variables included in our model. It is an indicator of capacity because experience is such an important teacher in any farming vocation. Many authors on agricultural extension, not just in coffee, discuss the importance of first-hand experience as a determinant of farmer decision-making leading to impacts on production outcomes (Maro, 2013; Swanson and Riikka, 2010; Rogers, 2003). The importance of farmer first-hand experience is validated by the trend towards participatory learning models, which are replacing "chalk and talk" extension models of the past (Waddington and White, 2014). Therefore in coffee we expect farmers with more experience to have lower CoP/KG cherry than those who are just getting started.

The model confirms our expectations, ($\beta = -0.162$, $p=.000$) by indicating the relationship of "number of years of coffee experience" is inversely related to CoP. In other words, "experience does matter." But, the small beta, -0.162, signifies that while years of farmer experience should be considered by national programs and NGOs seeking to impact CoP, the difference of "farmer experience" will be relatively small. This result leads to several recommendations. As mentioned above, the regression results support an emphasis on experiential learning opportunities for farmers, to the extent that learning-by-doing can equate to lessons learned over years of coffee farming. But the results also point towards a certain 'path' for generational change in coffee farming. The majority of farmers in our sample are older farmers with decades of coffee farming experience that apparently helps them have lower costs to produce than the younger farmers. So, like Maro, we recommend actively including their input on ways to improve soil fertility and other aspects of coffee cultivation (Maro, 2013). But, a national program seeking to reduce CoP over a long timeframe with thousands of farmers, should target bringing *young* farmers into coffee, so that five and ten years from now, these farmers will have the years of experience that appear to give farmers a cost-competitive edge.

6.1.3 Scale - Number of Fields and Total Land Owned

Two other capacity variables, (of the original eight capacity variables included on our model), show a significant correlation to cost of production: 'number of fields' and 'total land owned.' (In Table 15 see rows 2 and 6.) Like number of productive trees, these variables are inversely related to CoP, which I expected, given the similarity of what these variables are measuring. The earlier findings (section 6.1.1) show that farms with more trees will have lower costs, and it makes sense that farms with more trees are likely to be farms with more land and with higher numbers of coffee fields.

While we have noted that these three indicators related to farm size significantly lower cost of production (on average), we have not yet explored "why". One might assume that the inverse relationship is due to economies of scale. However, I hypothesize that there is little efficiency improvement when considering farms with 200 trees versus farms with 2000 trees, or .25 ha of land versus one ha of land owned. Farming Arabica coffee on small, mountainside plots in remote villages is labor intensive no matter the size or number of the fields. Weeding and harvesting, for example, two of the most time consuming tasks as shown in section 5.1, takes the same amount of worker time *per tree* whether there are 1000 trees or 100.

What could be different are other capacity factors. I hypothesize that the larger farms simply have more people working on them who know coffee, which means the "farmer experience" variable is higher in terms of all the people who see what is happening and have ideas about what to do based on their own training and past experience. Farmer experience has been shown to significantly reduce CoP ($\beta = -1.826$, $p=.000$). Also, while education of head of household does not test as significantly impacting cost of production (Table 15, row 14), an indicator of the composite level of education of all people managing the farm and working on the farm might, and I hypothesize this variable would correlate significantly to farm size, also. An indicator of the level and frequency of training of all people managing the farm and working on the farm might also test as significant and correlated to farm size. My hypothesis is that these three "scale" variables, number of trees, number of fields and total land owned, are showing us that large farms have knowledge and problem-solving capacity that the small farms do not have, and that is what is lowering their costs.

6.2 Cooperative Membership

In Rwanda "coffee farmers are encouraged to form cooperatives for addressing different issues which the single individual cannot handle" (NAEB, 2015, p. 15). However, the 2015 Coffee Census estimates that today only 14% of farmers are members of a cooperative (NAEB, 2015). One advantage of cooperative membership might be lower CoP/KG. It is thought that services and, in particular, the second payment that farmers receive as cooperative members, may motivate and support farmers to keep costs per KG low. For example, the cooperative may organize regular meetings with agronomists who teach best practices for inputs application and pruning. It is hypothesized that such training improves the productivity of cooperative farmers to a level higher than other farmers, enabling them to achieve a lower CoP/KG. Additionally, cooperatives may pay members a second payment after the coffee is sold and exported, typically six months after the harvest. Based on the price at which the coffee is sold, the cooperative determines a second payment, typically 5 – 20 RWF per KG cherry. We know from other studies that farmers receiving a second payment on average have higher productivity per tree than farmers who receive no second payment (AGLC, 2016e), and 67 percent of the farmers receiving a second payment received it from a cooperative (AGLC, 2016e). So there is evidence that cooperative members might have higher productivity than non-members, and this should be reflected in CoP/KG, being lower for coop members than for non-members.

The potential advantages of coop membership are not limited to lowering costs. There are many advantages to cooperative membership that are explored in greater detail elsewhere (AGLC, 2016b). The present analysis looks specifically at whether there are *cost* advantages to cooperative membership. If the hypothesis is supported, I expect to see a negative and significant coefficient for cooperative membership in the OLS regression model designed to estimate CoP/KG cherry as a function of cooperative membership, controlling on a set of other regressors thought to affect CoP (see Table 15 above). The results of the model do indeed support the hypothesized relationship, ($\beta = -0.083$, $p < .05$) that coop membership will generally indicate lower CoP/KG.

Cooperative members have, on average, CoP/KG cherry of 158 RWF/kg of cherry compared to non-members which have a mean of 202 RWF/KG, (Table 17). This implies that the benefits of cooperative membership, such as training opportunities and the second payment which could motivate farmers to implement best practices, may account for as much as a 44 RWF difference in a farmer's CoP/KG. Given the evidence from other studies (AGLC, 2016a; AGLC, 2016e) the second payment seems to have particular significance on farmer decisions that can impact CoP/KG.

It should be noted that this result is obtained while holding the number of trees, amount of land owned and number of coffee fields constant. This is important to note since it is widely known that cooperatives require a minimum number of trees, often about 200 – 300, to become a member. In Rwanda, cooperative farmers do indeed have more trees (873) than the average non-member (499).

Table 17: Comparison of CoP of Non Members to Cooperative Members

CoP/KG cherry (RWF)	N	Mean (Rwf)	Median (Rwf)	Std. Dev.
Non-Member	445	202	138	193
Coop Member	560	158	112	0
Difference:		44	25	

Note: p-value = 0.000 denoting significance of statistical test for differences in distributions across membership

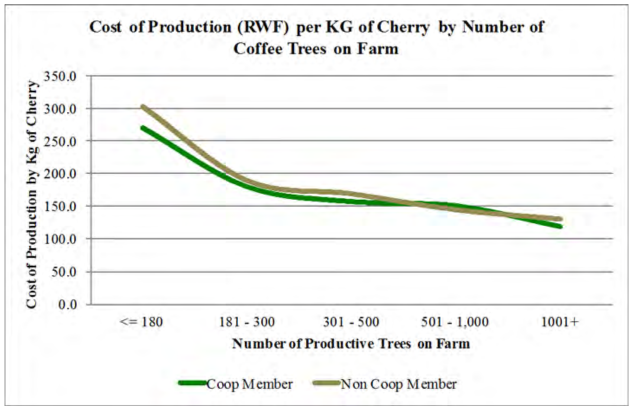


Figure 15: Shows CoP/KG cherry for Non-members and Members of Coops

Note: The CoP is plotted against numbers of trees on the farm. At the low end of numbers of trees, Coop Members fare better (lower CoP) than Non-Members. At the high end, they are nearly equal.

6.3 Gender of head of household

We know from many studies in agriculture in East Africa that culturally prescribed roles place women at the forefront of many agricultural processes (Hockett, 2014; Twin, 2014; Mitchell & Coles., 2010; Anunu, 2015). Evidence shows that the success of upgrading strategies for smallholder farmers is contingent upon the access to, distribution of, and decision-making ability over resources--by men and women (Twin, 2014). Identification and elimination of gender-biased barriers to economic empowerment not only serves to ensure the creation of robust sourcing strategies, it promotes the well-being of women in marginal household positions (Mitchell & Coles, 2010).

There is consistent and credible evidence that when the status of women is improved, agricultural productivity increases, poverty is reduced, and nutrition improves (Malapit, 2014). The Women's Empowerment in Agriculture Index (WEAI) is the index developed jointly by the United States Agency for International Development (USAID), the International Food Policy Research Institute (IFPRI), and the Oxford Poverty and Human Development Initiative (OPHI). Of the five domains of empowerment (5DE) in the first sub-index—the first one is relevant here: Decisions about agricultural production ("Production decision-making"). This is defined as "sole or joint decision-making power over food or cash-crop farming, livestock, and fisheries, as well as autonomy in agricultural production."[36]

[36] The other 4 domains of the 5DE index are access to and decision-making power over productive resources (e.g. land); Control over use of income; Leadership in the community; Time allocation. The AGLC baseline survey included a variable of male/female decision-making over income from coffee, which would correspond to another of the five domains of empowerment, but this variable was not significant in early versions of our model and was not included in the final model due to collinearity with the gender variable we do include, gender of the head of household.

It should be noted that Rwanda scored a relatively high .91 on the WEAI, indicating a relatively high level of empowerment for women,[37] (Malapit, 2014, p. 26). Therefore, it becomes even more relevant to test whether gender impacts various aspects of the coffee production, or whether gender parity has been reached in coffee in Rwanda. If it has, then it would play a less significant role in determining key indicators.

However, this seems unlikely. Given Rwanda's past, in particular the genocide in 1994, Rwanda has a large number of now aging widows, and a significant number of these women have coffee trees (VanDyk, 2005). In our sample, 185 households are headed by women and 90 percent of them are widows. Their average age of 58 is higher than the average for the sample. On average they have 1.5 children in the home beneath the age of 16 and they own 10,244 square meters of land (almost exactly one hectare). Coffee is 40 percent of their annual income, which on average is 362,000 RWF ($460). 50 percent have no education. So in testing whether the sex of the head of household impacts cost of production, we can test whether Rwanda's generally high score for equality applies in this situation also, or whether the issues of a genocide history have a continuing economic legacy today.

The regression model (see Table 15) shows the gender of the head of household has a significant and positive (β =0.076, p=.019) effect on cost of production. In the AGLC sample, we assume the head of household is the owner of the land and the coffee trees, so this result means that female farm-ownership and being a female head of household is an indicator of *higher* costs of production (33.67 RWF/KG cherry) than would be the case for land owned by a male or a household headed by a male.

Households headed by women have the highest CoP per KG cherry at 205 RWF, and this effect is significant, all other things equal. Their CoP of 205 RWF is not much higher than the mean for households headed only by a male, 199 RWF/KG, (i.e., males with no spouse). However, it is significantly higher than the mean for a household with both a male and his spouse (170 RWF/KG), and it is significantly higher than the overall average CoP/KG cherry of 177 RWF. As mentioned above, the reasons for the significant gender-based difference are not yet well understood. It could be due to the physical differences between males and females, meaning it takes women longer to do the same tasks, and therefore their costs are higher. It could also be that women more often hire labor and that they are paying more than the average male pays when wage labor is hired. An example might be if women have to hire workers to do pruning, and the men hire workers to do picking, but the wages for pruning are higher than wages for picking.

6.4 Farm Management - Inputs

We include the amount of *free* fertilizer and *free* pesticide as independent variables in the model. Since these inputs are free, they do not create issues of endogeneity with the dependent variable (CoP). We expect a negative relationship to CoP/KG cherry for both of these, since increasing applications of both should improve productivity of the coffee plant, which decreases CoP/KG cherry. With more fertilizer,

[37] The areas the study found for improvement in Rwanda were workload, access to and decisions on credit, and control over use of income.

each plant is healthier and produces more cherry. Application of pesticide is similar. With more protection against pests, each coffee plant should produce more cherry, thus reducing CoP/KG. However, the results with the model are not significant for these variables. This could be due to the very small amounts of fertilizer and pesticide that are applied, on average, in Rwanda today. As more farmers in Rwanda use more fertilizer, for example, the variable may begin to show the expected CoP reduction. Meanwhile, other factors such as number of trees and the length of the farmer's experience in coffee have a stronger impact on CoP.

6.4. Agro-ecological Factors - Slope

Geographic, environmental and agronomic factors are heavily touted in the literature as important determinants of costs of production. (Lundy, 2015; Aprile, 2015 & 2016; Kilambo, 2015; Nzeyimana, 2013; Lambot, 2004). The model in the present study includes elevation and average slope of the coffee fields visited during the field survey.

Lundy names "Environment" as one of the three major factors in the function of coffee cost of production, the other two being genetics and management, (Lundy, 2015). However, the paper by Burtica, et. al. (2013) does not discuss the impact of environmental variables on CoP. Nzeyimana and Lambot, on the other hand, discuss soil management (mostly mulching), erosion, slope and fertilization as a combination of factors that must be optimized in order for farmers to optimize productivity (Lambot, 2004; Nzeyimana, 2013). According to Lambot and Bouharmont, "cultivation on a very steep slope, as practiced in certain regions of Central Africa, entails reverting to anti-erosive methods [such as permanent mulching]" (Lambot, 2004). Nzeyimana, writing about Rwanda specifically, notes, "reduced land fragmentation, increased organic and inorganic fertilizer applications and mulching are all needed to boost yields. These practices will also help to improve the soils' chemical and physical properties and control erosion on the steep cultivated slopes" (Nzeyimana,2013). We note that the 'anti-erosive' methods prescribed by these authors involve higher costs for the farmer in terms of labor and any cash purchases of mulch.

Given these comments, we would expect elevation, rainfall (soil moisture), temperature, soil type and slope to affect CoP. Unfortunately, rainfall, temperature and soil type data were not yet available for the farms in our sample at the time of this analysis.[38] However, the enumerators for the baseline survey had tablets that could measure the slope of individual coffee fields. Elevation was determined based on the geo-coordinates of the coffee fields combined with an elevation layer in ArcGIS. We expect both of these variables to be positively correlated to CoP/KG, since both add difficulty and therefore cost to coffee farming.

Therefore, variables which we include in our OLS model representing "agro-ecological factors" include:

- Elevation
- Slope

[38] These three variables are expected to be available soon and this model can be updated at that time.

Contrary to expectations, only slope is a significant determinant of CoP/KG cherry, (β =0.065, p=.052). The coefficient is positive but small, which means steeper slopes increase the CoP, but not by much. The positive and significant relationship of slope to CoP can be explained by the extra anti-erosive measures discussed by Lambot and Bouharmont (Lambot, 2004). Mulching and other measures are known to be costly due to the extra labor and the cost of buying and/or transporting mulch material. In addition, productivity of the coffee plant is often lower on steep slopes, meaning fewer KG of coffee, which means higher CoP/KG.

A general comment can be made about the soil types in Rwanda and cost of production. Soil types in the four districts are mixed. Typically, a farm has a mix of good soils, poor and very poor soils. One can expect the areas with more poor soils in the mix to have the highest costs. Good soils are more productive, which reduces the unit cost of production.[39] The CoP comparison then depends on the soil types and the impact of fertilizers on these soil types. Data comparing different scenarios is forthcoming in the AGLC program.

7. Conclusions and Recommendations

A better understanding of determinants of costs of production is essential to understanding the profitability, and therefore the sustainability of coffee as a source of household income at the farm level as well as export revenue at the national level in Rwanda. This is one of the main reasons why the AGLC project has endeavored to provide this analysis of cost of production. Further, the report has described a methodology and quantitative estimation process that sector stakeholders can use to collect CoP data in other coffee producing countries with predominantly smallholder production.

In addition to satisfying the above dual objectives, the findings of this research provide some broad guidelines for the government of Rwanda and other leaders in the coffee industry to consider as they seek to guide and improve the future of coffee.

- Revise the formula used to establish floor prices for cherry in light of the 177 RWF/KG cherry value determined here. Consideration might also be given to the fact that CoP varies significantly across farm size groups.
- Develop and deploy information systems for regular updates to CoP estimates.
- Underwrite and support new studies to further investigate costs at the washing stations, costs related to gender, and environmental costs of coffee production. The impact of certifications on farmers' CoP should also be considered. All of these areas would be valuable complements to the results of this study.
- Establish and publish metrics related to quality as these are an important complement to cost numbers. They are also paramount to the future of Rwanda's coffee, yet they are noticeably scarce today. Top scores in Cup of Excellence competitions do not replace solid, repeatable studies on the level of quality Rwanda's supply chain is supporting. Also the summary explanation that 'fully washed coffee is high quality coffee' no longer satisfies the need for

[39] Ad hoc comments from Dr. Francois X. Narazambuye, University of Rwanda.

measurable quality criteria. Data on quality levels will enable research on the costs of production required to achieve different levels of quality.

- Create and regularly update data and diagrams of how cherry is transported from farm to washing station and how payments flow back to the farmer from the washing station. More detail on this research-related recommendation is considered below.

Recommendations for further research

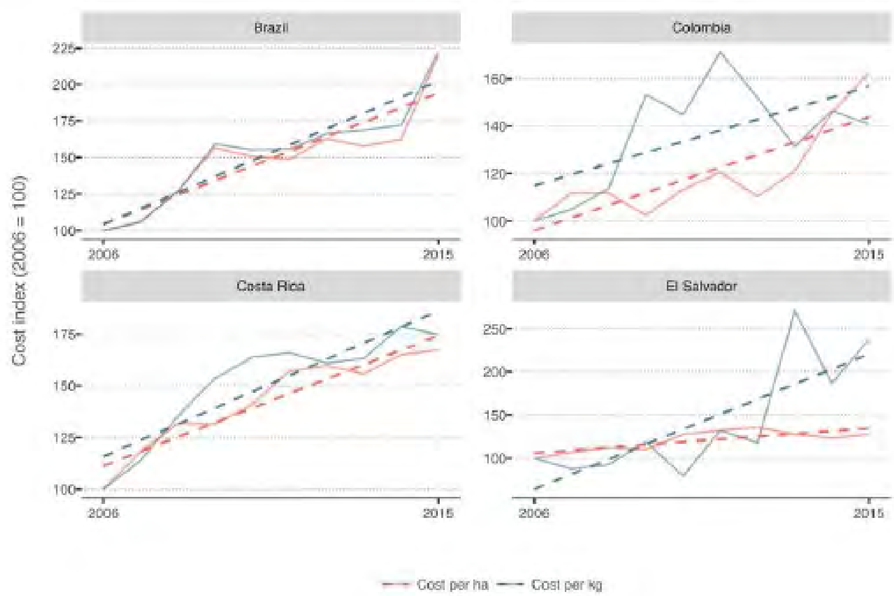
To support the policy recommendations above, there are clearly areas where further research is needed. We summarize ten areas for consideration below.

Scale and CoP/KG

As mentioned above, we found a correlation between the largeholder farmers and lower costs of production per KG (see Figure 13). Other ALGC research has addressed the topic of farmer *investments* and scale, and found that lack of farmer motivation is a key determinant of lower investment levels on the large farms (AGLC, 2016a). However, it is not clear which factors lead to average lower CoP/KG on the large farms. We hypothesize that as farm size increases, labor is used more efficiently, especially during harvest, due to collective knowledge and experience of the workers and management, both of which are not included as indicators. We also know from other AGLC research that large farms have on average lower yields per tree (AGLC, 2016a), which means pickers are picking *fewer* cherries per tree and less dense (lower quality) cherry on the large farms, meaning they have to walk further before collecting a full five KG basket, for example. This uncertainty about where cost savings are achieved on large farms, is what leads us to recommend further study in this area.

Three-Way Relationship between Productivity, Costs per Ha and Costs per KG

A recent report from the International Coffee Organization illustrated the three-way relationship of investments per ha, costs per KG and yields in four coffee producing countries over a ten year span, resulting in Figure 18. The solid lines represent the actual costs, the dashed lines the (linear) trends. The resulting “picture” helps visualize the impact of variability in yields.



Source: ICO, 2016

Figure 18: Comparing Costs per Hectare and per KG Over 10 Years

In Brazil and Costa Rica (left side of Figure 18), yields are fairly stable and this results in a close correlation between costs per hectare and costs per KG, and overall positive trends. In Colombia and El Salvador, however, (right side of Figure 18), we have examples where yields have declined. In Colombia, producers were devastated in 2008/2009 by an outbreak of leaf rust. Yields remained depressed until 2012/2013, so costs per KG went very high (labor was not very productive), while investments per hectare went down. Then after 2012/2013 we see the recovery to relatively high yields, which keeps the ten-year trend lines parallel. In El Salvador, however, yields contracted due to leaf rust also, but the country has not yet recovered to prior yield levels. So in this case (lower right of Figure 18) the trendlines cross, while investments per hectare (red line) remained almost flat, and costs of production per KG have been rising, steeply in years where further rust outbreaks occur (e.g. 2013).

Our recommendation is that similar tracking of Rwanda's costs per unit (KG), investments per asset (hectare or tree) and yields could be initiated to help move Rwanda's coffee sector into a more stable and positive direction for all three metrics. Our assumption is that, like El Salvador, Rwanda has depressed yields, and flat to negative investments per hectare or tree, which are resulting in increasing per-unit costs of production. Like Colombia, Rwanda must find a way to rejuvenate investments in the coffee sector to jump-start yields, which will, in turn, bring CoP/KG into a line which, in theory, can more consistently be compensated by market prices.

Quality and CoP

Further research is needed on the relationship between CoP/KG and quality outcomes of coffee. In order to raise quality across the country, we need to understand whether farms with low CoP on average produce the same quality of coffee as farms with high CoP. Given the relationship between CoP/KG and farm size, a related question is whether large farms in Rwanda (1000+ trees) on average produce the same quality of coffee as small farms (300 – 800 trees). In other words, studies need to be designed that can test, with quality as the dependent variable, which factors, (CoP level, farm size and other determinants), have significant impact. This will be complicated, of course, by the endogeneity of the variables. Once the main drivers of quality are identified, it will be useful to look at how Rwanda's coffee districts compare on these factors.

Nguyen et. al. (2015) address the quality and CoP relationship in a paper on Vietnamese coffee by using systems thinking to form causal loop diagrams. They show that coffee cherry quality is affected by seed quality, climate conditions and soil fertility. It is not clear whether the study included farm size or CoP as factors. The authors note that when producers obtain a higher profit from coffee farming, they are willing to invest more in technology, quality fertilizers and agrochemicals, which in turn improves coffee quality, (Nguyen et. al., 2015). Since Rwanda must succeed in the specialty (high-quality) markets of coffee, we would strongly urge similar research in the Rwandan context to clearly identify the main drivers of quality.

For example, one can advocate for quality premiums, but on what criteria will the premiums be based? When premiums are based on cup scores, other research (Church, 2013) has shown farmers can become discouraged because the cupping process is invisible to them and seems subjective. Premiums based on farmer behavior are already being tested in Rwanda by the Relationship Coffee Institute/Sustainable Harvest. An impact evaluation of their program would be helpful to understand the pros and cons of their methodology in terms of achieving quality improvements. Ideally, data compiled by AGLC could help, at least in part, to determine which farmer behaviors: a) significantly reduce antestia damage and b) improve cup scores, and then these behaviors could be targeted with premiums and other reward schemes by washing stations.

Estimate costs at the washing station/cooperative level

Further studies are needed to understand the costs at the washing station/cooperative level in Rwanda. Rwanda's supply chain structure with regional wet mills means the washing stations play a critical role as they are both service-providers and customers to the farmers. Discussions with stakeholders (AGLC, 2016c) often refer anecdotally to problems of some washing stations and best practices at others, and in general, point to opportunities for value chain enhancement at this level. But data on the 250 washing stations in Rwanda are scarce. The recent study by Machiavello and Morjaria (2015b), while shedding significant light on important aspects of the washing stations, was not designed to evaluate average costs of operation. TWIN also completed a study of washing stations in East Africa (TWIN, 2016), but the results are qualitative, not quantitative. Therefore, we recommend research that will help quantify the costs at the wet mill level and establish benchmarks for different levels of service.

Transport and payment systems for cherry

Deeper understanding of transportation and payment systems for cherry will likely be necessary if Rwanda chooses to implement incentive systems to improve quality. There appears to be a lot of variability in the methods by which coffee cherry is transported to the washing stations, meaning who transports it where and when. Only a fraction of the cherry arrives at the washing station carried by the farmer him/herself. However, there is not much reliable information today on this topic. There is ample talk about traders and middlemen, but not much data on the numbers of these individuals and the amounts of cherry they are moving. A true and updated picture of the system for collection and transport of cherry from farm to washing stations would need to include interviews of farmers, collectors and washing station managers. The payment system is related to the collection system and also seems to have a lot of variability. There is a need for further research into how and when payments are actually being made to the stakeholders in the chain between the washing station and the farm. We envision that details about cherry payments could be collected from interviews with farmers, collectors, washing station managers and probably also the washing station accountants.

Gender and control over coffee income

The degree to which women have control over coffee income should be evaluated in more detail. Ideally, a sample of households where the women collect the cash for coffee sales could be compared to a group of households where men collect the cash. Then the immediate location and "first use" of the coffee cash could be investigated and tested for any gender-related differences. The actual location for keeping the cash, if the farmer is paid in cash, would bring important insights about control over its use. I recommend three broad categories for responses to a question related to use of coffee income, namely: 1) home and family related needs, 2) farm and business related needs, and 3) entertainment and alcoholic beverages. Anecdotal examples imply that households where the female primarily decides the use of the coffee income will have significantly lower use of category three. If this can be shown with data to be true, washing stations and others may find it profitable to encourage cash disbursements to female household members. The AGLC mid-line survey will be collecting data at the household level that may help respond to these questions. I also hypothesize that truly joint decision-making in two-spouse households will have more efficient coffee production and therefore lower costs of production.

Women's involvement in coffee production

I recommend more thorough investigation to women's contributions to coffee production. There are several important areas that are not yet well understood. First, this study found that CoP is significantly higher for female headed households, and that these households comprise 19% of the sample. But the explanations for those higher costs are unclear. One hypothesis is that the difference can be attributed to physical strength, meaning women need more time or more hired help to complete the same tasks as men. A study to document what drives the costs of coffee production for these households using AGLC project data would be highly instructive. Next, we recommend further research on women's labor for coffee farming in Rwanda and women's involvement in decision making about the coffee farming practices. AGLC data should be sufficient to investigate marginal value product (MVP) of land and MVP labor for men and women. This may show a significant gender difference. These gender differences could be important for the design and evaluation of training and extension programs and reforms of banking, land ownership and marriage regulations.

Environmental and social costs and COP

One of the studies reviewed for this paper included estimates of environmental costs, such as water pollution and land degradation, and societal costs, such as child labor, worker underpayment, health and safety issues, (Coffee & Cocoa International, 2016). The study was done by IDH and True Price for coffee in Vietnam and results showed negative externalities (environmental and social costs) that almost double the farm gate price, creating a “true price” of EU2.60 per KG green coffee ($2.94/KG green). An effort to understand these costs is vital to long term sustainability goals, but these costs are invisible and therefore are not typically counted. However, unpaid, household labor also used to be commonly ignored and today many studies seek to value this cost of production. Costs like unpaid labor begin to be valued when industries and researchers come to understand how critical the resource is and therefore how important it is to be adequately compensated. The situation is similar with environmental services and social costs. If water and rich soils are needed for coffee, then the cost of ‘using up’ these resources needs to be assessed and included in larger estimation of COP, so that stakeholders are constantly forced to considering how these long-term costs will be paid.

Impact of training on CoP

I recommend investigating the impact of training on CoP and productivity. Future research should establish the expected ROI on training at the farm level. For example, does CoP/KG change after farmers receive training in pruning or tree renovation (stumping)? Can the largest labor costs, weeding and harvesting, be reduced with training? My hypothesis is that the cash cost of training may increase CoP in the short run, but the gains from improved yields over time result in higher profits per KG for the farm, even when prices decline. In other words, training has a positive ROI.[40] The Integrity/TMEA study in Burundi empirically showed this kind of impact after DAI training with farmers (Integrity, 2013).

Certification and CoP

I recommend a study focused on assessing CoP/KG of certified farms (RFA, organic, CAFÉ, FT, UTZ, etc.) vs. ‘conventional’ farming. Several studies have already been done evaluating the impact of certification on farm profitability and farmer livelihood. They are often complex studies because so many factors can impact profitability and livelihoods. Research on CoP would seem to remove some of the complexity and may offer important insights into how certification programs can better support more sustainable coffee farms.

Household Income Diversity and CoP

I recommend further research on the relationship between household income diversity and CoP. Although non-coffee income was not a significant determinant of CoP/KG in our model, I hypothesize that having a higher number of income streams improves resiliency to shocks from coffee volatility, which in turn can lower CoP, or at least lower variability of CoP/KG over the long term. However, it could be that scale plays a significant role, so I recommend examining the effects of household income diversity controlling for size of coffee plantation and other potential covariates.

Conclusion

With this research on costs of production, those who set cherry prices in Rwanda and those who purchase coffee anywhere in the coffee value chain are better able to change the incentive structure in ways that will motivate Rwanda’s coffee farmers to invest in their coffee. With more fair compensation

[40] This was a significant finding in the Integrity/Trademark East Africa report on CoP in Burundi, 2013 (p. 18). *“Improved yields are possible in Burundi, as demonstrated by DAI / PAIR with the intervention of training.”* Further detail in the LMCP, Presentation on CoP at SCAA, 2015, shows increased profits in a year with lower cherry prices.

of the costs of production, Rwanda’s farmers will be the source of a bright “second sunrise” for the coffee sector.

Appendix 1: Additional Tables and Figures

Table 1: CoP studies and types of metrics used.

Grouped by country and then sorted most recent to oldest.

	Study (Author - year)	Country	Type of Metric Used
1	AGLC/USAID - 2016	Rw & Bu	RWF or USD/KG cherry; RWF or USD/Ha
2	NAEB - 1990s	Rwanda	RWF/KG cherry; RWF/Ha
3	Technoserve 2011-2013	Rwanda	US$/kg green
4	SBUX FSC Rwanda - 2008	Rwanda	RWF/KG cherry
5	IDH and True Price - 2015	Vietnam	Euro/KG green
6	Univ. of Hawaii - 1998	USA	US$/acre
7	Wilson, 2010	Nicaragua	US$ per 100 lbs
8	Valkila 2009	Nicaragua	US$/kg (not clear if green or parchment)
9	COSA - 2015	LatAm + Kenya + Asia	$/lb green
10	USAID - 1996	Kenya + Ug + Tanz	KSHS/acre; USD/acre; Uganda shs/ha; USD/ha
11	Nyoro, Wanzala &Awuor 2001	Kenya	US$/KG green; Kshs/tonne; US$/tonne green
12	Karanja, Andrew M, 2002	Kenya	Kshs/tonne green coffee
13	FTUSA - 2015	Hond. + Peru	US$/ha
14	Committee on Coffee Competitiveness, 2015	Colombia	US$/lb. green
15	CIAT/CRS - 2015	Colombia	$/lb green
16	Fedessarrollo - 2012	Colombia	Pesos/ha
17	Solidaridad	Colombia	peso/ha and peso/arroba (weight)
18	IDH - Technoserve 2014	Colombia	US$/lb green
19	CRECE- UTZ, 2014	Colombia	US$/KG green
20	TMEA - Integrity - 2014	Burundi	FBU/KG cherry

Table 3: Detailed Breakout of Cultivation Tasks
(with percent household vs. wage for each task)

	1	2	3	4	5
N=1024	**Value HH Labor** (mean RWF, *% of total for this task)*	**Wages paid to hired labor** (mean RWF, *% of total for this task*)	**Total (mean RWF)**	**Total RFW/Ha**	**Total RWF/KG Cherry**
Harvesting	**10,376**	**18,761**	29,137	**173,862**	**51**
	36%	*64%*			
Weeding	**11,084**	**11,013**	22,097	**106,428**	**35**
	50%	*50%*			
Mulching	**7,846**	**8,703**	16,549	**89,383**	**31**
	47%	*53%*			
Pruning	**2,908**	**2,817**	5,726	**31,709**	**10**
	51%	*49%*			
Fertilizer Application	**1,684**	**1,548**	3,232	**14,592**	**5**
	52%	*48%*			
Pesticide Application	**799**	**826**	1,625	**7,449**	**3**
	49%	*51%*			
Planting Seedlings	**479**	**665**	1,144	**5,178**	**2**
	42%	*58%*			
Sorting	**671**	**448**	1,119	**6,325**	**2**
	60%	*40%*			
Stumping	**297**	**226**	523	**2,732**	**1**
	57%	*43%*			
TOTAL Cultivation Tasks	**35,868**	**44,314**	**81,151**	**438,552**	**137**
	44%	*55%*			

Table 3 illustrates how both (unpaid) household labor (column 1) and paid wage labor (column 2) are critically important to coffee cultivation in Rwanda. When time for all tasks is valued, household labor is is 44% and wage labor is 55%. For reference, the total value of all labor and the per hectare and per KG conversions are given in columns 3, 4 and 5.

Appendix 2: PEARL and SPREAD

- PEARL, 2000-2006, was in two three year phases funded at $3.7 and $3.2 million respectively.
- SPREAD, 2006 – 2012, with about $5 million in USAID funding.
- The projects were highly successful achieving several goals – rebuilding key agricultural institutions, raising incomes through coffee value chain development, and bringing the Cup of Excellence to Rwanda.

Appendix 3: Other Costs

While all of the major cost categories for Rwanda's coffee farmers are included in this composite measure, it is important to note that some items are not included in this calculation of cost of production which may be important to include in other countries and other contexts. Many important investments for coffee are long term, one-time investments. So, for example, some farmers in some countries have costs in the following areas that the AGLC survey would not have captured:

- Marketing and transport costs are not included in the CoP number, but these costs are estimated and used in gross margin calculations.
- Cost of water (as 'cost to the environmental system' if water is not an actual expense.)
- 'Environmental services' from the land and air.
- Land value.
- Value of free compost. (AGLC collected data on manure and mulch, but not compost - for example from cherry pulp composted at the washing station.)
- Getting soil analyses from a lab.
- Costs of getting a certification (e.g. Fair Trade, Rainforest Alliance, UTZ, Organic, 4C, CAFÉ, AAA). These costs are often born by the washing station.
- Any other accounting costs, record-keeping, audits, inspections, beyond certification requirements.
- Membership fees for joining a cooperative or maintaining membership.
- Costs of training workers.
- Worker housing.
- Building, stocking, maintaining a nursery.
- Energy (fuel).
- Installation of irrigation systems.
- Installation of erosion prevention (AGLC asked whether this was done, but did not estimate costs).
- Installation of infrastructure and purchase of animals for manure production.
- Expense for animal feed and labor for animal care for organic farms that utilize on-farm manure.
- Purchase and labor for planting of intercropped crops, including shade trees (AGLC asked whether this was done, but did not estimate costs).

While Rwanda's coffee farmers can have expenses in one or more of the above categories today, we note that they are very few. *Membership fees to maintain membership in a cooperative is a possible exception and will be covered in a future surveys with the AGLC sample.*

Appendix 4: Scatterplot of CoP and Number of Trees

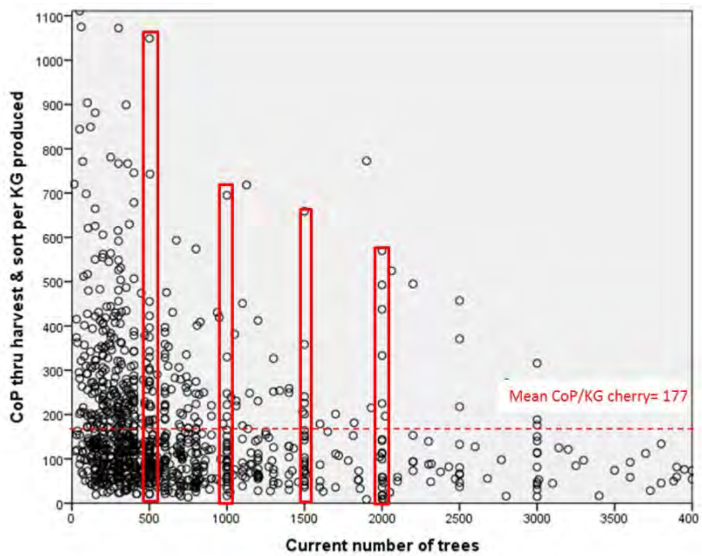


Figure 18: Scatterplot of CoP p KG Cherry vs. # of Trees

The scatterplot illustrates key situations that exist in Rwanda that can be missed if one assumes a simple linear relationship exists between CoP and number of trees. At the 500, 1000, 1500 and 2000 tree farm sizes, (and so on) there is wide variability in CoP/KG cherry achieved. This wide distribution of data is captured in the standard deviation numbers presented in the text, but this kind of visualization of the dispersion sometimes helps lay people understand why it can be dangerous to assume all farmers are close to a single average number given as "the" cost of production for an entire population. Not all large farmers have low CoP and many small farmers do have low CoP.

Appendix 5: Taxes and Inputs Table With Assumptions

	A. Value of tax Rwf/KG cherry	B. Value of one unit in RWF (KG or ML)	C. Value of recommended dose per tree (Rwf)	D. Value of recommended dose per KG cherry (Rwf)	E. Percent tax vs. value of recommended dose, (A/D)
Fertilizer	14	400	80	45.71	30%
Pesticide	1.57	14.6	0.82	0.47	335%
Both	15		80.82	46.18	33%
Assumptions					
Cost of fertilizer = 400 Rwf /KG (source: AGLC baseline survey)					
Cost of pesticide: = 14.6 Rwf/ml (source: AGLC baseline survey)					
Recommeded dose of fertilizer: 200g/tree/year (source: NAEB)					
Recommended dose of pesticide in 2015: .05625 ml/tree (source: NAEB)					
Average productivity: 1.75 KG cherry/tree (source: AGLC baseline survey)					
Fertilizer tax rate on green coffee: 97 Rwf/KG paid at export and included in coffee price (source: NAEB)					
Pesticide tax rate on green coffee: 11 Rwf/KG (source: NAEB)					

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