Coffee Production in Pacto, Ecuador: The Costs, Challenges and the Subjectivity of Measuring Them

By

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ABSTRACT

We conducted a cost of production study through farmer interviews to determine the costs, revenue and net benefits of farming coffee in Pacto, Ecuador in a standard year of production. Farmer interviews also included questions about agronomic challenges farmers face. Secondly, I performed a literature review of how cost of production studies have been shaped by the political economy of the coffee sector – particularly by the power relations between institutions within the coffee sector. I also consider the subjective decisions researchers must make in the design, data collection, analysis, and publication of cost studies, and how these have been shaped by the political economy of the coffee sector.

Our results indicated that farmers are losing money by producing coffee in Pacto, Ecuador. Results showed farmers are earning negative net benefits from coffee production in Ecuador, particularly when family labor is valued. Farmers also earned net negative equivalent daily wages from coffee production. Coffee farmers reported struggling with challenges related to lack of extension, pests and diseases, and environmental degradation. Further research is needed to determine if farmers and other stakeholders should continue investing in coffee production, or if other livelihoods might be more appropriate for farmers in this region.

Cost studies could benefit from increased transparency of the subjective decisions researchers make during the design and implementation, in order to help standardize and compare methodologies and results. Further research could also be conducted on how to increase the accuracy of farmer-reported data.

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INTRODUCTION

In Ecuador, arabica or high-quality coffee is primarily produced by small, family farms (USDA, 2018). The country produces about 135,000 60-kg bags of arabica coffee annually, and about 200,000 hectares of both high-quality arabica and low-quality robusta coffee are currently planted in Ecuador (USDA, 2018). As the coffee sector has continued to struggle in Ecuador in recent years, public and private sector efforts have tried to revamp the coffee sector. For instance, MAGAP, the Ministry of Agriculture and Livestock in Ecuador, invested in a $70 million "Reactivation of Ecuador's Coffee Cultivation Project" in 2015 to renovate 135,000 hectares of coffee cropland (USDA, 2015). Nevertheless, Ecuadorian coffee farms typically have high costs of production, particularly when compared to neighboring coffee-producing countries, with one study finding costs of producing coffee in Ecuador to be up to 240 percent higher than Peru and Colombia (De Valdenbro, 2018). Thus, Ecuadorian producers have difficulty competing in the international coffee market.

The high costs of producing coffee in Ecuador can be linked in part to the political economy of Ecuadorian economic development. As Ecuador embraced neoliberal economic principles in the 1990s, state institutions began to crumble in their deregulated states (Bowen, 2015). Corruption increased, multiple political and economic crises ensued, and eventually the currency collapsed, leading to Ecuador adopting the US dollar as its state currency in 2000 (Conaghan, 2016; Bowen, 2015). People grew increasingly suspicious and distrusting of the government during this era, opening the door to the election of Rafael Correa to the presidency (Conaghan, 2016; Bowen, 2015). Correa was a left-wing politician, critical of the past corruption and neoliberal approaches to governance, and he served multiple terms from

2006-2017. He laid the foundation of the political economy of economic development that is seen in Ecuador and its coffee sector today. However, out of all the dominant economic sectors in Ecuador, Correa intervened the least in the agricultural sector, leaving this sector open for control from competing interest groups (Bowen, 2015). This deregulation of the agricultural sector lends itself to increased influence of the private sector, the implications of which will be further discussed below. Nevertheless, his economic policies had overarching effects on all sectors of the economy. Under Correa, the minimum wage doubled (Clark, 2017). Ecuador continues to have the highest cost of labor in the Latin America – also in part due to the strength of the U.S. dollar (De Valdenbro, 2018). Furthermore, an import tax was levied, increasing costs of all agricultural inputs imported into the country (Red Fox Coffee Merchants, 2016). These policies have increased costs of labor but also inputs in the agricultural sector, contributing to the increased cost of producing coffee that is seen today in Ecuador.

The Ecuadorian coffee sector not only faces challenges economically, but also agronomically. For instance, coffee yields are about 6 times lower in Ecuador than Peru and Colombia (De Valdenbro, 2018). Farmers in Ecuador generally use low-cost coffee varieties that are low-yielding and more vulnerable to the common fungal disease coffee leaf rust. One study found only about 8 percent of farmers in Ecuador were growing newer, improved varieties (Jacomé et al., 2017). Another study found the outdated, low-productivity varieties common in Ecuador, such as Caturra, Typica, and Bourbon, to contribute to the region's lack of competitiveness on both the regional and global market (Conquito & Triplei, 2015). World Coffee Research gives Caturra and Bourbon a rating of 2/5 for productivity and a 1/5 for

Typica, and all three a "susceptible" rating for coffee leaf rust (World Coffee Research). Coffee leaf rust has been historically responsible for significant drops in production in Ecuador. For instance, a coffee leaf rust epidemic broke out across farms in Ecuador in 2013 (Avelino et al., 2015), reducing production by about 30 percent (USDA, 2018). In addition to low yields due to poor varieties and coffee leaf rust is the limited access to extension services and support from the government, reported in multiple informational interviews with coffee roasters and farmers (Caravela and AAPROCCNOP, personal communication, 2018). The lack of more technologically advanced production is found in Ecuador nationally, with coffee production in Ecuador largely performed by small family farmers with limited use of purchased inputs such as fertilizer and irrigation systems (USDA 2018). In summary, high costs, low yields and lack of extension plague the coffee sector in Ecuador.

In addition to the national challenges to growing coffee in Ecuador, the parish of Pacto itself faces its own set of specific challenges in the coffee sector. This study focuses on the parish Pacto located in the northern sierra province of Pichincha and was conducted in collaboration with the Ecuadorian organization Sun Mountain International, whose staff was interested in how to advance coffee development and ecotourism in Pacto specifically. As seen in Figure 1, Pacto is located in the Andean cloud forest, and thus does have the soil, climate, rain, and altitude requirements for growing arabica coffee (GESTNOVA 2015, Newton, 2018). However, most producers in Pacto have only been growing coffee for less than 10 years and lack technical knowledge, such as adequate fertilizer application and pest control (Caravela, personal communication, 2018). Farmers in Pacto also lack equipment that could be useful in post-harvest practices, which can greatly affect coffee quality (Gautz, Smith &

Bittenbender, 2008). For instance, farmers in this region typically wet process their coffee to convert the coffee cherry into parchment form that is then sold to buyers, according to Josue Reascos, the representative of the coffee association AAPROCCNOP (Josue Reascos, personal communication, 2018). Parchment coffee must maintain a moisture content of 9-12% in order to prevent the development of mold, bacteria, or yeast (Gautz et al. 2008). Thus, farmers in Pacto dry their coffee beans in greenhouses, yet many lack the equipment to be able to detect when the beans have reached the desired moisture content (Josue Reascos, personal communication, 2018). While some coffee associations will share expensive devices to measure moisture content, it is difficult to ensure all members can have access to the equipment when needed (Josue Reascos, personal communication, 2018). Furthermore, the cost of producing coffee in Pacto is particularly high, making the coffee difficult to sell given buyers must pay a higher price (Caravela, personal communication, 2018). And the cost of production studies that had been performed in the region to date lacked information useful to coffee associations, given the study's costs were based on pre-determined averages that some farmers seemed skeptical about (Josue Reascos, personal communication, 2018). Environmental issues are also created due to coffee production in Pacto. For instance, wastewater from the processing of coffee cherries is often not treated before it is simply dumped onto mountainsides, often ending up in local groundwater (Caravela and AAPROCCNOP, personal communication, 2018). Therefore, coffee producers in Pacto face high costs of production, environmental challenges and a dearth of technologically advanced knowledge and equipment.

Figure 1. Photograph of a coffee plantation in Pacto, Ecuador

The objectives of this study were two-fold:

1. Evaluate the dichotomy between the limitations of growing coffee in Ecuador and the public push for coffee plantation renovations and for farmers to increase production and quality. We designed a study to evaluate the annual costs, revenue and net benefits of farming coffee in Pacto, Ecuador and the agronomic challenges coffee farmers face.
2. Review cost studies to date, how they have been shaped by the political economy of the coffee sector, and the subjective choices that researchers must make. Particular attention is given to how the power relations of institutions within the coffee sector generally affect the design, data collection, analysis and publication of cost of production studies of coffee cropping systems. Given the limited number of farmers we were able to interview due to time constraints, the hope is that this

detailed literature review of coffee cost studies and description of our methodology can provide a foundation for further, more comprehensive research in Pacto and beyond.

THE POLITICAL ECONOMY & SUBJECTIVITY OF COST STUDIES

Cost studies or cost of production studies in agriculture have primarily been used to determine farmer profitability in different cropping systems: "Careful attention to all costs generally means good profits can be achieved with a wide range of cropping systems." ("Corn Production", 2006). Cost of production studies of coffee are influenced by and influence political economy, and this affects the decisions that are made in the design, data collection, analysis, and publication of cost studies. I use a political economy approach similar to the applied political economy analysis developed by USAID, which specifically analyzes "the power dynamics and economic and social forces that influence development" (Menocal et al., 2018, p. 1) In particular, I look at how power shifts towards private industry have led to the private sector playing a leading role in coffee research and extension. The political economy of the coffee sector and the subjectivity of cost studies have led to studies with differing methodologies that are not comprehensive or suitable for many smallholder farmers in the Global South.

During the 1990s, many national coffee agencies in Latin America, where most coffee is grown, dissolved under pressure from Western countries, international banking institutions, and various intra-state sources (Topik, Talbot, & Samper, 2010). This dissolution significantly decreased the domestic regulation of the coffee sector. Meanwhile, coffee traders and roasters from Western industrialized countries consolidated, increasing their control over purchasing, distribution, and roasting of coffee (Topik et al. 2010). This restructuring led to the power dynamics we see today in the coffee industry, where downstream stakeholders such as multinational traders and roasters capture most of the profits from the coffee industry, while upstream supply chain actors lack financial and decision-making power. Currently, more than 78% of the income generated by the coffee value chain is retained by consuming countries, rather than producing countries (Slob & Osterhaus, 2006). Another result is the solution-making in the coffee sector is more and more often left to the private sector (Topik et al., 2010). An example of private-led solutions can be seen in Caravela, the coffee importer/exporter, and its extension service for coffee farmers in Ecuador to reduce their costs and improve their yields (De Valdenbro, 2018). Thus, private and downstream actors have an increased influence on coffee production in Latin America.

These power dynamics manifest themselves in how cost studies in coffee are designed and implemented, as many of the studies and literature reviews on costs of producing coffee have been conducted by industry figures, such as coffee importers and exporters, roasters, certification bodies, and other industry groups. The Specialty Coffee Association (SCA) – the trade organization for the high-quality, specialty coffee industry – conducted one of the most comprehensive literature reviews to date on costs of producing coffee (Montagnon, 2017). Public-private partnerships have often conducted coffee cost of production studies, like the notable Cornell University and Fair Trade study (Gomez, Aguilera, Rivadeneira, & Anunu, 2017). The University of Michigan and a coffee roaster in Los Angeles, Coffee Manufactory, completed another notable cost of production study (Carnemark et al. 2019). In Ecuador specifically, Caravela, the coffee importer/exporter, conducted one of the most prominent cost studies in the region (De Valdenbro, 2018). Lastly, many costs of production studies focus on evaluating the socioeconomic impacts of voluntary sustainability certification schemes, such as Fair Trade and Rainforest Alliance (Elliott, 2018). Thus, the political economy of the coffee sector where private industry has come to dominate the landscape has led to corporations, industry groups, and certification schemes conducting or funding many cost studies.

Though a quantitative method, the design and implementation of cost studies involves many subjective, qualitative judgements; and the private sector has their own set of biases that can be introduced into the research. Table 1 illustrates the subjective choices, judgements, and assumptions that occur throughout the study design, data collection, and data analysis, and publication process. The subjective choices made in the design of cost studies can leave out many small, family farming. For instance, many smallholders are unable to meet the standards of quality and quantity and lack the financial resources to participate in certification schemes and are thus underrepresented in the studies focused on certification schemes mentioned above. These small producers are also often the most low-income and marginalized (Elliott, 2018) and thus could stand to benefit the most from participating in cost studies. Furthermore, family labor is a crucial measurement when accounting for costs incurred in coffee production particularly on small farms where it makes up the majority of labor costs. However, it can often be left out of the study entirely, the calculation is unclear, or the methodologies are inconsistent across cost studies (Montagnon, 2017). It is also generally unclear if more participatory approaches such as the inclusion farmers' input and feedback are included in the design of cost studies (Montagnon, 2017; Conquito & Triplei, 2015; Echavarría & Montoya, 2013). While Gomez et al. (2017) reported using participatory research, it was unclear if farmers participated in the design of the cost study. Therefore, oftentimes, cost studies are not designed in a way that can truly capture the smallholder experience.

Table 1. *Primary Subjective Choices in Cost Study Design, Collection, Analysis and Publication*

Phase of Research	**Subjective Choice**	**Our Choice**
Design	Who designs the study?	UC Davis research team and coffee association members
Design	What is research question of focus?	Evaluate the average annual costs, revenue and net benefits of farming coffee in a standard year in Pacto, Ecuador
Design	Where will research be conducted?	Pacto, Ecuador
Design	What is the time frame?	Establishment year and standard year of production
Design	Selection of research subjects	Association member farmers
Design	What is measured?	Costs and revenue in a standard year and costs in establishment. See Table 2 for all costs included
Data Collection	How is data collected?	Through farmer interviews based on farmer recall and bookkeeping
Data Collection	Who collects data?	UC Davis all-female research team
Data Collection	How are questions framed?	Questions framed through labor days and cost per unit
Analysis	What results are calculated?	Average short-term and long-term total costs, net benefits, EDW with and without family labor costs
Analysis	How are results calculated?	Results calculated based on averages from farmer-reported data

Publication	How are results presented?	In USD/ha, USD/plant, and USD/lb of parchment coffee
Publication	Is the methodology transparent?	Detailed methodology is provided in Table 2

Due to the political economy surrounding coffee cost studies, where many of the main funders of research are private roasters, certifiers, and traders, researchers often choose to focus on profitability as the most important metric to analyze. Profitability is generally defined as the difference between the revenue and the cost of producing coffee (International Coffee Council, 2016). Often, researchers are most concerned with how to make the coffee industry more economically sustainable and do not ask the greater question of whether small farmers should be growing coffee in the first place, especially when other potentially more lucrative or stable opportunities are possible. For instance, the introduction of the International Coffee Council's study states, "specific policies need to be formed to address the issue of economic sustainability of coffee production, stabilizing supply in the future…" (International Coffee Council, 2016, p.1). This sentiment is also echoed in the Specialty Coffee Association's literature review of coffee cost studies: "The coffee industry cannot afford to ignore a risk to production on such a global scale, even if the form it takes is still nebulous" (Montagnon, 2017, p. 2). Thus, the main goal of these studies is to perform an economic analysis that informs industry leaders on how to ensure that farmers continue producing coffee, guaranteeing a stable supply of coffee to buyers. In summary, the institutional power of private actors in the coffee sector may have led to the current focus on profitability and a failure to include some of the most crucial metrics to small farmer systems. This is a clear subjective choice in the analysis of coffee cost studies. The result is a reinforcement of the current political economy and power structures within the coffee system in Ecuador and in Latin America more generally.

For many of these studies, profitability has become the main indicator of decent livelihoods for farmers but focusing simply on profitability provides a relatively myopic picture. The SCA study mentions how profitability has become synonymous with farmer livelihood (Montagnon, 2017). The International Coffee Council's cost of production study also simply reports what years coffee farming was profitable in various countries without further context (International Coffee Council, 2016). This focus fails to tell the story of the opportunity costs associated with choosing to farm coffee rather than perform another local job or rent out the land, which could earn the farmer more money. It also does not provide any information about whether profits are enough for coffee farmers to be earning a living wage in their respective region. For example, only one study in the SCA cost study meta-analysis "explicitly addresses the importance of family labor" and calculates the Equivalent Daily Wage (EDW) that a farmer is effectively earning by growing coffee (Montagnon, 2017). The EDW could then be used to determine if a farmer is earning a living wage. Different organizations have developed frameworks to determine what a living wage is in different regions, such as the Global Living Wage Coalition (GLWC), which determines if people have access to a basic but decent lifestyle (Carnemark, 2019). Coffee cost studies could do more to provide more context in what they choose to measure and report to determine better options might exist for farmers other than coffee production.

The subjective choices that must be made when designing and conducting coffee cost studies have led to a wide range of differing methodologies and results that can be difficult to compare. Different methodologies are used to collect data; some studies use a questionnaire structure, some interview various stakeholders, and others predict costs using averages such size of farm and yields (Montagnon, 2017). For instance, the Cornell and Fair Trade study used averages to determine benchmarks for each farmer cooperative considered in the study (Gomez et al., 2017). One notable coffee cost of production study completed in Pacto, Ecuador by the organizations Conquito and Triplei also assumed averages in terms of yield and costs for producers of different levels of technology adoption and size (Conquito & Triplei, 2015). Using averages for different farm sizes, such as small, medium, and large farms, can ignore some of large variation that can be present in terms of costs within each farm size (Montagnon, 2017). What is measured also varies, with different costs accounted for or left out of certain studies (Montagnon, 2017). For example, in the SCA study, only 4 out of 11 studies explicitly considered family labor and administration costs (Montagnon, 2017). In summary, coffee researchers must make many assumptions and subjective choices, and none are immune to error. Researchers should be more explicit about their methodologies and clearly explicate where subjective judgements are made to allow for better comparison between studies. The methodology section below and Table 1 illustrate the subjective choices we made and why throughout the design, data collection, analysis, and publication process.

METHODOLOGY

Design

Our cost study was designed by our UC Davis research team in collaboration with the local organization Sun Mountain International and coffee association members in Pacto, Ecuador. Our data was based on interviews with coffee association members in Pacto. We used actual data collected from the farmers and our study does not include any averages or assumptions about yield or cost based on farm size, with the intention of increasing the accuracy of the data by including more variation. We worked with two coffee associations, AAPROCCNOP and AAPROCAFEP due to pre-established relationships between Sun Mountain and the associations.

Coffee associations are groups of coffee farmers located in the same region that pay a membership fee to access shared resources, such as coffee dryers and equipment to measure coffee bean's moisture content. Membership also allows farmers to sell their coffee as a group, which can provide a better price guarantee and allow them to access larger markets (AAPROCCNOP, personal communication, 2018). Our project collaborator Sun Mountain International introduced team members to the coffee associations in the area during association meetings. Researchers then signed up farmers for interviews at these meetings. Thus, there was some selection bias in the farmers that were chosen for interviews, as they were all members of coffee associations and had more access to shared resources and markets.

Data Collection

The interviews were administered in Spanish by the UC Davis research team to farmers that were members of coffee associations in the Pacto, Ecuador region from July-August 2018. Interviews generally lasted from 1-3 hours, and the 18 farmers interviewed were provided with lunch as compensation for their time. Interviews were generally conducted on-farm in order to walk through the farmers' coffee plantations and to be more convenient to the farmers. Given the small sample size, I did not perform a complex statistical analysis to test for significance of the data; rather, I reported averages and general trends in the data.

We collected data on producer's agronomic challenges, costs – both annual and amortized establishment costs – and revenue during a standard year of production. We define a standard year of production as a year without significant shocks to the system (such as a coffee leaf rust outbreak) or an exceptional production.

We defined a standard year of production to farmers and we asked them to report on the 2018 year of production, unless the farmers did not believe it was reflective of a standard year. It is important to note that since we interviewed farmers towards the end of the harvest season (July and August 2018), farmers expected to continue producing and selling coffee through September and thus had to project some future revenue and costs. Focusing on a standard year allowed for a more simplified methodology, as we did not have to perform a full land use system analysis over the lifecycle of a coffee plantation. We also did not have enough time to get the detailed information needed to perform a full land use system analysis. Thus, our study only provides a snapshot in time of a coffee farmer's production in a standard year and their establishment costs.

The interview structure consists of five primary categories: general farm description, agronomic practices and challenges, short-term costs, long-term costs, and revenue. The definition and questions asked for each category can be found in Table 2. The first category of questions asked for a general description of the farmer's coffee plantation. These questions asked about farm size, varieties of coffee grown and how many hectares and plants of each, how land was acquired, and the number of plants and hectares actually producing coffee cherries currently and when they were planted. Farmers were also asked questions about their agronomic practices and challenges, and this is the second category. The questions consisted of how long they ferment their coffee; their water source and how they dispose of wastewater; pests, weed, diseases, and soil observations; intercrops and shade trees grown, and inputs used.

Table 2. *Interview Categories, Definitions, and Questions Asked*

Interview Category	**Definition**	**Questions asked**
General Farm Description	General attributes of farmer's coffee plantation	1. Farm size 2. Varieties of coffee 3. Hectares of coffee 4. Hectares of coffee currently producing 5. Number of coffee plants 6. Number of coffee plants currently producing 7. How land was acquired 8. When planted
Agronomic Practices and Challenges	Management practices and production challenges	1. Fermentation hours 2. Water source 3. Wastewater disposal process 4. Pests 5. Weeds 6. Diseases 7. Nutrient deficiencies 8. Types of intercrops and shade trees 9. Agricultural inputs
Short-term costs	All annual costs incurred during a single standard year of production	1. Variable costs: materials, inputs, paid labor, and transportation costs 2. Fixed costs: Taxes, land rental costs 3. Family labor costs
Long-term costs	All costs associated with establishing the production of coffee	1. Loan repayments 2. Establishment costs: Paid labor, materials, water, trainings, and transportation costs 3. Family labor costs
Revenue	Total revenue from all coffee products in a standard year of production	1. Coffee products sold 2. Price received for coffee products

Short-term costs evaluation included questions about all annual costs incurred during a single standard year of production on a per hectare basis. It was always clarified with farmers how many hectares and plants that were producing coffee during this standard year and when they were planted. Doing so ensured that we only considered costs of coffee currently in production, not coffee that had been recently planted. In this way, we would be able to more accurately calculate net benefits in the analysis, since only the costs and revenue associated with the coffee plants currently producing was considered. Short-terms costs included three cost sub-categories: variable costs, fixed costs, and family labor. Variable costs include costs that fluctuate depending on how much coffee is produced, while fixed costs are costs farmers must cover independent of how much coffee is produced. Fixed and variable costs are often included in coffee cost of production studies, though family labor is not necessarily valued (Montagnon, 2017). Fixed costs consisted of annual taxes (both property and association taxes) and land rental costs if applicable. Total property and land rental costs were multiplied by the ratio of hectares in coffee production to total hectares rented or owned. Annual costs also included variable costs, which were materials, inputs, paid labor, and transportation costs associated with their production. Transportation costs consisted of gas for their car or motorcycle required for their coffee production, and any taxi or bus costs associated with their coffee production. Materials included irrigation equipment; gas, oil, and electricity for machinery; water costs; costs to use association materials like the dryer; and post-harvest materials, such as harvest bags, GrainPro bags, sacks, and colanders for washing. Inputs included fertilizer, pesticides, herbicides, fungicides, and any other applications. Paid labor consists of all labor activities in which an individual was paid a wage to perform the activity.

These activities were all disease, pest, acid and weed control; shade tree management; clearing land before applications; fertilizing and other applications; composting; pruning; stumping; irrigation; administration; transportation, harvesting; post-harvest activities, such as washing, depulping, fermenting, soaking, draining, and drying the coffee; hulling; maintaining equipment; and dumping waste products, such as waste water and the coffee pulp (see Table 3). The bulk of labor needs for growing coffee occur during the harvest season which is approximately from May-September, with peak harvest in August and September (AAPROCCNOP, personal communication, August, 2018).

All of the same activities listed above under paid labor were asked about for family labor as well. Family labor was accounted for by asking farmers how many labor days (8-hour days) out of the year are needed to perform labor tasks on farm in a standard year. Annual family labor, while a variable cost, was included as a separate sub-category in order to calculate the total short-term cost with and without family labor costs included. Including family labor increased our study's applicability to small, family farmers. When included in the total short-term cost, family labor was valued by multiplying the total labor days by an average local rural wage of $15/day – the wage of a day laborer in Pacto, Ecuador determined through our farmer interviews. Determining the daily wage for family labor is a key assumption that must be made in cost studies and could have significant impacts on the results of the study if this wage is either decreased or increased.

Table 3: *Short-term and Long-term Labor Activities Considered for Paid and Family Labor*

Labor cost category	**Activities considered**
Short-term labor costs	1. Disease, pest, acid and weed control 2. Shade tree management 3. Clearing land before applications 4. Fertilizing and other input applications 5. Composting 6. Pruning 7. Stumping 8. Irrigating 9. Administration 10. Transportation 11. Harvesting 12. Post-harvest activities: washing, depulping, fermentation, soaking, draining, and drying the coffee; hulling; maintaining equipment; and dumping waste products
Long-term labor costs	1. Plantation establishment: Clearing the land, initial soil sampling, hole-making for seeds, planting shade trees and intercrops, managing existing trees, planting coffee, chemical fertilizer application, making compost, applying compost, any type of weed, acid, pest, and disease control, building irrigation systems, irrigating, managing and administrating, and transportation 2. Seed and seedling establishment: preparing and building a nursery and/or germinator, preparing the substrate, sheathing, cleaning and water, transplanting to bags, applying fertilizer or any other applications, and transportation 3. Post-harvest establishment: infrastructure establishment, installing the depulper, installing the greenhouse, installing a wash and fermentation system, and transportation

Long-term costs included all costs associated with establishing the production of coffee on a per hectare basis. Long-term costs were separated into three sub-categories: loan repayments, establishment costs, and family labor. Loan repayment cost was calculated by asking the producer how much their total repayment was. The establishment cost sub-category included paid labor, materials, water, trainings, and transportation costs. Paid labor activities included plantation establishment labor, such as clearing the land, initial soil sampling, hole-making for seeds, planting shade trees and intercrops, managing existing trees, planting coffee, chemical fertilizer application, making compost, applying compost, any type of weed, acid, pest, and disease control, building irrigation systems, irrigating, managing and administrating, and transportation. It also included seed and seedling establishment activities such as preparing and building a nursery and/or germinator, preparing the substrate, sheathing, cleaning and water, transplanting to bags, applying fertilizer or any other applications, and transportation.

Post-harvest activities were also accounted for, like infrastructure establishment, installing the depulper, installing the greenhouse, installing a wash and fermentation system, and transportation. Materials included equipment and machinery used to establish and maintain coffee production, such as lawn mowers, weed whackers, chainsaws, machetes, machete sharpeners, hole-makers, hoes, shovels, wheelbarrows, irrigation equipment, and gas and oil for machines. It also included materials for seeds and seedlings, such as the seeds or seedlings themselves, seedbeds, nurseries, germinators, substrate for seeds, bags, fertilizers and other applications. Establishment materials also included post-harvest machinery that farmers purchased to process coffee from cherry into parchment form, such as a depulper, fermentation tanks, barrels, pumps, hoses, greenhouses, equipment to monitor relative humidity, infrastructure, and any electricity, gas and oil costs associated with operating this machinery the first year. For equipment and machinery, the cost was multiplied by the percentage of time in decimal form that the equipment is used for coffee production out of the total time that the equipment or machinery is used. For instance, if the farmer used a weedwhacker 50 percent of the time for coffee production, then we would multiply the overall cost by .50. We did not employ this calculation for miniscule costs of smaller equipment, such as shovels, which were often only $5. Materials also consisted of transportation costs like taxis or buses associated with any traveling needed for establishing their coffee production, intercrop and shade tree seeds/seedlings and applications such as fertilizers, pesticides, herbicides, fungicides used during the establishment of coffee.

The third and final sub-category under long-term costs was family labor. Similar to the short-term costs, family labor was calculated by asking how many 8-hour labor days were required for establishment activities. This again was separated out from other costs in order to calculate total long-term costs with and without family labor. When included in the total cost, family labor was valued by multiplying a local rural wage of $15/day by the total number of labor days to calculate the total family labor cost. Family labor activities considered were the same as those listed under paid labor above. Dollar value during the establishment year was converted into the 2018 value (the year of the interviews) by multiplying establishment costs by the 2018's Consumer Price Index (CPI) and dividing this by the CPI of the establishment year in Ecuador. Annual CPI information from the International Monetary Fund (IMF) was used (International Monetary Fund, 2019). This number was then divided by 14 years to amortize the cost over an average lifespan of a coffee system in the region

(Conquito & Triplei, 2015) to arrive at long-term costs for a single, standard year of production.

One choice we made was to not include depreciation costs in long-term costs because of the difficulty estimating salvage values due to the rural, informal marketplace where coffee production is relatively new and there is a wide range in original value of machinery and equipment used. Other studies on smallholder costs of production have also assumed a salvage value of zero for farm equipment, since small farmers' equipment usually do not become obsolete during the lifecycle, are generally entirely used up during their useful life, and do not have a residual value (McConnell & Dillon, 1997 and Boakye-Achampong et al., 2017). Thus, all equipment and machinery were assumed to reach a value of zero by the end of the life cycle of the coffee plantation. A straight-line depreciation method was applied, which assumes consistent, uniform usage and wear and tear over the equipment or machinery's useful life. The formula for straight-line depreciation is $D=(C-SV)/L$ where D is the item's annual depreciation cost, C is the purchase cost of the item, SV is the salvage value, and L is the item's useful life. Given there is no salvage value, the cost of the equipment and machinery from the coffee's establishment was simply divided by 14 years – the life of a coffee plantation in the region – to achieve a depreciation cost for a standard year of production.

The final and fifth category was revenue. Farmers were asked how much coffee sell and what price they received in a standard year of production. Total revenue included all qualities of coffee sold and all forms of coffee sold (namely in the cherry and parchment form.) However, many farmers had newly planted coffee and had either not reached a full year of production or the interview year was their first year of full production. In these cases, it was not possible to calculate net benefits for these farmers, but their establishment costs were used to estimate average establishment costs.

We attempted to design as comprehensive of a cost study as possible given our time and resource restraints. Our study considered costs associated with family labor, establishment, and administration, which can oftentimes be left out of cost studies or unclearly calculated (Montagnon, 2017). However, our study included many of the same standard costs included in cost studies as well, such as paid labor, inputs, transportation, and fixed costs (Montagnon, 2017). Therefore, while we used cost categories similar to previous studies, our individual cost categories are more comprehensive in scope than previous studies.

Analysis

After these interviews were recorded, we calculated total costs and revenue mentioned above and performed two calculations central to the study: a net benefit calculation and an EDW calculation. Four net benefits scenarios were then considered on both a per hectare and per plant basis. Net benefits were not calculated on a per pound basis due to the unreliability of our weight data. The equations for each net benefit scenario are defined below:

1) **Short-term net benefits without family labor**=
Revenue – Short-term costs no family labor

2) **Long-term net benefits without family labor**=
Revenue – (Short-term costs no family labor + Long-term costs no family labor)

3) **Short-term net benefits with family labor**=
Revenue – Short-term costs with family labor

4) **Long-term net benefits with family labor**=
Revenue – (Short-term costs with family labor + Long-term costs with family labor)

By creating four scenarios, we could better determine the effect of including long-term, amortized establishment costs into the equation and see how that affects coffee profitability. We could also better determine the effect of valuing family labor on farm profitability in these different scenarios. This method is similar to that employed by Gomez et al. (2017) who created four scenarios to determine whether a coffee farm is profitable over time. Their first scenario included variable costs; their second included variable costs and fixed costs; their third considered variable costs, fixed costs and depreciation; and their fourth considered all costs from the third scenario plus the amortization of farm establishment costs and opportunity costs, which included valuing family labor. If a farmer did not earn positive net benefits in the first scenario, they were considered uneconomical. If farmers' revenue exceeded costs in the second scenario, they were considered economical in the short-term. If revenue exceeded costs in the third scenario, they were economical in the medium-term, and economical in the long-term if revenue exceeded costs in the fourth scenario. The graphic below is a visualization of our four scenarios, based on Gomez et al. (2017). As a farmer moves across the graphic, earning positive net benefits when both the short-term and the long-term costs are considered and particularly when family labor is valued, then the more economically sustainable their coffee production becomes (see Figure 2). Median net benefits in these four scenarios were calculated rather than averages. I chose to present results in terms of the median rather than average in order to reduce the influence of outliers given the small sample size.

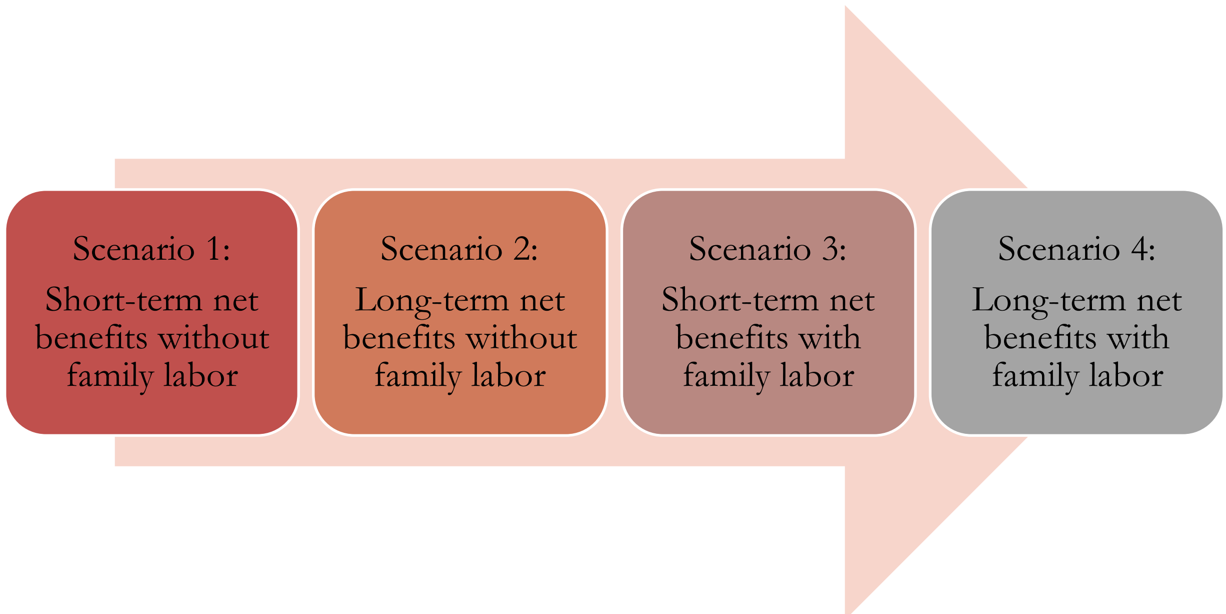

Figure 2: Four net benefit scenarios, where farmers achieve increasing economic sustainability when they are able to achieve positive net benefits with increasing cost categories, in particular with the addition of long-term costs and family labor costs.

Furthermore, we chose to include opportunity costs to determine if farmers would be better off farming a different crop or performing a different local job rather than dedicating their time to coffee farming. Opportunity costs such as returns to land and family labor are less common metrics in coffee cost studies, as often profitability is the main outcome considered in coffee cost studies (Montagnon, 2017). To do so, we calculated EDW or Equivalent Daily Wage in which family labor is left out of total short-term and long-term costs, and net benefits are divided by the total number of family labor days to see how much farmers are paying themselves per day. The median short-term and long-term EDW was then compared to the average going rural wage of $15/day to see if farmers are making more money growing coffee than they would be performing another local job off-farm. This comparison allows us to look at opportunity costs of labor. Both a short-term and long-term scenario was considered, with equations below following the methodology of Montagnon (2017).

$$Short - term\ EDW = \frac{Short\text{-}term\ net\ benefits\ without\ family\ labor}{Family\ Labor\ Days}$$

$$Long\text{-}term\ EDW = \frac{Long\text{-}term\ net\ benefits\ without\ family\ labor}{Family\ Labor\ Days}$$

RESULTS

The farmers produced coffee on a median of 1 hectare and grew a median of 2750 plants per hectare.

Of the arabica varieties grown, 82% of farmers reported they were growing Caturra, 41% were growing Typica and 41% were growing Sarchimor, while much lower percentages of farmers were growing other varieties, as seen in Figure 3.

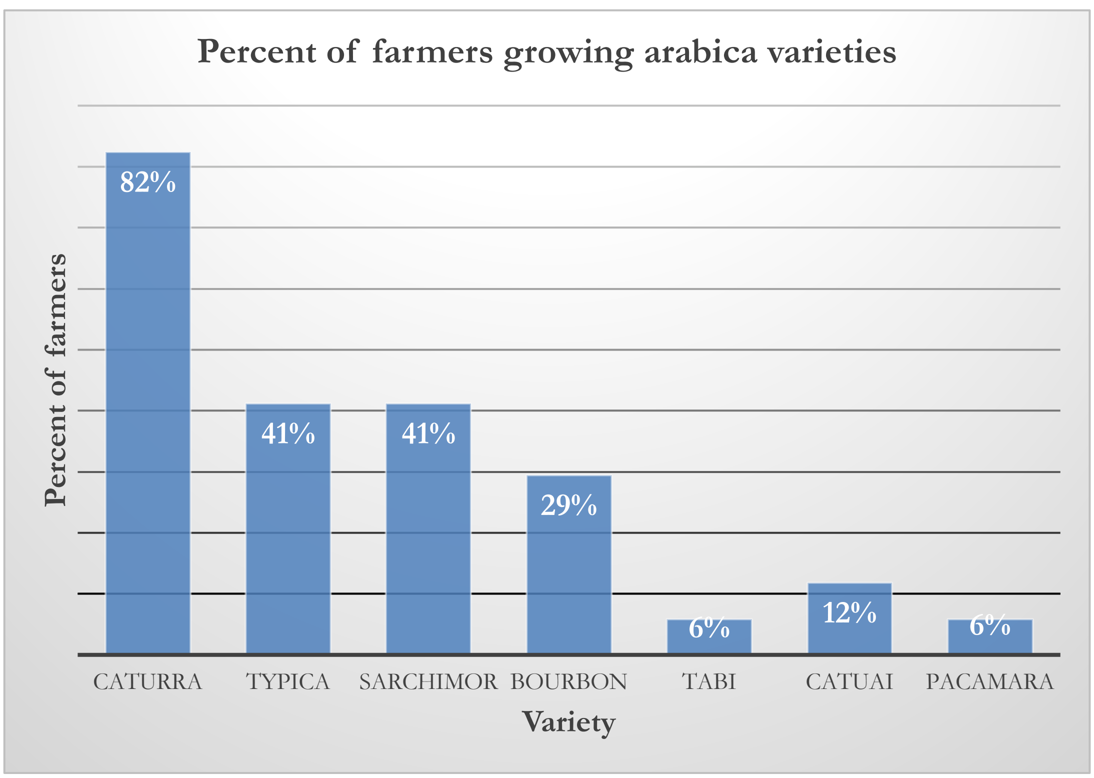

Figure 3. Percent of farmers growing arabica varieties

Farmers had been growing coffee for five years on average. While we did not have time to ask 8 farmers, all other farmers reported intercropping their coffee trees with other species, but a visual inspection of the coffee farms showed all farms were intercropping. None of the farmers treated their wastewater before dumping it. Farms were all rainfed, and only a few farmers reporting irrigated their seedlings. No farmers had any certifications, such as Fair Trade, Organic, or Rainforest Alliance. About 64% of farmers reported receiving free or subsidized inputs of some kind during their coffee establishment, such as seedlings, equipment, or fertilizer, from the government or local NGOs working to promote coffee in the region. Three farmers interviewed were not asked this question due to time constraints.

Out of potential pests and diseases, coffee leaf rust and coffee borer beetles were the most widespread, with 91% of farmers reported currently having coffee borer beetles and 91% reported currently struggling with coffee leaf rust (see Table 4). Other commonly cited pests and diseases include rooster's eye, coffee thread blight, and ants. Seven farmers were not asked about their pests and diseases due to time constraints.

Table 4. *Percent of Farmers Reporting Specific Diseases and Pests*

Disease/Pest	**% of Farmers**
Coffee borer beetle	**91%**
Ants	**27%**
Coffee leaf miner	**9%**
Doesn't know	**9%**
Coffee leaf rust	**91%**
Rooster's eye	**45%**
Coffee thread blight	**36%**

While all farmers reported using chemical fertilizer, 40% of farmers also reported using an organic fertilizer of some kind, such as chicken manure or cherry skins from the coffee cherries. In terms of weed management, many farmers used both chemicals and manual labor to control weeds. 83% of farmers reported weeding using manual labor of some kind, such as a weed whacker, and 58% reported using chemical treatments. Six farmers were not asked questions regarding fertilizers and weeding.

Farmers reported their short-term or their annual costs during a standard year of production first, and these costs were analyzed per hectare. Short-term cost sub-categories included variable costs excluding labor, fixed costs, and paid labor. Overall annuals costs were also analyzed with and without including family labor costs. Family labor costs as mentioned were assumed to be the rural local wage of a day laborer: $15/day. As seen in Table 5, including family labor costs effectively doubled the annual costs of production for farmers in a standard year. Short-term costs results are based on costs taken for 10 farmers.

Table 5. *Average Short-term Costs in a Standard Year of Production (USD/ha)*

Cost sub-category	**USD/ha**
Variable costs	$ 552.80
Fixed costs	$ 159.24
Family labor costs	$ 1,939.95
Paid labor costs	$ 902.33
Total with family labor	**$ 4,014.72**
Total no family labor	**$ 2,074.77**

Cost sub-categories also contribute larger or smaller percentages to the overall total depending on whether family labor is valued. When family labor was not included, variable costs made up 90% of total costs, while fixed costs only made up 10% of the total short-term costs on average. When family labor was included, the cost of family labor made up 55% percent of the total on average. In both scenarios, fixed costs make up a relatively small portion of the annual costs.

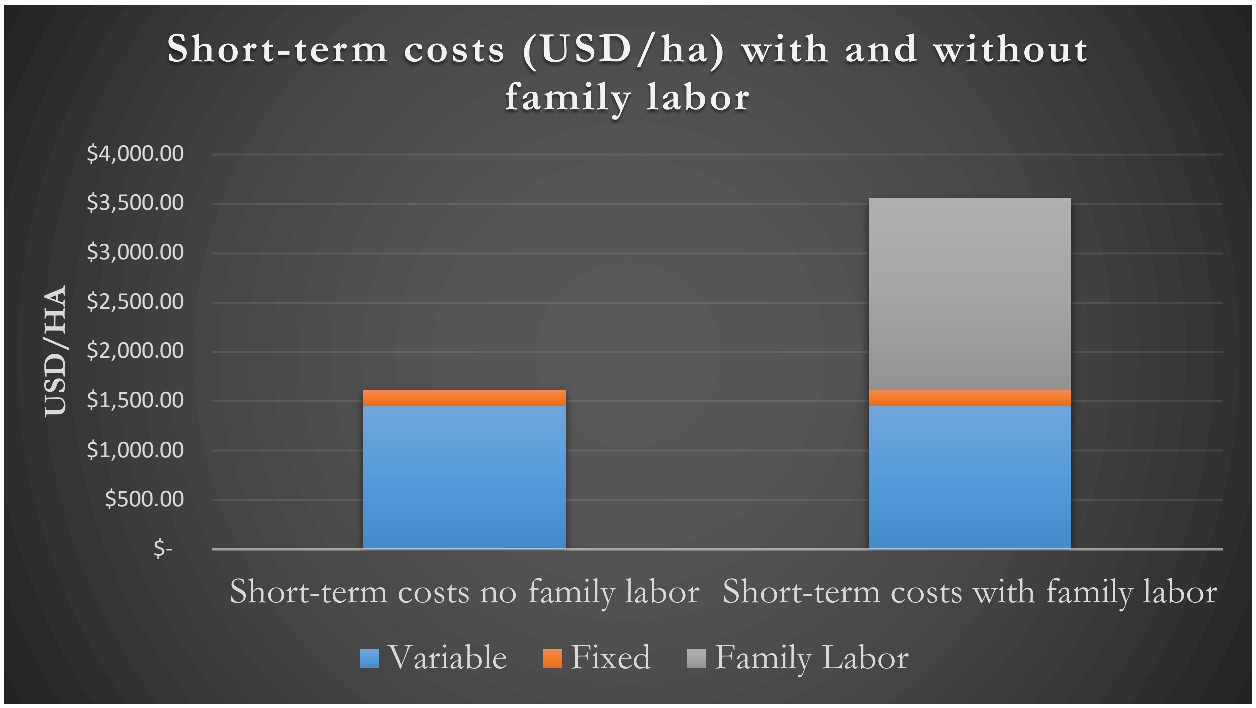

Figure 4. Average short-term costs in USD/ha with and without family labor

Furthermore, when we break out paid labor from the overall variable costs, we can see how labor costs as a portion of overall costs changed with the addition or subtraction of family labor costs. If family labor was included, all labor costs in total made up 80% of a farmer's short-term costs/ha on average. When family labor was excluded from the calculation, only 56% of costs were made up by labor costs, namely from paid labor. Meanwhile, variable costs other than labor now made up 34% of the total – a much larger piece of the pie.

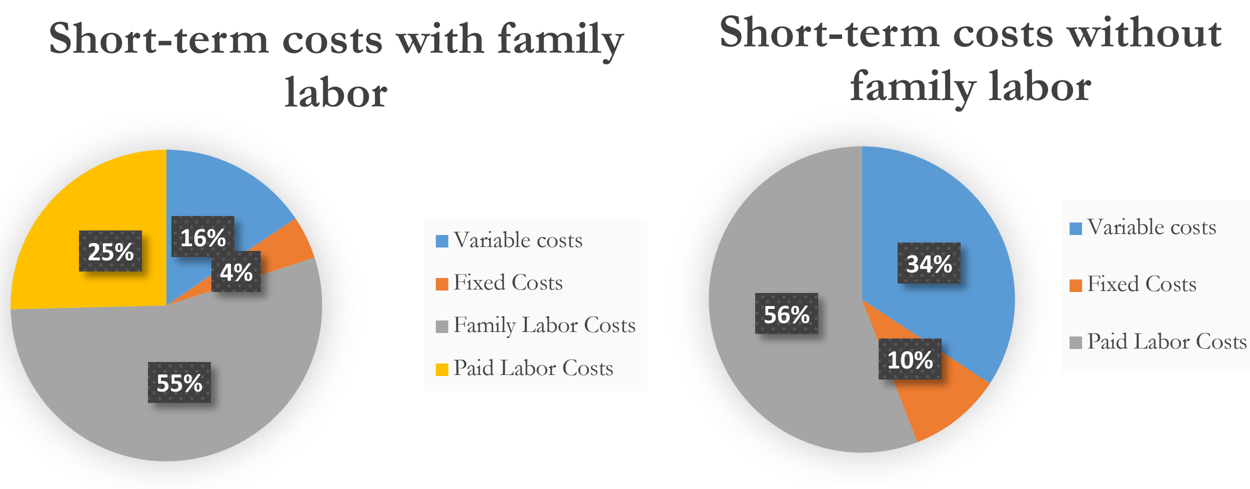

Figure 5. Average short-term costs in USD/ha broken up by cost sub-category with and without family labor

In terms of long-term costs attributed to a standard year (i.e. all loan, establishment costs and establishment family labor costs divided over the total number of years of the system), these costs in general were much lower than short-term costs (see Table 6). About 44% of farmers had taken out a loan. The average interest rate was about 11%, with lower rates if farmers received the loan from a cooperative, and higher if they had received it from the public bank, BanEcuador. Long-term cost results were based on information provided by 13 farmers; however, post-harvest establishment costs were not included for four farmers due to time constraints. Thus, many of long-term costs are likely higher than those reported in this study.

Table 6. *Average Long-term Costs in a Standard Year of Production (USD/ha)*

Long-term cost sub-categories	USD/ha
Loans	$ 165.83
Establishment	$ 253.43
Establishment Family Labor Days	74.48
Establishment Family Labor Costs	$ 80.59
Total with family labor	**$ 463.14**
Total without family labor	**$ 373.75**

The total long-term cost also increased with the inclusion of family labor, but not as dramatically (see Figure 6). The reason for this could be that family labor requirements were lower in the establishment year and more focused on purchasing equipment and inputs needed for the coffee system, and/or due to time constraints that at times did not allow us to collect all information for labor costs for this category.

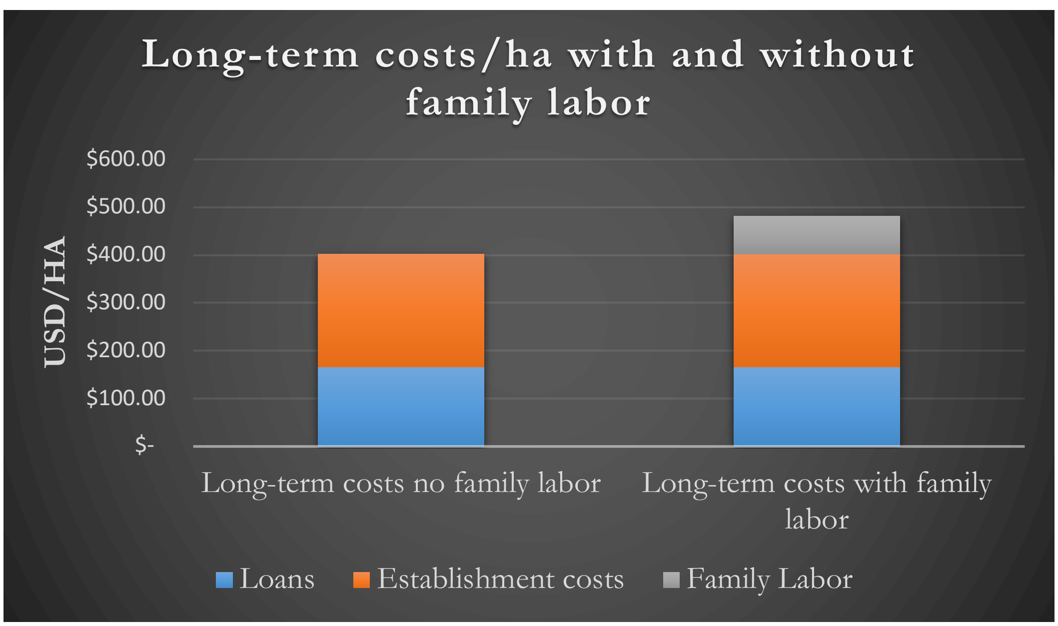

Figure 6. Average long-term costs in USD/ha with and without family labor

As seen in Figure 7, family labor costs made up a much smaller portion of the total cost than in the short-term cost category (16% compared with 55% previously.) Loans made up about a third of total long-term costs in this scenario and all other costs made up about half of all costs. Loans could make up a high percentage of the total because of the four farmers who we were not able to collect post-harvest establishment costs for and thus had lower establishment costs. When family labor was left out of the long-term cost calculation, then establishment costs rose to 60% of the total and loans costs increased to 40%.

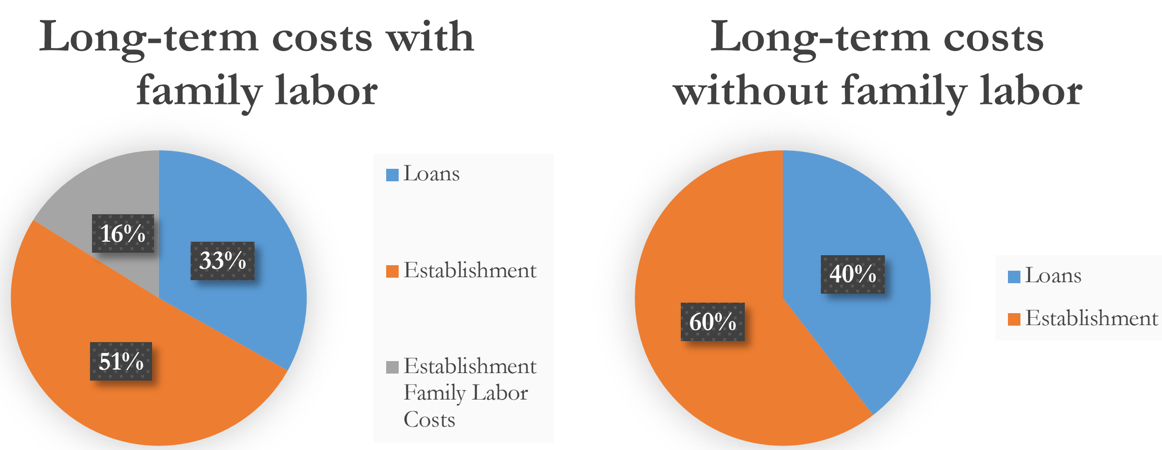

Figure 7. Average long-term costs in USD/ha broken by cost sub-category with and without family labor included

The average revenue per hectare was $3,100.04 and revenue per plant was $1.61 in a standard year. These averages were calculated based off estimates provided by 11 farmers. Farmers generally were paid $165-$185 per 100 lbs. of "primero" or their highest quality parchment coffee after association fees, depending on the quality of their coffee. Farmers also less commonly sold "café segundo" and "café pasilla" – second and third-tier quality coffee – for about $140 and $100 per 100 lbs of parchment coffee respectively. Two farmers sold coffee in the form of coffee cherries. In general, revenue appeared to increase as annual costs increased (see Figure 8).

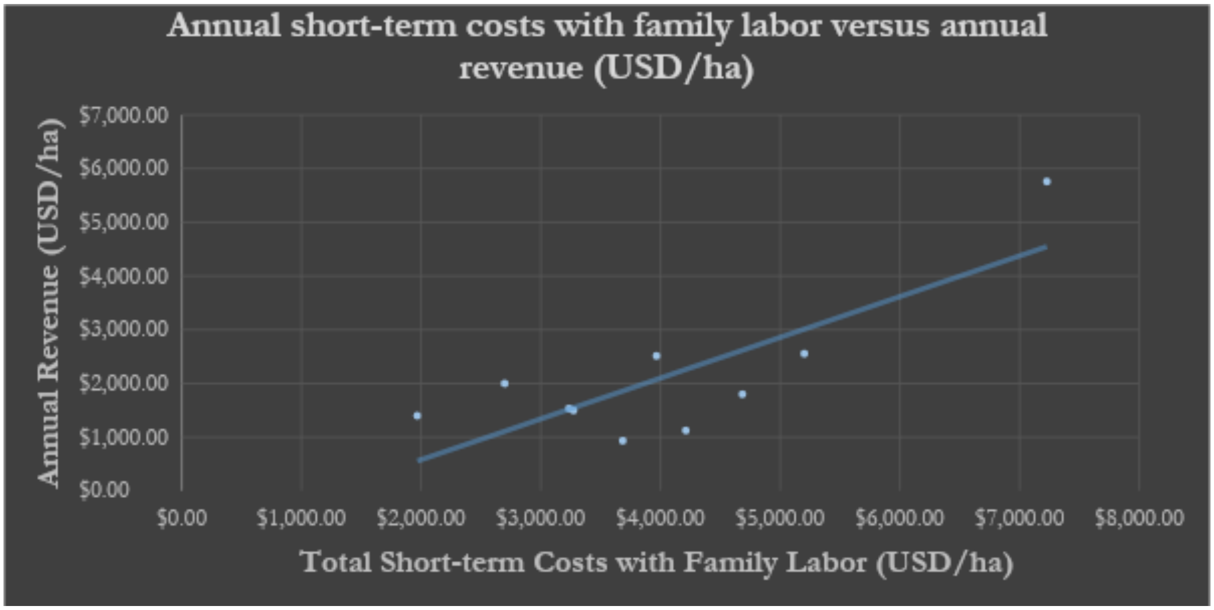

Figure 8. Annual short-term costs with family labor versus annual revenue (USD/ha)

However, with increased net annual costs, there appeared to be a downward trend in short-term net benefits in a standard year (See Figure 9).

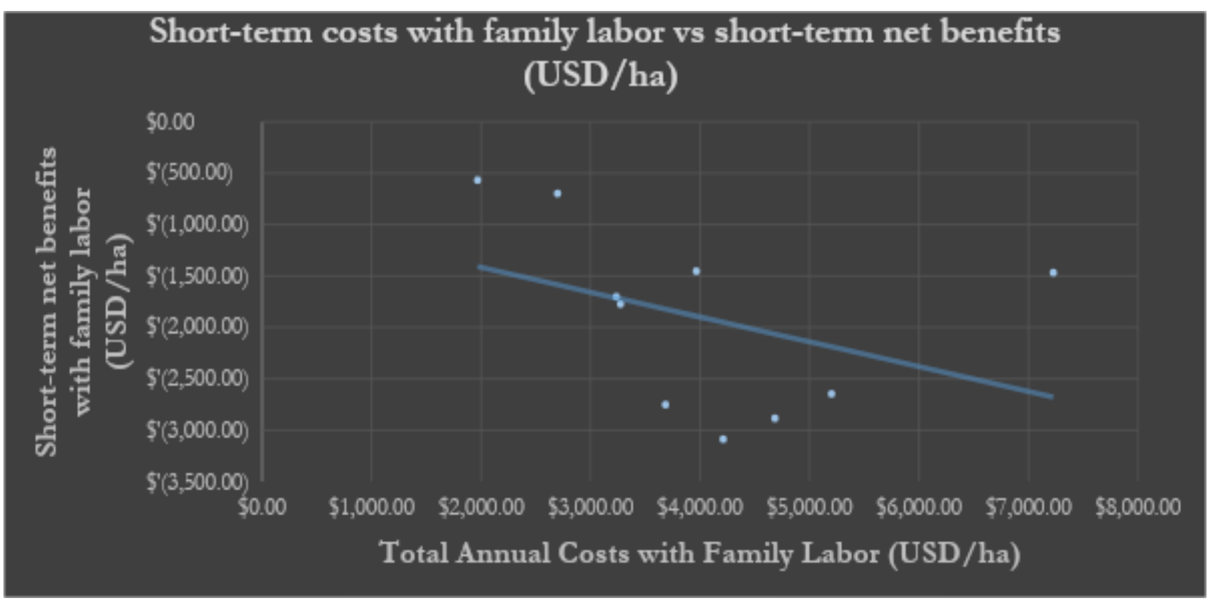

Figure 9. Annual short-term costs with family labor versus annual short-term net benefits

Using the cost totals and revenue in a standard year, net benefits/ha for each farmer were then calculated with short-term costs included (short-term net benefits) and then with both short and long-term costs included (long-term net benefits.) Short-term and long-term net benefits were also calculated with and without family labor valuation for both scenarios. Then, medians were calculated in the four different scenarios. These results are displayed in Table 7. Net benefits were only calculated for the farmers for whom we had complete information. For instance, if we ran out of time to ask a farmer about his long-term costs, then we did not calculate long-term net benefits for that farmer. Short-term net benefits were based off of responses from 10 farmers while long-term net benefits were based off of responses from 7 farmers.

Table 7: *Median Net Benefits per Hectare in a Standard Year over the Short- and Long-term*

Net benefits/ha	USD with family labor	USD without family labor
Short-term net benefits	-$1737.42	-$432.43
Long-term net benefits	-$2,435.43	-$712.20

In all four scenarios, median net benefits were negative, and much more significantly so when family labor was valued (Table 7). The only scenario that yielded slightly less net benefits for farmers on average was the short-term scenario without the inclusion of family labor. However, in this case, net benefits were still -$432.43 in a standard year. The addition of family labor significantly decreased net benefits in both the short-term and long-term scenario (Figure 10).

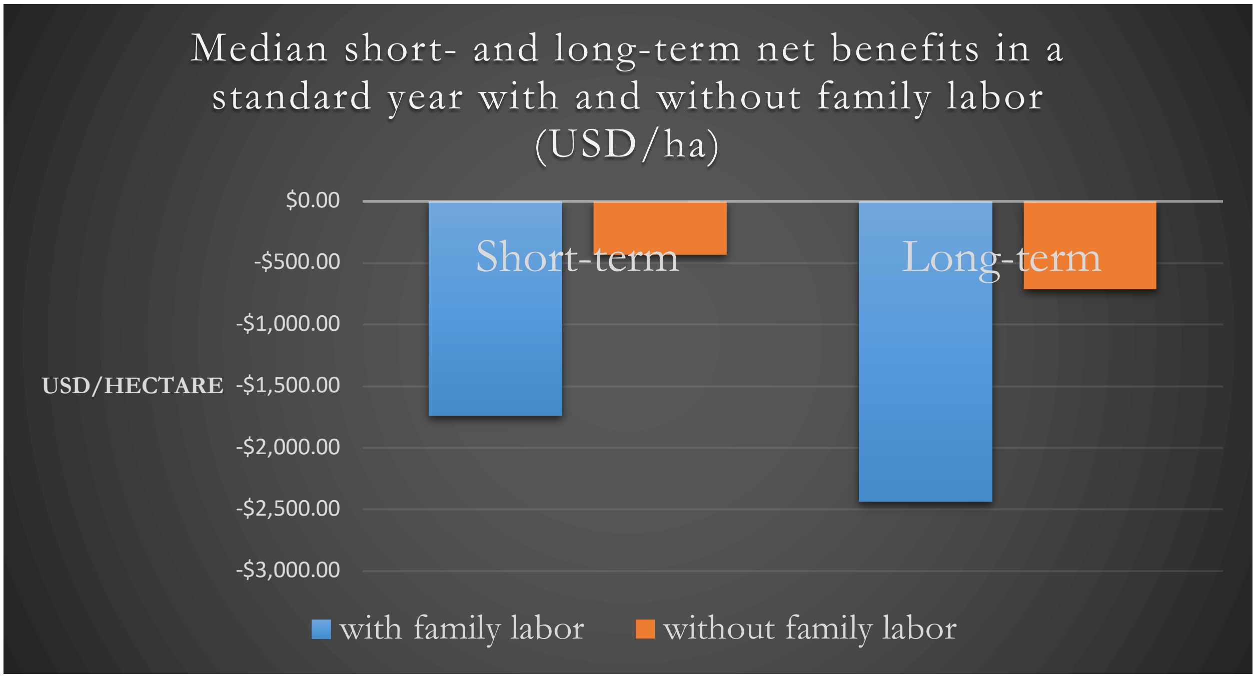

Figure 10. Median short-term and long-term net benefits in a standard year with family and without family labor (USD/ha)

Net benefits were also calculated on a per plant basis, with similar results in Table 8 below. Again, there was no scenario that yielded positive net benefits for the farmers.

Table 8: *Median Net Benefits per Plant in a Standard Year over the Short-term and Long-term*

Net benefits/plant	USD with family labor	USD without family labor
Short-term net benefits	-$0.73	-$0.13
Long-term net benefits	-$0.75	-$0.16

The distribution of producers' long-term net benefits with family labor included is displayed in Figure 11 to demonstrate the variation in net benefits.

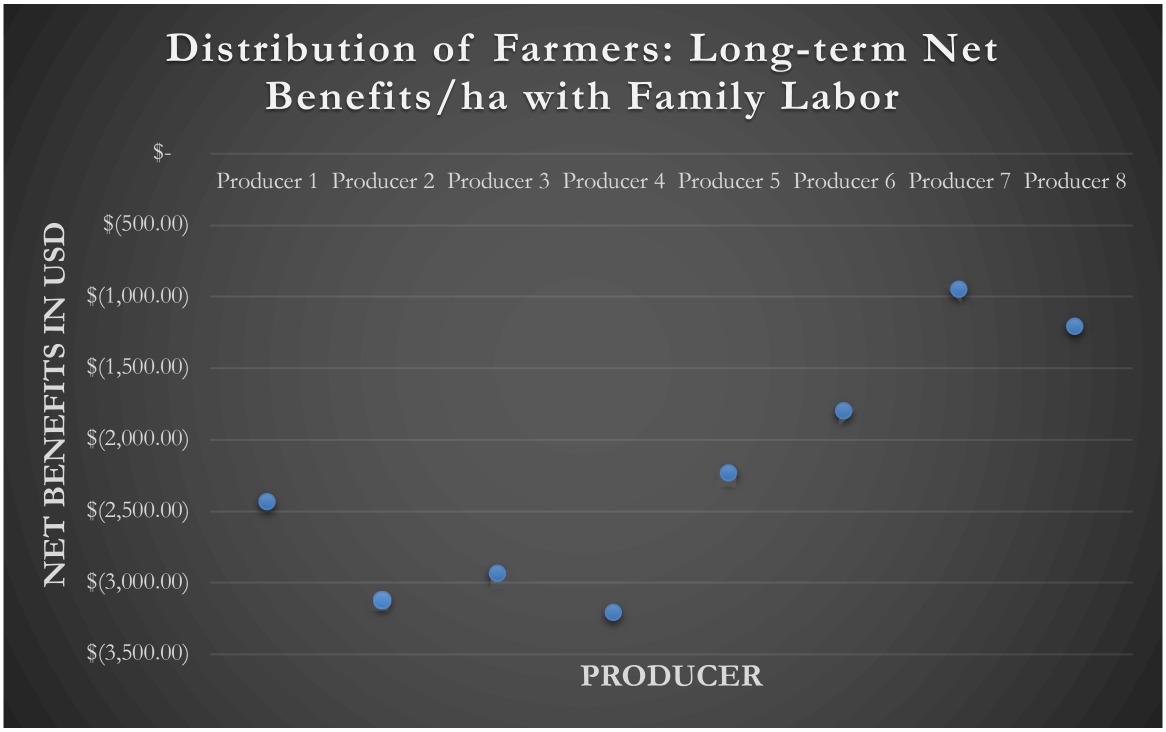

Figure 11. Producer distribution of long-term net benefits with family labor

The median equivalent daily wage (EDW) was then calculated in the short-term and long-term. The median EDW for farmers and their families was found to be -$3.69 when only short-term annual costs and labor were included, and -$4.31 when long-term costs and labor were included (See Figure 12). Thus, farmers were in effect paying themselves negative wages by growing coffee, and these wages were much lower than the average local rural wage of $15/day. The four farmers asked reported that coffee made up about 45% on average of their annual income.

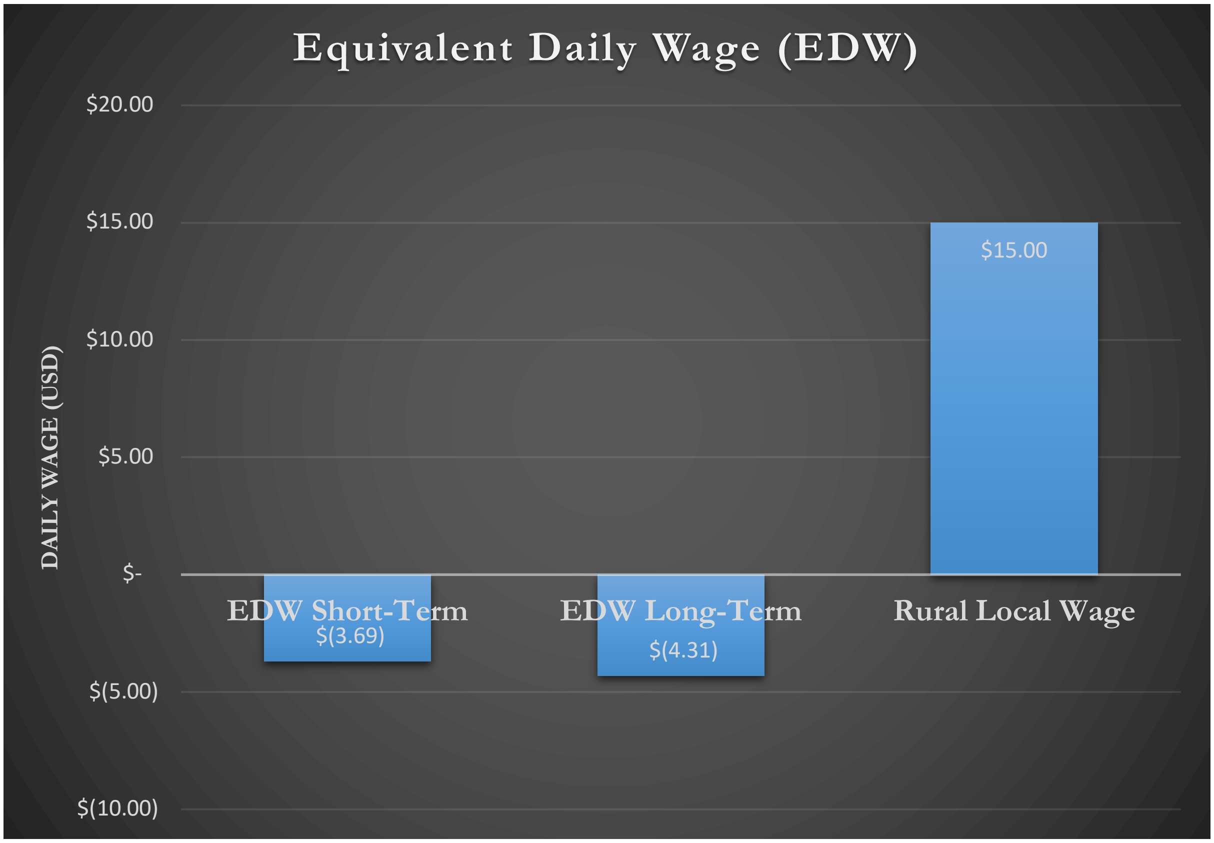

Figure 12. Median equivalent daily wage from coffee production for family labor in the short-term and long-term as compared to an average rural local wage

DISCUSSION

Cost Study

My primary finding is that coffee farming in the Pacto, Ecuador region is currently not economical for the smaller farmers we interviewed. If farmers were getting paid for their labor, coffee farmers and their family members would be earning negative daily wages from coffee production (See Figure 12). Furthermore, net benefits from coffee production in a standard year were negative in all scenarios (See Table 7). While the incorporation of long-term costs decreased net benefits, the incorporation of family labor into costs had the greatest negative effect on net benefits (See Figure 10). These results are particularly concerning given the four farmers asked reported coffee production made up 45% of their annual income on average. Furthermore, half of the farmers asked had taken out loans to invest in their coffee production that many are still in the process of repaying. And, more than half of farmers reported receiving free or subsidized inputs of some kind during their coffee establishment, yet these were not enough to make coffee production economical for the producers.

Furthermore, it is likely that farmers have lower net benefits year to year than those reported in a standard year due to shocks to the system because of disease outbreaks such as coffee leaf rust. As mentioned, coffee leaf rust can reduce production by 1/3 in Ecuador (USDA, 2018). Furthermore, it generally takes farmers two years to return to normal production after a coffee leaf rust outbreak, and, without proper pruning or replanting, another outbreak can occur (Neill, 2013). Based on the harvest yield data for Ecuador, it appears a shock (significant drop in yield) likely due to coffee leaf rust, occurs every 7 years (International Coffee Organization, 2019). Thus, coffee leaf rust and its impacts can have significant impacts on coffee production during a plantation's lifecycle. In conclusion, if a producer is not performing well during a standard year, the farmer likely would not perform well in a longer-term land use analysis or during other years of production. This is because of the multiple years during a coffee plantation's lifecycle that production is lower than a standard year due to shocks from diseases like coffee leaf rust for instance.

Other studies have reached similar results. I compared my results to those from a local study by Conquito & Triplei (2015) and to a meta-analysis performed by Montagnon (2017) that compared results from a range of coffee-producing regions. Montagnon's (2017) meta-analysis found costs of production per hectare to vary from a few hundred dollars to $4,000-

$5,000. My study's results were at the high end of that range, with costs of production found to be about $2,448/ha in a standard year with amortized establishment costs included and without family labor included, and $4,477/ha in a standard year with both family labor and long-term amortized establishment costs included. As mentioned, these costs are likely higher given that in many interviews, we were unable to account for all establishment costs. Montagnon (2017) also found net income per hectare to range from -$1890 to $2400, with a mean of $323. One study focused on greatly by Montagnon (2017) found costs of production to exceed the guaranteed price in Colombia by 17% on average, and in some regions more than 40% (Echavarría & Montoya, 2013). Meanwhile, our farmers' median net benefits ranged from -$2,435 to -$432 depending on what costs were included in the calculation (See Table 7). Thus, our results were on the low end of the net income range, and the high end of the costs range provided by Montagnon (2017). These differences could be due to the increased comprehensiveness of the costs we tracked, and also due to the increased costs of producing coffee in Ecuador relative to other countries (De Valdenbro, 2018).

Furthermore, a common underlying assumption is that growing high-quality, high-producing, or certified coffee, which often equates to higher production costs, will result in higher yields and thus greater profitability. Research based on this model supports this assumption (Espinosa-García et al., 2016) and has demonstrated that higher productivity results in higher costs of production (Echavarría & Montoya, 2013). However, our research and other recent research is disproving some of these assumptions. Recent research has found that higher yields as a result of adoption of best practices do not necessarily result in higher profitability, and that lower production costs can be associated with higher profitability

(Echavarría & Montoya, 2013; Montagnon, 2017). For instance, Montagnon (2017) found that farms with total costs per hectare of less than $3000 were mostly profitable, while farms above this cost are only profitable if high-yielding or if receiving high prices. In our study, we also found that increased costs were generally associated with lower net benefits (See Figure 9). Thus, more research could help determine if encouraging small farmers to adopt practices that increase productivity and quality are worth the costs of implementing them, given the high costs of labor and inputs. This research could focus on a larger number of producers (of all sizes and levels of technology adoption) and specific practices often recommended by extensionists, such as pruning or improved post-harvest or nutrient management practices, to determine what management practices could be worth the added costs.

I compared our results with those from a similar study performed in the region by Conquito & Triplei (2015). Conquito & Triplei (2015) analyzed cost of producing coffee for three different farmer types: high-tech, medium-tech, and low-tech farmers. They define high-tech farmers as those with all the necessary technical knowledge and resources to implement best agronomic and post-harvest practices (Conquito & Triplei, 2015). They define medium-tech farmers as having technical knowledge but not full access to all equipment, fertilizer and pesticides needed to achieve best practices (Conquito & Triplei, 2015). Lastly, low-tech farmers have some technical knowledge and 1.5 hectares of coffee or less and are mainly run on family labor (Conquito & Triplei, 2015). Given that a few of our farmers met their definition of a medium-tech farmer, I compared our results to their results for both low-tech and medium-tech farmers. Their study found the average costs for a low-tech farmer in the region to be about $2525/ha in a standard year of production, including amortized establishment costs (Conquito & Triplei, 2015). Adjusted for inflation, this cost translates to about $2,573.58 in 2018. For a medium-tech farmer, total costs in a standard year of production were $3,926/ha, or $4,001.53/ha in 2018 (Conquito & Triplei, 2015). In our study, costs in a standard year of production, including short-term and amortized establishment costs (labeled long-term costs in our study) resulted in a total to $2,448/ha in a standard year. Thus, our cost totals are comparable when accounting for the same cost categories for a low-tech farmer but are lower than Conquito & Triplei's medium-tech cost total. After accounting for family labor, our short-term costs rose to $4014/ha in a standard year – much higher than the Conquito & Triplei average of $2,573 for low-tech farmers, but somewhat on par with their average of $4,001.53 for medium-tech farmers. And once amortized long-term costs with family labor valued were included, total costs in a standard year increased to $4,477/hectare. Thus, our calculated total costs exceeded the costs valued by Conquito & Triplei, primarily due to the valuation of family labor. However, when comparing the same cost categories, our results were on par with their results for low-tech farmers thus validating the results of both studies.

Conquito & Triplei (2015) did not calculate net benefits or income, but we can make inferences from their study to compare net benefits of our study and theirs. The revenue in a standard year for a farmer in our study was about $3,100/ha. In the Conquito study, revenue in a standard year was about $1800/ha for a low-tech farmer when applying the average price of one quintal (100 lbs.) of parchment coffee in the region – $180 (AAPROCCNOP, personal communication, 2018). For medium-tech farmers, revenue in a standard year was $3600/ha. Thus, our average revenue of $3,100 was closer to the revenue of a medium-tech farmer in

Conquito & Triplei's study. However, our average revenue included one outlier producer who was not considered a small farmer, given they had five hectares of coffee and had a much higher yield and higher revenue per hectare. When the median was calculated instead to remove some of the influence of this farmer's exceptionally higher yield and revenue, the median revenue in a standard year of production became $1800/ha, equal to the Conquito & Triplei average of $1800 for a low-tech farmer. Therefore, our median annual revenue was equal to Conquito & Triplei estimates for low- but not medium-tech farmers. While the Conquito & Triplei study did not calculate net benefits, if we were to do so ourselves, we would find that a low-tech farmer would be making a negative net income of -$773.58/ha in a standard year and a medium-tech farmer would be making a net negative income of -$401.53/ha. Median net benefits in our study, using the same cost categories as the Conquito & Triplei study, were -$712/ha on average, and thus almost as negative as their net income for low-tech farmers. However, with the inclusion of family labor for both short and long-term costs in our study, our net benefits dropped to -$2,435 – a much more negative result. Thus, both our study and Conquito & Triplei (2015) confirm similar annual revenue for small farmers and that costs generally greatly exceed revenue for coffee farmers in the Pacto, Ecuador region.

Agronomic Challenges

In addition to the economic impacts, we noted many agronomical concerns in our interviews with the coffee farmers. Farmers had on average established their coffee plantations around 2013 and were generally producing 1 hectare of coffee with a median of 2750 plants per hectare. This is a lower planting density than seen typically in neighboring countries; for instance, the average is 5000 plants in Colombia (Echavarría & Montoya, 2013). Farmers were also growing outdated varieties that are low in productivity and highly vulnerable to coffee leaf rust and other diseases. Sarchimor is known for average cup quality but is much more resistant to coffee leaf rust (World Coffee Research). Out of the varieties reportedly grown, Sarchimor only makes up 41% of the varieties mentioned by farmers, while Caturra, a much lower yielding and disease-susceptible variety, makes up 82%. Farmers also were all struggling to address pests and diseases. Coffee leaf rust and coffee borer beetles were the most widespread, with 91% of farmers reporting struggling with coffee borer beetles and 91% reporting struggling with coffee leaf rust. The high incidence of this pest and disease is likely connected to the lack of resistant varieties planted and lack of proper management practices.

We also observed certain management practices with implications for the environment. Surrounding forest was often cleared to make way for either coffee plantations or for the crop that had been planted prior to coffee plantations. While all farms observed had intercropping of some kind on their plantation, farms generally had low levels of shade trees and would not qualify as a multi-strata agroforestry system. In addition to these land use concerns, all farmers asked did not treat their wastewater generated in the post-harvest wet process before dumping it, generally down a ravine. Wastewater from coffee wet processing is high in sugars and acidity, which can create anaerobic and toxic conditions in local waterways (von Enden et al., 2002; Rattan et al., 2015). Water treatment options that involve multiple tiers of treatment, such as neutralization tanks, biogas digesters, and water filtration systems do exist (von Enden et al., 2002; Rattan et al., 2015) however no farmers we interviewed had adopted them. We concluded that coffee production in Pacto is currently uneconomical and has multiple negative environmental implications.

Data Accuracy

Choosing to collect data through farmer interviews came with limitations. Due to time-constraints, it was not possible for all farmers to answer all questions of the interview. Sometimes only costs in a standard year could be recorded, and information on establishment costs and some agronomic questions was not possible to collect. Thus, one limitation of the study is a small sample size for some questions. Therefore, rather than reporting the raw numbers of farmers who responded one way or another, we usually presented results as percentages. When there was a significant number of farmers who were not asked a certain question (more than two) this is noted in the results. Further research involving a larger sample size would be beneficial to ensure greater accuracy of the profitability and challenges of coffee farming in Ecuador.

Collecting data through farmer interviews also left the data open to inaccuracies due to poor record keeping or farmer biases. Farmers often appeared to be estimating costs and labor inputs, which could lead to inaccuracies in our data. There is a dearth of research analyzing how subjectivity and biases affect reliability of data (Fermont & Benson, 2011). Research has found farmer's estimates of their labor can be prone to inaccuracies and dependent on factors like the season they are interviewed or the sequence of questions (Arthi, Beegle, De Weerdt, & Palacios-López, 2016). However, some research has shown gaps of time of up to a year after the farming season to have little effect on farmer data accuracy overall (Beegle, Carletto, & Himelein, 2011). Therefore, our data from a standard year of production is likely more accurate than our data from the establishment of the coffee plantation. However, farmer recall and prediction has been found to be a more accurate predictor of production than other methods such as the crop-cut method (Fermont & Benson, 2011). More research is needed to determine the biases associated with farmer recall and prediction and how best to avoid them.

The research team also had difficulty at times determining the best manner to phrase questions regarding labor spent on production activities. At times, it was difficult to assign a cost value to particular farmer activities, given farmers do not necessarily measure certain activities in "labor days" – our primary unit of measurement for labor. For instance, farmers would give answers such as administration makes up 15% of my total time spent on coffee production, and we would have to estimate the labor days after determining the farmer's total time spent on coffee production. Estimation was often involved and questions about the reliability of our data arose. More research is also needed to determine the best manner to phrase questions so that farmers can more accurately answer interview questions.

CONCLUSION

In conclusion, the coffee farmers in Pacto, Ecuador whom we interviewed were facing many agronomical and environmental challenges associated with growing coffee and were losing money in producing coffee. When all costs were taken into account, farmers were experiencing net negative benefits and earning a negative equivalent daily wage.

Future research, policy and development work could help address some of these issues in the region. One gap identified was farmer access to technical knowledge of best management practices in coffee production. For instance, more extension services could be focused on how to prevent and treat pests and diseases as well as determine proper fertilization application rates. Extension efforts could also focus on increasing adoption of wastewater treatment systems, given no farmers were treating the wastewater from coffee processing. However, given the low profitability of coffee production for these farmers, this suggestion should be taken with caution. Farmers could adopt practices that increase costs but do not achieve sufficiently high yields and prices to justify the higher costs. Price premiums would likely be needed for farmers to adopt better environmental practices, such as treating wastewater. However, given Ecuador's already high cost of production and high prices needed to cover costs, negotiating higher price premiums for improved management practices might prove difficult to do. Further research should address whether farmers should focus on lowering their production costs and labor investment rather than invest more time and money into their coffee farms.

The possibility also exists that it may not be in farmers' best economic interest to produce arabica coffee in the Pacto, Ecuador region. Particularly given the high costs of labor, which made up 80% of farmers' annual costs, producers simply may not be able to compete with neighboring countries' lower costs of production and costs of labor. Thus, the push to promote arabica coffee production led by Ecuador's ministry of agriculture and other local NGOs may not benefit producers, particularly in Pacto, Ecuador. One potential area of further research to address this question of whether or not farmers in Pacto should produce coffee in the first place could be to complete a land use system analysis or cost of production study comparing other common livelihoods in the region, such as sugarcane production and cattle ranching, to coffee to determine if better options exist result in higher net benefits for the farmers.

Further research could also help identify cases where Ecuadorian producers are achieving positive net benefits and high equivalent daily wages from coffee production and what differentiates those farmers from ours. Given our study primarily focused on small farmers who had recently began coffee farming, it would be interesting to include farmers who have been farming for longer periods of time than the farmers included in our study, and also more large, high-tech farmers in a future study. It also would be interesting to compare certified and uncertified producer, and association farmers and nonmembers. Furthermore, costs vary greatly between regions (Echavarría & Montoya, 2013). Thus, a comparative study could compare various regions as well as farmer types.

While we had time and resources restrictions, we would have liked to have surveyed a greater quantity and variety of farmers to better determine the variables that separate successful farmers from unsuccessful farmers. For instance, there is a well-known relationship between soil fertility and coffee cup quality (Njoroge, 1998.) In our study it would be desirable to take soil tests at every farm and determine relationships between net benefits and soil fertility and health. Given the impact of altitude on coffee quality, it would have been interesting to analyze how altitude affects farmer net benefits, along with post-harvest practices that can greatly influence coffee quality and vary depending upon altitude. These relationships would have been possible to analyze with a larger sample size.

Additionally, the results of this study are based on a set of assumptions made due to time restrictions of the project period and of the interviews themselves. Further studies could be done that better account for depreciation costs of both machinery and plantations, sample more and a greater variety of farmers, and ask more detailed questions about the entire lifecycle of coffee plantation production rather than only the establishment and standard years. Since detailed questions might be difficult to ask if a researcher is trying to sample a large number of farmers, a method to achieve greater accuracy would be using focus groups that delve deeper into the true costs of producing coffee in Pacto, Ecuador. Focus groups are routinely used by UC Davis to determine management practices and costs used to estimate total cost and revenue in their cost studies (Professor Dan Sumner, personal communication, December 2018). Using focus groups could allow a more detailed look at the net benefits of a full lifecycle of coffee production without being overly burdensome on farmers' time. Cross-checking the answers from a focus group and a survey could help prevent aforementioned inaccuracies from farmer-reported data. Meanwhile, individual farmer interviews could complement the use of focus groups to reach average costs of production in a standard year, as performed in this study. In conclusion, while our study painted a rather discouraging picture of coffee production in Pacto, Ecuador, more comprehensive research is needed to help identify potential solutions for these farmers.

Cost of production studies in the coffee sector in general could be improved. They could be more explicit about subjective choices that were made in their methodologies and use more consistent methodologies for better comparisons between them. Better consistency could be achieved by more comprehensively including costs associated with growing coffee, particularly family labor costs, administration costs, and establishment costs. Studies should also expand beyond a focus on short-term profitability and take into account opportunity costs to small family farmers and long-term economic sustainability. When assumptions are made, researchers could also use sensitivity analyses to permit consideration of alternative scenarios and determine which factors are most important in the outputs of these models. Furthermore, more research is needed to determine the reliability of different data collection methods, such as farmer-based interviews, and the biases that might be introduced.

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