Received: 31 May 2022 | Accepted: 22 January 2023

DOI: 10.1111/ajae.12389

ARTICLE

Paying more to make less: value degrading in the coffee value chain in eastern Uganda

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Funding information
German Research Foundation, Grant/Award Number: RTG1666

Abstract

Value upgrading through processing has been a core tenet of value chain interventions focusing on improving smallholder farmer welfare improvements. However, assessing the quality of processed agricultural products may be more difficult than unprocessed products. The resulting information asymmetry between producer and the buyer may lead to perverse outcomes for agrarian households. Using primary panel data collected from over 1500 coffee growing households in eastern Uganda and employing fixed effects approaches, we show that grower-level post-harvest processing has characteristics of a market for lemons and is associated with lower coffee income compared with unprocessed coffee production. Activities aiming at moving growers up the value chain should thus be integrated with relevant characteristics of the value chain, such as quality assurance. We add to the literature by presenting a clear description of the pathway from supply chains with asymmetric information over produce quality to diminished farmer welfare with a novel focus on post-harvest processing.

KEYWORDS

asymmetric information, coffee, market for lemons, quality uncertainty, Uganda, upgrading, value chains

JEL CLASSIFICATION

D8, O13, Q13

1 | INTRODUCTION

Poverty remains a key source of concern for global development objectives (World Bank 2020). Growth in the agricultural sector has been found to be up to four times more effective in reducing poverty than growth in other sectors in poor countries (World Bank 2007). As a result, a market-based value chain approach has been embraced as a key pro-poor growth and development strategy (World Bank 2007; FAO 2008; UNIDO 2011; Stoian et al. 2012). Value chain approaches emerging out of supply chain research in the 2000s (Gereffi et al. 2005; Gibbon & Ponte 2005) take a whole-of-system perspective: providing a powerful tool to develop a broad view of key potential constraints to the efficiency and distributional equality (across the different levels) of the supply chain. Producer-level interventions including technology adoption or upgrading to improve product quality, on the other hand, do not take account of demand-side limitations, information asymmetry between value chain actors, and other institutional factors (de Janvry & Sadoulet 2020), and can lead to net losses for farmers when traders or processors do not pay for higher quality.

In the case of smallholder-dominated systems, asymmetric information may undermine efforts at upgrading thereby potentially creating a perverse effect where value chain upgrading interventions generate a 'value degrading' outcome.[1] Our focus is on value chain interventions promoting adoption of basic home-based processing activities that allow the household to capture rents from downstream levels of the supply chain (Webber & Labaste 2009; Mitchell & Coles 2011). This 'functional' upgrading is potentially useful as a development tool (i.e. to increase household income) under the minimally necessary condition that the gross margins from home-based processing activities are positive; that is, they generate a positive variable profit. A stronger condition for enhanced identification is that the gross revenues from the total yield of processed product are higher than would be the case if the product were sold directly as a raw commodity to account for the fixed and variable costs of processing.

We argue that functional upgrading through post-harvest processing may generate a negative income effect for cash crops grown by smallholder producers. This argument hinges on quality concerns: observability of quality is often diminished for partially processed produce not only because key harvest-related information (e.g. ripeness) is not able to be easily assessed but also because information on the quality of processing practices are difficult to assess for partially processed produce. The producer has full knowledge on the initial quality of harvested produce and of their own activities in processing whereas the buyer is only able to ascertain extreme quality failings in the processed product. This compares to freshly harvested produce that can often be assessed for freshness, disease, and insect damage easily (e.g. coffee). Difficulties in assessing the quality of a purchased product when investment in quality by producers is costly results in a classic 'market for lemons' problem (Akerlof 1970). The lemons market problem is characterized by agents (producers) having incentives to pass off low-quality produce as high-quality produce and principals (the buyers) being unable to assess the quality of contracted produce and offering lower prices as a hedge against the possibility of purchasing lower quality produce.[2] In this classic market dilemma there is a strong tendency for a race to the bottom, bottom in this sense being a low-quality, low-value equilibrium.

In this paper we present a study focused on smallholder coffee farmers to consider the potential for a value degrading outcome from functional upgrading through post-harvest processing. Our

[1]Value chain upgrading is defined, broadly, as producers or firms moving to higher value activities to increase the benefits, such as profits, value added, and capabilities, from production (Gereffi et al. 2010). Product upgrading is defined as producers moving to higher value products (e.g. through quality enhancing and adopting sustainability labels) whereas functional upgrading is producers taking on new actions, such as processing, and producing more complex products (Humphrey & Schmitz 2002).

[2]Note that in many smallholder-dominated supply chain cases 'contracts' are once-off farm-gate or buyer-gate contracts for the purchase of presented produce. They are often undertaken in challenging conditions in a market place at the homestead of a producer or in public places with substantial demand on the buying agent in assessing large numbers of producers' submissions. The number of potential buyers and sellers are such that there is little opportunity for formalization of relationships through longer term contracting or 'trust' based approaches, particularly with very small producers where the transaction costs of such formalization are likely to outweigh the value derived from such approaches.

main research question is the following: Does functional upgrading through post-harvest processing of coffee reduce the coffee income earned by smallholder producers? We describe the nature of the coffee processing and the environment facing smallholder coffee farmers in our setting and derive two hypotheses to test the key conditions associated with value degrading induced by a market for lemons. To test our hypotheses and thus answer the research question of whether functional upgrading through processing leads to lower coffee income, a large sample of over 1500 Arabica coffee (*coffea arabica*) growers in eastern Uganda were surveyed in 2018 and, again, in 2019 using a questionnaire that incorporated information on production, costs of production, revenue, psychosocial phenomena (e.g. cognitive ability, and risk and time preferences) and sociodemographic factors. Observing households across two periods allows for using fixed effects (FE) regressions to account for potential selection bias associated with the choice to process coffee by sample households. Results from our panel data analysis support our main proposition that value-degrading outcomes are present in home-processing of coffee and that those negative effects relate to characteristics of lemon markets as described by Akerlof (1970).

In particular, the results regarding value-degrading are both substantive and significant with processing of coffee generating an average of a 10–20% decline in revenues and profits. Our description of 'value degrading' indicates a potentially straightforward strategy to assess the potential for value degrading outcomes in the adoption of home processing. Specifically, our analysis and results show that a small set of basic information criteria should be considered as indicative of a likely value degrading outcome: (1) costs of processing are positive and significant; (2) there is substantial overlap in the equivalent marginal revenues for processed and fresh produce; (3) there is a lack of cheap and effective quality assessment for processed product; and (4) production can be characterized as being dominated by smallholder farmers. In cases exhibiting these characteristics, we claim that value degrading outcomes are likely to occur, generating perverse outcomes for target producers in typical value chain intervention programs (i.e. smallholder farmers with a substantial reliance on the target crop for their household income).

This study lies at the intersection of two broad literatures: (i) quality uncertainty and asymmetric information and (ii) agricultural value chains. Informational asymmetries have traditionally been studied in credit and insurance markets primarily in advanced countries (Akerlof 1970; Rothschild & Stiglitz 1978; Stiglitz & Weiss 1981; Chiappori & Salanie 2000; Crawford et al. 2018). There is an increasing interest in the aspects of uncertainty about product safety and quality in agricultural markets with recent studies demonstrating that information asymmetries generate low-value outcomes for market actors (Fafchamps et al. 2008; Kadjo et al. 2016; Park et al. 2020; Abate et al. 2021; Bold et al. 2022). Relatedly, there is a growing literature indicating the informational asymmetries regarding authenticity and safety of inputs with serious health and environmental implications. Fraudulent or counterfeit inputs including pesticides (Haggblade et al. 2017; Haggblade et al. 2019; Haggblade et al. 2022), herbicides (Ashour et al. 2019), seeds (Gharib et al. 2021; Hsu & Wambugu 2022), and fertilizers (Michelson et al. 2021) have been documented in various developing countries. As a result, third-party certifications, group-based testing, and quality labels aimed at improving the accuracy of quality signal across the value chain have gained in importance. Notable studies testing the effectiveness of such instruments on welfare, with a focus on staple foods and dairy markets, include Saenger et al. (2014) in Vietnam; Hoffmann and Moser (2017) in Kenya; Abate and Bernard (2017) and Anissa et al. (2021) in Ethiopia; Bernard et al. (2017) and Prieto et al. (2021) in Senegal; Bai (2021) in China; and Treurniet (2021) in Indonesia.

Our contribution lies in providing a conceptually based consideration of information asymmetries in relation to value chain upgrading. We not only uncover asymmetric information regarding produce quality but also demonstrate that when information asymmetries across the value chain exacerbate with upgrading, what is seemingly an upgrading activity, post-harvest processing in fact generates lower value outcomes for smallholder producers compared with marketing of raw product. We thus extend the literature on quality uncertainty and asymmetric information to (i) the coffee value chain and (ii) value upgrading.

Second, our study adds to the value chain literature by formally and empirically analyzing, in terms of welfare outcomes, a value chain upgrading activity that is common among smallholder farmers but that has been rarely considered by researchers. A majority of existing empirical studies in the value chain literature examine value upgrading by sustainability certification/labels and quality improvement (Wollni & Zeller 2007; Barham & Weber 2012; Ruben & Fort 2012; Dragusanu et al. 2014; Chiputwa et al. 2015; de Janvry et al. 2015; Minten et al. 2018; Dragusanu & Nunn 2018; Sellare et al. 2020; Arslan et al. 2022). Our study differs from these studies by assessing the welfare effects of upgrading through moving from an unprocessed fresh produce to a processed and more sophisticated product (i.e. functional upgrading), and with an additional focus on informational inefficiencies in the value chain.

Vicol et al. (2018) is one of few studies with a focus on welfare effects of post-harvest processing in the coffee sector in Indonesia. Vicol et al. (2018) argue against profitability of upgrading through processing fresh coffee produce because smallholders capture little value due to an incapacity to produce higher quality coffee products. Related, but focusing on wine/grape production, Ponte and Ewert (2009) argue that smallholder farmers are better off downgrading (e.g. not post-harvest processing) in the value chain for South African wine when, for instance, they face high standards making it unviable for them to sustainably participate in the value chain. Despite providing useful insights into the relationship between functional upgrading and profitability along with the potential pathway to success or failure, these studies do not quantitatively analyze the effects of upgrading at the household level nor provide a quantitative consideration of the presence of lemon markets associated with upgrading. With this paper we provide early quantitative evidence on the household-level profitability of upgrading through post-harvest processing in the coffee value chain.

Third, we explore the factors associated with value upgrading through processing. We consider the role of physical constraints (distance, access to fresh coffee traders), knowledge (understanding of quality signals), time and risk preferences, and cognitive performance as drivers of choices to process (and how much to process) coffee. The inclusion of cognitive ability measures also provides for insights related to the capacity of coffee growers to select high-quality coffee and to maximize returns associated with different market pathways. These factors are based on the literature (Fafchamps & Hill 2005; Bellemare & Barrett 2006; Maertens & Barrett 2013; Gertler et al. 2014; Kondylis et al. 2017; Ruhinduka et al. 2020) along with qualitative evidence obtained during discussions with producers. Documenting the role of several factors associated with participation in post-harvest processed coffee markets, this study relates to several other strands of the literature such as the literature that identifies information as a barrier to adoption of welfare-improving practices (Foster & Rosenzweig 1995; Hanna et al. 2014; Maertens and Barrett 2013; Kondylis et al. 2017), the literature that associates cognitive ability with better socio-economic outcomes (Murnane et al. 2000; Heckman et al. 2006, Almlund et al. 2011; Gertler et al. 2014); the nascent literature that explores psychosocial factors in upgrading (Ruhinduka et al. 2020) and the literature that studies the role of transaction costs in agricultural marketing by smallholder farmers (Key et al. 2000; Fafchamps & Hill 2005; Bellemare & Barrett 2006; Ouma et al. 2010).

The factors that we consider in order to shed light on the drivers of post-harvest processing such as cognitive ability and knowledge about product quality are quite novel. Given the existence of a lemons market, we also document the characteristics of 'lemon' suppliers i.e. producers who strategically engage in processed coffee markets. In particular, we find suggestive evidence that a group of producers who have a good understanding of the coffee markets (i.e. producers with higher levels of cognitive ability and coffee-related knowledge) process lower-quality coffee cherries into parchment potentially to exploit the prevalent asymmetric information. Hence, our study expands the adverse selection literature for a major cash crop produced by smallholders in developing countries.[3]

[3]Adverse selection arises when an informed individual's trading decisions depend on his/her privately held information about the product. The quality of the product is exogenous, and decisions (of market participation) are made ex-post according to the private information about quality. Adverse selection typically implies that only low-quality products are transacted in the market. In contrast to the prediction of Akerlof (1970) that adverse selection leads the market to collapse, however, we believe that what we observe is more in line with predictions of Miyazaki

The remainder of this paper is organized as follows. Section 2 describes the coffee markets, processing activities, and the context in which coffee-growing households operate. In Section 3 we present our hypotheses. Section 4 presents data and sample characteristics. Section 5 describes the empirical approaches used in this study. Section 6 presents results, and conclusions are offered in Section 7.

2 | COFFEE PRODUCTION AND MARKETS IN EASTERN UGANDA

In our study area, coffee is typically harvested from September/October to December/January. Coffee production begins each year with a harvest of coffee cherries, a fruit containing the seed commonly called a coffee bean—the key product of value in coffee supply chains. Coffee cherries should pass into processing within 24 h of being harvested because the coffee fruit is highly perishable. Thus, farmers must typically either sell harvested coffee cherries fresh on the day of harvest to a trader/processor or choose to process them at their homestead.

Wet processing for the most common coffee type involves: (1) mechanical removal of coffee cherry skins and fruit (pulping); (2) fermentation to remove the remaining mucilage on the coffee bean and to develop flavors; (3) drying of the bean in a way that minimizes contamination from dirt, dust, and smoke.[4] The end product of this process is called 'parchment coffee' due to the papery skin that remains covering the green bean, the latter being the final export-ready product. The parchment is removed during milling/hulling to produce the green bean.

The processing, drying, and sorting process used to produce parchment coffee involves a transformation requiring five kilograms of harvested fresh coffee cherries to produce one kilogram of parchment (Mujawamariya et al. 2013, Sualeh & Dawid 2014).[5] Thus, for profits from coffee to be increased for households undertaking processing, the price of processed product (parchment) needs to be at least five times higher compared to coffee cherries not including the costs of processing. Evidence from market prices in the region at the time of this study provides the first indications of potential value degrading.

Table 1 presents an outline of fresh coffee cherry market prices and processed coffee prices (in coffee cherry kilogram equivalents) in the study region over the two harvest seasons (2017 and 2018). Although the outline in Table 1 indicates a substantial potential for value degrading (fresh coffee revenues and processed coffee revenues substantially overlap), these comparisons do not

TABLE 1 Coffee cherry prices and processed coffee prices (in coffee cherry kilogram equivalents).

Price	Fresh coffee cherries	Processed parchment coffee (market price per kilogram of parchment coffee)	Processed parchment coffee (in fresh coffee cherry kilogram equivalents)
Minimum price observed (US c/kg)	30 cents	140 cents	28 cents
Maximum price observed (US c/kg)	40 cents	220 cents	44 cents

(1977) and Wilson (1977) that prices stabilize at average rates and low-risk individuals (e.g. good parchment producers) subsidize high-risk individuals (e.g. bad parchment producers).

[4]There are typically three methods of processing Arabica coffee in the world: wet, dry (natural), and semi-dry (honey) processing. In our study area, coffee is traditionally wet processed.

[5]5-to-1 conversion ratio (fresh cherries to parchment coffee) is a commonly accepted ratio in east Africa. In their work in Rwanda, Mujawamariya et al. (2013) reports that "one needs about 5 kg of berries to produce 1 kg dry coffee." In a lab study, Sualeh and Dawid (2014) study the conversion rates across beans and processing methods, and show that conversion rates vary between 5.4 and 4.7 for (washed) Arabica coffee in Ethiopia. Hence, we have a good reason to believe that 5-to-1 conversion ratio is a good approximation and based on scientific calculations.

account for the costs of processing coffee cherries nor for the savings in transport associated with marketing of the processed product (a weight saving of five times and a large space saving).

For example, for many farmers the sale of fresh coffee cherries requires either engagement of a local trader or transport to the local buying centers of a large processor/exporter in the area.[6] In most cases, before being accepted by agents at the buying centers cherries are assessed for quality using a rapid visual qualitative assessment of ripeness and the presence of damage from pests and diseases. Quality thresholds applied by traders/processors are relatively easy to meet; yet, there are a number of growers who have to sort their cherries at the buying stations in order to pass the assessment. Cherries that are sorted out are either sold to traders to bulk their coffee or home processed into parchment.

Post-harvest processed coffee (parchment) markets are differentiated from fresh coffee (cherry) markets in three ways: (1) parchment coffee is substantially easier to transport being approximately five times less weight and substantially lower in volume, (2) fresh cherries are perishable and should be marketed quickly after harvest whereas parchment has relative storability,[7] (3) quality of processed parchment coffee is much more difficult to assess because complex physical and chemical transformations occur during processing of coffee cherries that are not visible to the naked eye (Poltronieri & Rossi 2016). Indeed, although coffee cherries are more easily quality differentiated on the basis of color and the presence of insect damage to the cherry, processed coffee is largely of a uniform color when dry and damage is difficult to discern except for gross quality issues (e.g. stones and major insect damage).[8] Parchment coffee that will yield low-quality final coffee and that can yield high-quality coffee can trade at similar prices because they are, to a large extent, imperceptible from each other.

Last, the costs of post-harvest processing can be substantial involving the requirement to pulp cherries using a pulper, a fermentation process of 24–36 h, the need for drying equipment, and the substantial time that it takes to dry parchment. Producing high-quality parchment requires attention to cleanliness and fermentation and a high level of effort given to drying over a relatively long time period (e.g. up to 3 weeks) to avoid fungal and soil contamination. If little effort is made (e.g. minimal fermentation and rapid drying of three to 5 days on the ground), the quality of parchment will be low even if the cherries are high-quality to begin with.

The outline of processing coffee above indicates that (1) differentiation of processed coffee quality is nearly infeasible for open market transactions by buyers in coffee growing areas (e.g. there is no effective and/or efficient quality assessment technology), and (2) it is costly to produce high quality coffee as opposed to producing low quality coffee, that is, farmers/processors have an incentive to produce lower quality coffee and to attempt to pass it off as high quality. This outline is essentially a description of the key conditions outlined by Akerlof (1970) that are likely to lead to the emergence of a market for lemons, a situation wherein buyers' lack of confidence in product quality leads to low offer prices that crowd out high-quality produce.

3 | HYPOTHESES

The contextual discussion above outlines the argument for the presence of a market for lemons in partially processed coffee markets but not necessarily in freshly harvested coffee cherry markets in

[6]Anecdotal evidence suggests market access is typically not a problem for a majority of growers in the study area because there are many buying centers across the district. This buyer has a processing station where coffee cherries are processed while quality parameters are monitored.

[7]The moisture content of the parchment coffee should be about 11–13% at the time of the sale. This gives producers some flexibility in marketing parchment. But, once the parchment reaches the optimum moisture level, it should be marketed relatively quickly (because storing parchment coffee is associated with risks of mold and theft given the limited resources of the producers in our area). Given the lack of large variations across the coffee buying season, there is little reason to think that our results would depend on strategic behavior around selling of parchment coffee. Our understanding is that sales decisions are associated with household cash needs rather than strategic price arbitrage.

[8]This aspect is a key reason for the emergence of 'relationship trade' in specialty coffee markets (Vicol et al. 2018) as an effort to mitigate the difficulties in assessing quality through the development of trust and mutually beneficial investment in quality. In the open market, however, coffee processed using low-quality and high-quality coffee can trade at similar prices given that differentiation of coffee quality is difficult.

smallholder coffee production regions. This is termed the 'value-degrading' problem—wherein actions targeting improved value through processing, or general investments in product quality at the producer level, are undermined by institutional factors, in this case a market for lemons, and that may lead to perverse outcomes.

Our argument regarding the presence of a market for lemons in upgraded markets for coffee farmers implies that necessary conditions for upgrading to be income improving for participating households are unlikely to hold. These conditions are based on the costs and revenues from the choice to direct a unit of freshly harvested coffee cherries to a home-based processing activity and subsequently to a coffee parchment market.

For positive investment costs, and positive variable costs (of processing and transport), the annual net return to production of processed coffee (π_P) is:

$$\pi_P = P_P Q - C_Q - C_P - d(I_P)$$

Where:

P_P = Price for processed product
Q = Quantity of raw product
C_Q = Variable costs for production (harvest, agronomy, transport) of raw product
C_P = Variable costs for processing and transport of processed product
$d(I_P)$ = Annually depreciated costs of investment in processing capital

In contrast, the returns to production of raw product (π_R) are:

$$\pi_R = P_R Q - C_Q$$

Where:

P_R = Price for raw product
C_Q = Variable costs for production (harvest, agronomy, transport) of raw product

In terms of the first condition discussed above, for processing to generate higher income and act as a development program it is necessary that the returns to processed product are at least as large as those for production of raw product:

$$\pi_P > \pi_R$$

$$P_P Q - C_Q - C_P - d(I_P) \geq P_R Q - C_Q$$

Assuming costs for investment in processing capital and/or processing are positive, a stronger (necessary) condition is that the gross margin for processed product is greater than that for production of raw produce[9]:

$$P_P Q - C_Q - C_P > P_R Q - C_Q$$

Thus, our first hypothesis is that that the profits from processed coffee are higher than those for direct sales of fresh coffee cherries:

> **Hypothesis 1 (weak).** A greater proportion of total coffee production allocated to processed coffee production is associated with lower average profits (profit per kilogram of total coffee production by a given household).

[9]Note that the gross margin argument simply removes the inclusion of the depreciated investment costs term for parchment production. The gross-margin argument is stronger because the $d(I_P)$ term can be assumed to be non-negative and is likely to actually be nonzero (positive-definite) for most households.

An even stronger condition for home-based processing to generate a positive income effect for participating households, given that both the investment and variable costs of upgrading are positive, is that average revenues (in raw-product unit equivalents) are sufficiently greater for home-based processing than for production of raw product:

$$P_P \gg P_R$$

This stronger condition allows a direct comparison of price equivalents (in fresh coffee cherry quantity equivalents) between sales of unprocessed coffee (cherries) compared to sales of processed coffee (parchment):

> **Hypothesis 2 (strong).** A greater proportion of total coffee production allocated to processed coffee production is associated with lower average unit revenues (revenue per kilogram of total coffee production by a given household).

Rejection of these hypotheses provides support for the presence of a lemons market. In the case of Hypothesis 2 rejection also indicates that households are willing to invest money in processing activities that earn them lower returns in comparison to direct marketing of freshly harvested coffee cherries. Under the assumption that households act to maximize utility, the presence of lower profits or revenues from participation in parchment markets raises questions over why households would take a course of action that is more complex and is apparently dominated by a simple one in terms of financial returns.

A range of possible reasons are raised as likely and are explored, along with other socio-demographic factors in a follow-up analysis of the 'drivers' of home processing and marketing of processed coffee. First, it may be that quality criteria in the fresh cherry market shift producers with lower knowledge on quality expectations to produce substantial levels of parchment production. Growers with lower investment in agronomy or from lower quality regions (i.e. lower altitudes that tend to be drier and hotter) or growers who hire coffee pickers who are not incentivized to harvest high quality coffee may also find it more difficult to meet quality requirements of buyers and so seek to produce more parchment. Informational barriers, a commonly documented barrier to adoption of welfare-improving agricultural practices (Foster & Rosenzweig 1995; Conley & Udry 2010) may thus play a role in the extent to which producers engage with post-harvest processing.

Secondly, behavioral factors can also play a role: Larger (lumpsum) payments may be viewed as 'worth' more or may be easier to manage for households that face social and psychological constraints in saving income. For example, Collins et al. (2009) document demand for small irregular flows of income to be aggregated into lumpsums for investment by the poor in developing countries where financial markets are often missing (Banerjee & Duflo 2007; Dupas & Robinson 2013). Cognitive abilities may play a role in parchment production decisions through a variety of mechanisms such as easing information constraints about effective cost and price differentials in coffee markets and thus influence coffee growers to select high-quality coffee and to maximize returns associated with different market pathways. In addition, Ruhinduka et al. (2020) find that risk and time preferences significantly explain post-harvest decisions of rice farmers in Tanzania.

Last, physical constraints may also play a role in the extent to which coffee farmers sell parchment coffee. Physical barriers may include the distance to coffee buying centers (market). Roads in the area can be hazardous after rain potentially increasing transport costs. For example, Fafchamps and Hill (2005) show that farmers do factor in physical and cash constraints in their marketing decisions and are more likely to transport their product to the market (versus selling at farm gate) when the market is closer and the quantity sold is large.

4 | DATA

Primary data were collected from coffee growing households in the district of Kapchorwa in eastern Uganda in the months of March and April of 2018 and 2019. This is the period following the main coffee harvest season in the region (September/October to December/January). Households were randomly selected from a list of coffee farmer groups obtained from the largest coffee exporter in eastern Uganda that has operated in the project region for approximately 20 years and dominates coffee markets in the region (UCDA 2020). The sample consists of over 1500 households across 190 villages in 19 parishes of the district.

Key outcome variables are coffee revenues per kilogram and profits per kilogram. We calculate coffee revenues per kilogram (r_i) and profits per kilogram (π_i) as follows:

$$r_i = \frac{R_{i,c}}{H_{i,c}}$$

$$\pi_i = \frac{R_{i,c} - C_{i,c}}{H_{i,c}}$$

Where:

$R_{i,c}$ = Revenue from all coffee sales for household i

$H_{i,c}$ = Harvest of all coffee sales for household i

$C_{i,c}$ = Production and marketing cost of all coffee sales for household i

Coffee revenues are calculated as the sum of coffee revenues earned from any coffee sales throughout the season. Coffee prices for either of the two marketing pathways (cherries or parchment) are calculated by dividing the quantity of coffee sold for the respective pathway by the total revenue for that marketing pathway. Coffee profits are calculated by subtracting production and marketing costs from total coffee revenues. Production and marketing costs include cost incurred for harvesting coffee, post-harvest processing (pulping, fermenting, and drying) for parchment producers, and transport costs for marketing coffee each time the household sold their coffee.[10] During data collection, we first established how many times in the entire harvest season producers harvested their coffee (four times on average). Then, we asked how many kilograms (of fresh cherries or parchment) they sold at what prices (per kilogram) each time. Our assessment of revenues, costs, and profits is thus based on season-averages.[11]

Given the prevalence of certification/labels, we incorporate price premium (commonly called bonus) into revenue calculations. However, the number of producers who received such payments is very small. All farmers in our sample are sustainability certified regardless of the type of coffee they sell (processed or unprocessed). Certification procedures, however, are unaffordable and are thus handled by the largest exporter in the area and not by individual producers. As a result, the costs of certification are not relevant for producer profits. Similarly, price premium is not paid (in monetary terms) to the individual farmers. Our analysis does not consider the non-monetary benefits that producers receive.[12]

[10]Marketing costs are key to our analysis because fresh cherries have to be marketed quickly after harvesting due to their perishable nature and are bulkier than parchment coffee. Hence, marketing of cherries takes place more often and is more costly than marketing parchment coffee.

[11]Coffee price fluctuations are rather seasonal and do not affect producer revenues and profits considerably on a daily basis within a given season. Hence, we think that using season-average coffee prices and profits is sufficient for our analysis and does not pose a threat to our findings.

[12]We are aware that the exporting company provided non-monetary benefits such as biogas and pruning knives to farmers in the past and started to conduct community projects, such as building schools, with the price premium obtained from the international market. One reason for not returning the premium to individual producers is the concerns about the (fair) distribution of price premiums. We are informed that smaller producers were not able to capture any benefits because of a minimum quantity threshold; a farmer needs to produce a certain quantity to be eligible for a price premium. As a result, the company decided to return the premium in the form of community projects rather than individual payments to the producers to benefit the whole community including small producers.

One variable of interest is whether the household engaged with post-harvest processing, measured by an indicator variable taking the value 1 if the household processed any coffee and 0 otherwise. The share of parchment produced (out of all harvested cherries) is calculated by dividing the quantity of coffee cherries used to produce parchment by the total harvest of coffee cherries for each household (in kilograms).

Explanatory variables include knowledge on coffee quality that is measured by a count variable (0–10) constructed using questions on improved harvest practices and coffee quality. Answers to these 10 questions were scored 0 for incorrect answers and 1 for correct answers. The variable on coffee quality knowledge was then obtained as the sum of 0–1 coded answers to the coffee-quality questions. This is a common approach to measuring knowledge in the literature (Kondylis et al. 2017; BenYishay & Mobarak 2019; Hörner et al. 2022). Following Laajaj and Macours (2017), the Raven's progressive matrices (developed by J.C. Raven in 1936) were used as a measure of cognitive ability. Specifically, a count variable (0–10) was constructed by summing the correct scores given for answers to Raven's progressive matrices tests (0–5) and math tests (0–5). Knowledge and cognitive ability test questions are presented in the appendix.

Risk preferences were measured using four survey questions, such as "How would you rate your willingness to take risks in general/farming?" "Would you like to try a new agricultural practice which allows you to earn a much higher income?" Time preferences were measured using four survey questions, such as "Do you store a lot of food at home?" "How often do you put extra money aside for expected needs/shocks?" "How far do you think ahead when making major decisions?" Answers to both sets of questions were recorded based on 3-point scale options (0 no/low, 1 neutral/medium, 2 yes/high).

Market access was proxied with distance in kilometers to the nearest buying center to which farmers transport their coffee. The answers of households that did not transport coffee to buying centers or those who reported to not have knowledge about the distance are replaced by village averages. The remaining variables were utilized as standard survey variables, such as age, sex, and educational attainment of the household head, household assets, and other crop sales.

4.1 | Summary statistics

Table 2 presents sample characteristics (mean and standard deviation of dependent and independent variables) across producer categories for the baseline sample whereas Table 3 presents sample characteristics based on the follow-up data. p-values for differences in variables of interest across three categories can be found in Tables A1 and A2 in Appendix S1.

Of all households in the sample, 955 sell fresh coffee cherries exclusively (59%), 451 (28%) sell both coffee cherries and parchment, and 204 (13%) sell only parchment. For the group of households that sell both coffee cherries and coffee parchment, the share of cherries taken up by parchment varies between 8% and 99% with a mean of 64%.

There are large differences between households who engage with parchment production and those that do not. For instance, households who produce only parchment earn 1049 Ushs per kilogram of coffee harvested, whereas households that sell only cherries earn 1225 Ushs per kilogram (p-value for difference = 0.000). The difference in average profits when normalized by harvest levels is even higher between producers who engage with parchment and those who do not (740 versus 1039 UShs with a p-value of 0.000 for difference). On the other hand, households who produce parchment own larger coffee farms, and as a result, they harvest larger amounts of coffee. Total profits of parchment producers are, on average, higher (1.5 million UShs) than for those who sell only fresh cherries (600,000 UShs).

Households that produce both cherries and parchment earn 1127 UShs per kilogram of coffee and 865 UShs as profits, which lie between what is earned by producers who sell only cherries and only parchment. Note that this joint-production cohort are also the farmers who have significantly higher knowledge about coffee quality and cognitive ability than the rest of the farmers in the sample (Table A1 in Appendix S1).

TABLE 2 Sample characteristics across producer categories (baseline data).

	Baseline means and standard deviations		
Explanatory variables	**HH sells only unprocessed coffee**	**HH sells both unprocessed and processed coffee**	**HH sells only processed coffee**
Time-varying variables			
Revenues per kg (UShs)	1225.081 (5.649)	1126.479 (4.939)	1048.756 (7.973)
Profits per kg (UShs)	1040.396 (9.592)	866.164 (13.710)	738.783 (19.439)
Share of processed coffee (%)	0.000 (0.000)	64.433 (1.032)	100.000 (0.000)
Coffee harvest in tons	0.543 (0.022)	1.488 (0.070)	1.931 (0.161)
Pest and disease pressure (0–7)	1.050 (0.042)	1.083 (0.060)	1.100 (0.091)
Hire labor for harvesting (0/1)	0.416 (0.016)	0.612 (0.023)	0.622 (0.034)
Number of extension meetings attended	0.919 (0.054)	1.529 (0.114)	1.095 (0.150)
HH size	6.219 (0.080)	6.720 (0.114)	6.249 (0.156)
Number of HH assets per capita	0.430 (0.012)	0.457 (0.017)	0.476 (0.025)
Other crop sales per capita (000 UShs)	0.176 (0.011)	0.210 (0.014)	0.237 (0.022)
Time-invariant variables			
Altitude (in 1000 meters)	1.784 (0.008)	1.781 (0.009)	1.730 (0.014)
Distance to buying center in km	15.886 (0.281)	14.569 (0.403)	14.572 (0.352)
Distance to tarmac road in km	3.207 (0.125)	2.246 (0.125)	2.461 (0.238)
Experience with coffee farming in years	25.145 (0.459)	27.895 (0.660)	27.484 (1.078)
Coffee farm size in acres	1.321 (0.031)	1.839 (0.071)	1.617 (0.087)
Quality knowledge score (0–10)	4.730 (0.057)	5.330 (0.094)	4.970 (0.120)
Parchment knowledge (0/1)	0.505 (0.016)	0.399 (0.023)	0.448 (0.035)
Cognitive ability score (0–10)	3.976 (0.074)	4.178 (0.107)	3.873 (0.162)
Risk averse (0–8)	4.795 (0.031)	4.733 (0.047)	4.587 (0.055)
Forward looking (0–8)	2.785 (0.050)	2.570 (0.066)	2.214 (0.096)
Female household head (0/1)	0.138 (0.011)	0.161 (0.017)	0.124 (0.023)
HH head age	51.727 (0.442)	52.749 (0.634)	53.493 (0.960)
HH head education in years	8.794 (0.182)	9.285 (0.258)	8.736 (0.388)
N	947	446	201

Note: UShs refers to Ugandan Shillings. 3600 UShs∼1 USD.

5 | IDENTIFICATION AND ESTIMATION STRATEGY

In this section we first present our identification and estimation strategy to establish whether post-harvest processing reduces revenues and profits per kilogram of coffee harvested. In the second subsection we present the estimation strategy for an analysis of factors that predict engagement with parchment production.

5.1 | Estimating the effect of post-harvest processing coffee on revenues and profits

We set out to establish the role of parchment production in affecting total household coffee revenues and profits. Under the lemon-market hypothesis associated with 'value-degrading' we outlined earlier, those households processing coffee to produce parchment (or more parchment) would make

TABLE 3 Sample characteristics across producer categories (follow-up data).

Explanatory variables	Follow-up means and standard deviations		
	HH sells only unprocessed coffee	HH sells both unprocessed and processed coffee	HH sells only processed coffee
Time-varying variables			
Revenues per kg (UShs)	1185.570 (4.937)	1145.924 (10.919)	1127.749 (10.338)
Profits per kg (UShs)	956.856 (12.541)	906.055 (33.766)	888.534 (25.991)
Share of cherries processed (%)	0.000 (0.000)	61.747 (1.803)	100.000 (0.000)
Coffee harvest in tons	0.478 (0.015)	1.108 (0.082)	1.191 (0.099)
Pest and disease pressure (0–7)	1.545 (0.045)	1.705 (0.097)	1.607 (0.130)
Hire labor for harvesting (0/1)	0.536 (0.015)	0.734 (0.031)	0.634 (0.040)
Number of extension meetings attended	1.930 (0.055)	2.121 (0.120)	1.959 (0.161)
HH size	6.479 (0.072)	6.889 (0.157)	6.538 (0.207)
Number of HH assets per capita	0.339 (0.007)	0.327 (0.014)	0.378 (0.023)
Other crop sales per capita	0.726 (0.016)	0.764 (0.041)	0.865 (0.052)
N	1172	207	145

Note: UShs refers to Ugandan Shillings. 3600 UShs∼1 USD.

lower profits than those producing only fresh coffee cherries (or producing a lower share of parchment in total coffee output).

To explore the relationship between processing decisions and revenues and profits per kilogram of coffee harvested, we estimate the following model using OLS:

$$Y_i = \alpha_0 + \alpha_1 T_i + X_i + \gamma_g + \varepsilon_i \quad (1)$$

Yi measures outcomes, revenues or profits per kilogram of household *i*. *Ti* represents an indicator variable that takes the value 1 if the household *i* processes coffee and 0 otherwise. Alternatively, *Ti* was also measured as a share of processed coffee. *X* is a vector of covariates including household characteristics, such as household size, sex and education of the household head, household assets, and crop sales (other than coffee). Factors affecting coffee quality and quantity (quantity of coffee harvested, experience with coffee farming, altitude, pest and disease damage, harvesting labor, the number of extension meetings attended within the past year) are also included in *X*.

To rule out some of the endogeneity concerns (e.g., that processing coffee is correlated with profits via network mechanisms or other ways), we control for distance to the nearest coffee buying center (nearest market) and tarmac road. Additionally, to control for innate ability, business acumen, and understanding of costs—which is usually unobserved—we incorporate cognitive ability and knowledge about coffee quality and about effective cost of processing into the specifications. Time and risk preferences are also controlled for due to the opportunity cost of post-harvest processing and relative storability of processed coffee compared with the high perishability of fresh coffee cherries. In a more conservative specification, group fixed effects (γ_g) are incorporated (88 farmer groups, which are formed mostly at the village level). Under the identifying assumptions, α_1 is the causal effect of parchment production on revenues and profits. We used log-linear specifications because it is a common practice in economic analysis to log transform typically noisy financial variables such as prices and profits. This way, the effect of outliers (or right-tail observations) on the results are minimized and the distribution of the outcome variables converges to a normal distribution. It also makes it easier to interpret the results in percentages—given that Ugandan shillings might not speak to the audience or in USD the purchasing power issues are not taken account of. We clustered standard errors at the farmer group level.

Despite the very rich set of covariates (including psychosocial characteristics) and group fixed effects, this approach might still be confounded by endogeneity of the processing decisions. A

majority of studies in the literature that assess the effect of upgrading using cross-sectional observational data deal with the endogeneity issue by matching and balancing methods (Ruben & Fort 2012; Chiputwa et al. 2015; Meemken & Qaim 2018). Although these methods account for observed heterogeneity, they might fail to adequately control for unobserved characteristics between the farmers who process coffee and who do not.

To account for selection bias to the extent possible, we make use of the panel data collected, employ fixed effects (FE) approach, and estimate the following equation:

$$Y_{it} = \beta_0 + \beta_1 T_{it} + Z_{it} + \delta_{gt} + \theta_i + e_{it} \quad (2)$$

where *Yit* measures our outcomes of household *i* in year *t*. *Ti* represents post-harvest processing (either binary or continuous as above). *Z* includes a subset of variables in *X* that vary with time, such as coffee harvest in tons, pest and disease damage, hired labor for harvesting, the number of extension meetings attended within the last year, along with household assets and crop sales (the remainder are zeroed through the household FE approach). δ_{gt} is group-time fixed effects which capture the time-varying farmer group characteristics. θ_i represents household fixed effects. The FE estimator was used taking advantage of repeated measures across two sampling efforts (one in Year 1 and the following one in Year 2). The FE estimator controls for time-invariant heterogeneity and thus for individual-level propensities to engage in coffee processing based on often unobservable phenomena, such as cognitive ability, and risk and time preferences. Log-linear specifications and robust standard errors are used.

5.2 | Estimating drivers of post-harvest processing

A substantial portion (59%) of the growers in the sample do not engage in post-harvest processing and the share of cherries processed into parchment takes the value of zero for them. To explore the drivers of parchment production, first, the decision to whether ($y = 1$) or not ($y = 0$) produce parchment was modeled as a binary choice with coefficients for drivers estimated using the probit model. Secondly, for those who home-process coffee ($y = 1$) the extent of processing, the share (percentage) of harvested cherries taken up by parchment production was modeled as a continuous choice model and estimated using OLS. Both equations were estimated using cross-sectional equations over the baseline sample data as the more comprehensive of the two survey efforts. Explanatory variables included environmental variables such as altitude (as a measure of coffee farm quality), coffee lost as a result of pest and disease; coffee quality knowledge measured using a short task on classifying photos of coffee cherries, psychological variables such as cognitive ability measured using the Raven™ matrices, and risk and time preferences; and production-related variable such as coffee harvest in tons, coffee farm size in acres and agronomic investment, and farming effort or motivation related variables such as the number of extension meetings attended in the last 12 months and whether the household attended training organized to improve coffee quality for a related project. In addition, standard sociodemographic variables were included such as household size, household assets, and other crop sales. This part of the analysis is based exclusively on the rich baseline data collected since most time-invariant variables including distance to nearest tarmac road, risk and time preferences, and cognitive ability were not collected in the follow-up data.

6 | RESULTS

In this section results of our empirical analyses are presented. In the first subsection we focus on the effect of post-harvest processing on revenues and profits per kilogram. In the second subsection, we shed light on to the drivers of post-harvest processing.

6.1 | Revenues and profits per kilogram

The estimated effects of post-harvest processing on the two outcome variables, revenues and profits per kilogram of coffee harvested, are summarized in Table 4. Presented specifications from OLS estimations include coffee quality-related factors, household characteristics, psychosocial factors, and farmer group fixed effects (FE), whereas FE estimations include a subset of time-varying factors, group-year FE to control for time-varying farmer group-specific factors, household FE to control for time-invariant unobserved heterogeneity, and a year indicator (time FE) to control for year effects. All results show a significant and substantial negative effect of the choice to produce parchment on revenues and on profits.

Engaging with post-harvest processing is associated with a decrease of between 10 and 13% in revenues earned per kilogram of coffee harvested. Panel data specifications with group-year FE or household FE (controlling for unobserved heterogeneity) do not change the magnitude of the coefficient indicating that revenues are indeed likely to be exogenous to processing. The variation of the effects on profits is larger with reductions associated with the choice to process coffee in the order of 11% (panel data FE specifications) to 26% (baseline data OLS specifications). Controlling for time-varying group characteristics does not reduce the magnitude of the coefficient accounting for endogeneity of profits to processing to a large extent. The coefficient of processing coffee turns marginally insignificant when household FE are included for the sample as a whole (Column 12) but is significant and negative for those who process more than 25% of their coffee.

In other words, producers processing a large share of their coffee have considerably lower profits. This is an interesting finding as coffee growers producing a small amount of processed coffee may be doing so opportunistically to make use of the rest of the fresh coffee due to various reasons including poor quality. We provide additional evidence for this argument in Section 6.2.

After establishing that participation in processed coffee markets reduces coffee earnings, we turn to assessing how variation in the extent of processing affects revenues and profits per kilogram. Table 5 summarizes the baseline and panel data estimation results. Baseline data OLS estimations show that a one percentage point increase in the share of cherries produced into parchment is associated with a 0.1% decrease in revenues per kilogram of coffee harvested (Column 1–3). The magnitude is twice as large in panel data specifications (Column 4–6). The effects on profits per kilogram are, again, higher than on revenues per kilogram—a result that supports the discussion in Section 2 and 3 that costs associated with processed coffee production are assumed to be positive. Results show that one percentage point increase in the share of coffee processed reduces coffee profits by 0.3–0.4% (Column 7–9). Panel data models lead to similar results in terms of direction and significance, but accounting for time-variant group and household heterogeneity reduces the coefficient to 0.2% (Column 10–12).

Overall, all estimates from these two approaches (binary indicator for processing and continuous share of processed coffee as a portion of harvested coffee) indicate strongly negative effects of processing on coffee profits and on revenues per kilogram of coffee harvested. At lower shares of processing, this represents a small portion of profits. For farmers who process 100% of the harvest into parchment, on the other hand, the effect is substantial, supporting the value degrading hypothesis.

Given the large seasonal fluctuations in coffee prices, one might wonder whether our findings can be generalized to other years or the years we collected data are representative of the average year. Figure A1 in the appendix presents annual average coffee prices based on data obtained from the International Coffee Organization (ICO). Accordingly, the years of 2017 and 2018 do not stand out and are relatively similar to the 30-year average. We thus conclude that our findings do not stem from exceptional circumstances.

6.2 | Drivers of post-harvest processing

In this section we present results from the estimation of the decision to participate in the parchment market (binary) and also of the extent to which households engage with parchment, measured by

TABLE 4 Revenues and profits per kilogram explained by the decision to process coffee (0/1).

Explanatory variables	Revenues per kg (log)						Profits per kg (log)					
	Baseline data			Panel data			Baseline data			Panel data		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Process coffee (0/1)	−0.102*** (0.007)	−0.120*** (0.007)	−0.114*** (0.009)	−0.126*** (0.006)	−0.121*** (0.006)	−0.113*** (0.008)	−0.235*** (0.0227)	−0.253*** (0.0230)	−0.256*** (0.0230)	−0.111*** (0.043)	−0.112** (0.051)	−0.095 (0.075)
Baseline HH and farm controls		Y	Y					Y	Y			
Group FE			Y						Y			
Time-variant HH and farm controls				Y	Y	Y				Y	Y	Y
Year 2019 indicator				Y	Y	Y				Y	Y	Y
Group-year FE					Y						Y	
Household FE						Y						Y
Constant	7.101*** (0.00671)	6.290*** (0.218)	6.703*** (0.288)	6.195*** (0.0154)	6.359*** (0.0229)	7.078*** (0.0211)	6.912*** (0.0146)	6.200*** (0.600)	6.429*** (1.032)	5.156*** (0.101)	6.002*** (0.122)	6.505*** (0.187)
Observations	1594	1594	1594	3118	3118	3118	1594	1594	1594	3111	3111	3111
R-squared	0.130	0.179	0.269	0.195	0.278	0.122	0.085	0.120	0.201	0.038	0.115	0.051

Note: HH and farm controls include coffee harvest in kg, experience with coffee farming in years, altitude and altitude squared, pest and disease pressure, hired labor for harvesting coffee, distance to buying centers in km, distance to nearest tarmac road in km, household size, sex and education of the household head, and number of assets and crop sales per capita along with knowledge about coffee quality and processing costs, cognitive ability, and time and risk preferences. The difference in the number of observations between revenues and profits estimations stems from negative profits (dropped due to log-transformation). Standard errors clustered at the farmer group level are reported in parentheses.
***$p < 0.01$,**$p < 0.05$,

TABLE 5 Revenues and profits per kilogram explained by the extent of post-harvest processing (%).

Explanatory variables	Revenues per kg (log)						Profits per kg (log)					
	Baseline data			Panel data			Baseline data			Panel data		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Share of coffee processed (%)	−0.001*** (0.000)	−0.002*** (0.000)	−0.002*** (0.000)	−0.002*** (0.000)	−0.002*** (0.000)	−0.002*** (0.000)	−0.003*** (0.000)	−0.003*** (0.000)	−0.004*** (0.000)	−0.002*** (0.001)	−0.002*** (0.001)	−0.002** (0.001)
Baseline HH and farm controls		Y	Y					Y	Y			
Group FE			Y						Y			
Time-variant HH and farm controls				Y	Y	Y				Y	Y	Y
Year 2019 indicator				Y	Y	Y				Y	Y	Y
Group-year FE					Y						Y	
Household FE						Y						Y
Constant	7.104*** (0.00644)	6.245*** (0.202)	6.628*** (0.269)	6.138*** (0.0149)	6.299*** (0.0223)	7.086*** (0.0209)	6.914*** (0.0142)	6.128*** (0.577)	6.276*** (0.988)	4.991*** (1.580)	5.880*** (1.522)	6.523*** (0.154)
Observations	1594	1594	1594	3118	3118	3118	1587	1587	1587	3111	3111	3111
R-squared	0.175	0.227	0.308	0.227	0.305	0.145	0.105	0.141	0.219	0.040	0.116	0.052

Note: HH and farm controls include coffee harvest in kg, experience with coffee farming in years, altitude and altitude squared, pest and disease pressure, hired labor for harvesting coffee, distance to buying centers in km, distance to nearest tarmac road in km, household size, sex and education of the household head, and number of assets and crop sales per capita along with knowledge about coffee quality and processing costs, cognitive ability, and time and risk preferences. The difference in the number of observations between revenues and profits estimations stems from negative profits (dropped due to log-transformation). Standard errors clustered at the farmer group level are reported in parentheses.

***$p < 0.01$,**$p < 0.05$,

the share of fresh coffee processed into parchment (continuous), conditional on participation in the parchment market (Table 6).

Results suggest a negative relationship between coffee quality and the probability of processing coffee into parchment. Coffee quality is likely to be associated with the production of parchment given the common requirement that coffee cherries presented for sale must be above a minimum quality. Altitude is considered a key factor that affects coffee quality to a large extent (Decazy et al. 2003). Results presented in Table 6 show that both altitude and altitude squared are significantly correlated with the likelihood of processing coffee (Column 1) and share of coffee processed (Column 3–4).

Additionally, households who hire picking labor are more likely to process coffee (Column 1 and 2). This latter factor may indicate additional challenges, where it is difficult for farmers to contract for quality-focused harvesting by laborers—an aspect raised by farmers in farmer-field workshops and discussions. Hired pickers are paid per basket of cherries they fill, generating an incentive for them to pick quickly and unselectively reducing the quality of cherries harvested (and monitoring each picker during harvest is costly). These findings indicate that quality requirements in the fresh coffee market may be constraining fresh cherry sales and leading to higher levels of processed coffee production.

Results regarding coffee knowledge show that coffee quality knowledge is positively associated with the probability of engaging with parchment (Column 1 and 2). Scoring one point higher on the coffee quality knowledge test is associated with a 1.4 percentage points increase in the likelihood of engaging with parchment production. On the other hand, knowledge about coffee quality is decreasing in the share of cherries taken up by parchment. Although it may seem counterintuitive at first glance, this finding indicates that farmers who have higher levels of coffee quality sell both fresh cherries and processed parchment, but are able to direct more of their harvest to the coffee cherry market compared to those parchment producers with lower coffee quality knowledge. One plausible explanation is that growers who have a greater degree of knowledge about coffee quality can identify and home process the cherries that are likely to fall below the quality threshold in the fresh coffee cherry market (and cannot be marketed).

Additionally, given that only about half of the producers know roughly how many kilograms of coffee cherries need to be processed to produce a kilogram of parchment coffee, we suggest that there may be informational barriers about the value of processed coffee production and thus about the effective price differentials between fresh cherries and parchment coffee, leading to a higher likelihood of participation in parchment markets. Results show that knowledge about effective cost of parchment is negatively associated with processing coffee. In particular, farmers who know how many kilograms of cherries need to be processed to produce one kilogram of parchment coffee are 5–7 percentage points less likely to process coffee. This result is highly significant.

Cognitive ability, a factor often associated with socio-economic success, may ease such information constraints and thus be associated with processing decisions. A negative and significant relationship between cognitive ability and the share of cherries taken up by parchment is found for Models (3) and (4). It appears that farmers with higher cognitive ability tend to engage in processing to a lesser extent conditional on processing. Additionally, forward-looking time preferences are also associated with lower levels of coffee processing.

One could imagine that those who have higher cognitive ability are also knowledgeable about coffee quality and are able to better understand the characteristics of cherry and parchment markets. Hence, it may well be the case that they produce relatively a smaller amount of parchment and possibly using lower quality cherries that might fail to be marketed in the cherry market. In fact, farmers who report to produce parchment using lower quality cherries also have significantly higher knowledge scores and cognitive ability scores than the rest of the producers (Table A4 in Appendix S1). This small group of growers, who process only lower quality cherries, also have significantly higher coffee profits than the rest of the parchment producers (p-value = 0.002) but still lower than the farmers who only sell fresh cherries (p-value = 0.000). As mentioned in the previous section, those

TABLE 6 Determinants of post-harvest processing.

	Process coffee (0/1)		Share of processed coffee (%)	
	Marginal effects		Coefficients	
Explanatory variables	**(1)**	**(2)**	**(3)**	**(4)**
Coffee quality knowledge score (0–10)	0.014** (0.006)	0.014** (0.006)	−1.346** (0.528)	−0.515 (0.547)
Parchment knowledge (0/1)	−0.068*** (0.022)	−0.049** (0.022)	0.473 (1.912)	2.472 (1.933)
Cognitive ability score (0–10)	−0.008 (0.005)	−0.006 (0.005)	−1.305*** (0.454)	−1.450*** (0.477)
Risk averse (0–8)	−0.012 (0.012)	−0.020 (0.012)	−2.495** (1.038)	−1.381 (1.068)
Forward looking (0–8)	−0.000 (0.008)	0.005 (0.008)	−1.393** (0.695)	−1.229* (0.702)
Distance to buying center in km	0.001 (0.001)	0.000 (0.002)	−0.044 (0.132)	−0.001 (0.164)
Distance to tarmac road in km	−0.012*** (0.004)	−0.005 (0.004)	−0.166 (0.353)	0.212 (0.391)
Number extension meetings attended	0.019*** (0.006)	0.019*** (0.006)	−0.725* (0.413)	−0.577 (0.438)
Harvest in tons	0.195*** (0.013)	0.197*** (0.014)	1.674*** (0.589)	1.148* (0.606)
Altitude (in 1000 meters)	4.112*** (0.753)	1.257 (1.140)	165.565** (69.688)	191.291* (106.186)
Altitude squared	−1.212*** (0.215)	−0.387 (0.324)	−51.668*** (19.943)	−58.107* (29.948)
Pest and disease pressure (0–7)	0.000 (0.008)	−0.008 (0.009)	0.603 (0.729)	−0.364 (0.769)
Hire labor for harvesting (0/1)	0.052** (0.023)	0.055** (0.023)	−0.636 (2.040)	0.873 (2.104)
Experience with coffee farming in years	0.003*** (0.001)	0.002*** (0.001)	−0.090 (0.070)	−0.099 (0.073)
Female household head (0/1)	0.043 (0.034)	0.013 (0.033)	−3.765 (2.874)	−5.745* (2.936)
HH head education in years	−0.000 (0.002)	−0.002 (0.002)	−0.053 (0.214)	−0.233 (0.218)
HH size	0.007 (0.005)	0.003 (0.005)	−1.687*** (0.428)	−1.553*** (0.438)
Number of HH assets per capita	−0.042 (0.033)	−0.052 (0.033)	0.897 (2.793)	−0.221 (2.808)
Other crop sales per capita	0.019 (0.037)	0.008 (0.038)	2.546 (3.382)	2.769 (3.465)
Group FE		Y		Y
Observations	1594	1594	647	647
R-squared			0.109	0.310

Note: Baseline data. Marginal effects from Probit estimations. The analysis in the last two columns is based on a subset of producers who engage in processing. Standard errors are reported in parentheses.
***$p < 0.01$,**$p < 0.05$,*$p < 0.1$.

coffee growers may be opportunistically processing a small share of their coffee that is of low quality (which otherwise cannot be marketed in the fresh coffee market), and this can be considered additional evidence for the market for lemons.

Distance to buying centers potentially acts as a constraint to farmers selling harvested cherries given the need to market these in a short time frame after harvest. Results show, however, that distance to buying centers is not significantly associated with participating in processed coffee markets or with the share of coffee processed. Anecdotal evidence and focus group discussions suggest that market access is typically not a problem for most farmers as there are many buying centers across the district. Distance to nearest tarmac road is negatively associated with the decision to process coffee in the first specification but not in the second (when farmer group fixed effects are included).

Last, quantity of coffee harvested significantly predicts parchment production. Households with higher quantities of coffee harvest are more likely to process coffee. Among others, this might stem from market capacity constraints. Qualitative evidence from farmer discussions indicates that in the peak season the cherry market may saturate due to buying agent cash and/or processing constraints,

and the largest exporter may stop buying cherries in the late afternoon due to a lack of capacity of processing fresh coffee. This would give growers no option but to home-process harvested cherries leading to higher levels of parchment sales. Although such instances do not happen very often (only a few times during the whole season), cannot be predicted, and thus usually come as a surprise, it might nonetheless tilt the scale toward processed coffee for large producers.

7 | CONCLUSION

This study focuses on the analysis of one key question: Can upgrading through post-harvest processing undertaken by smallholder coffee growers generate negative income effects through value degrading? The rationale for this question arises from asymmetries in information regarding quality attributes of many north–south type commodities, such as coffee, when those products are partly processed. Partial processing often involves processes that make it difficult for buyers to assess the harvest attributes of the primary products (e.g. ripeness, disease/pest impacts). The result is that there is potential for a market for lemons to arise out of incentives for producers undertaking partial processing to pass off low-quality produce as high quality and out of the inability of buyers to effectively assess quality. One caveat is that our results are based on self-reported sales data, which are often associated with recall biases. Producers in our sample are smallholders who do not consistently keep sales records.

A sample of over 1500 coffee farmers located in the Mount Elgon region of Uganda was used to consider this question. Analysis using fixed effects methods indicates that partial processing of fresh coffee cherries into parchment coffee involves a substantial reduction in both coffee revenues and profits. These results, consistent across various specifications, indicate that upgrading through post-harvest processing by smallholder coffee growers is unlikely to generate income improvements. Considering the drivers of processed coffee production among sample farmers, a number of findings indicate potential rationalization of processing coffee, despite its lower profit and revenue potential. Post-harvest processing appears more likely to be associated with market access constraints, market information limits, and other psychosocial constraints (e.g. cognitive ability and time preferences).

The results of this study suggest that 'upgrading' interventions should be focused on improving supply chain efficiency, information transmission, and potentially market structure, rather than on producers adopting on-farm processing activities. Although we imagine that these results are likely to hold in similar cases where processing destroys relevant quality signals when there may be a premium for quality, we are unable to conclude that results would hold in other settings given that practices and regulations differ largely across countries. Our findings are based on data collected from coffee growers in eastern Uganda in the years of 2018 and 2019, and future research could shed light into the extent to which our results hold in other settings and years. Future research could also test the effectiveness of potential contracts and quality-signaling instruments. One key intervention may be to seek to improve contracting arrangements between traders/processors and farmers to provide for quality premium gradients in pricing structures for freshly harvested produce.

ACKNOWLEDGMENTS

The authors would like to thank Marc Bellemare, Jeffrey Bloem, Rocco Macchiavello, Matin Qaim, Bernhard Brümmer, Makaiko Khonje, Raphael Brade, and Viviana Uruena for their constructive feedback on earlier versions of this article. The authors are grateful to Randy Stringer, Adam Marley, Karl Hughes, Judith Oduol, Prossy Isubikalu, Daniel Oryem, Filder Aryemo, Jacob Ocen, Julius Njoke, and the field teams who made this research possible in different ways. This research was conducted as part of Cansın Arslan's doctoral research under the supervision of Meike Wollni at the University of Göttingen, Germany. This research was part of Research Training Group 'GlobalFood' agenda and of the World Agroforestry Centre (ICRAF) project Value Chain Innovation Platforms

for Food Security in Eastern Africa (VIP4FS). Financial support to this research from the German Research Foundation (DFG) through grant RTG1666 and the Australian Centre for International Agricultural Research (ACIAR) is gratefully acknowledged.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Arslan, Cansın, Daniel Gregg, and Meike Wollni. 2024. "Paying More to Make Less: Value Degrading in the Coffee Value Chain in Eastern Uganda." *American Journal of Agricultural Economics* 106(1): 96–117. https://doi.org/10.1111/ajae.12389