Received: 5 February 2021 | Revised: 26 August 2021 | Accepted: 22 December 2021

DOI: 10.1002/agr.21730

RESEARCH ARTICLE

Agribusiness WILEY

# Prices, specialty varieties, and postharvest practices: Insights from cacao value chains in Ecuador

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## Abstract

Efforts to improve cacao value chains often assume that production of fine and flavor varieties will raise smallholder incomes. Undertaking postharvest practices of fermentation and drying is another exercise assumed to increase value-added capture by smallholder producers. This study employs household data from 340 cacao farms in 15 villages in coastal Ecuador during 2018 to empirically assess these assumptions. Contrary to the common belief of the international development community, we find that the production of fine and flavor cacao varieties has no association with the price received by small-scale producers. This is mainly due to (i) low productivity and (ii) nonexistent price premiums. Findings also suggest that the use of postharvest practices of fermentation and drying may lead to substantial price responses irrespective of the type of variety grown. The results presented here have implications for program interventions aimed at increasing farmer revenue. Programs promoting the use of fine and flavor varieties alone might be misguided and can be improved by training in modern processing techniques, regardless of the variety produced. [EconLit Citations: O12, Q01, Q12, Q13].

**Abbreviations:** ATE, average treatment effect; BASIC, Bureau for the Appraisal of Social Impacts; CCN-51, Colección Castro Naranjal 51; FAO, The Food and Agriculture Organization of the United Nations; FFCRP, Fine and Flavor Cacao Reactivation Program; HH, household head; ICCO, International Cacao Organization; LATE, local average treatment effects; MAGAP, Ministry of Agriculture of Ecuador; USD, US dollar.

  

**KEYWORDS**
cacao, fine and flavor cacao, postharvest practices, premium cacao, price premiums, specialty cacao, value chains

## 1 | INTRODUCTION

Manufacture of gourmet chocolate requires use of fine and flavor cacao varieties as inputs, as these cacao varieties provide distinctive tastes and colors required for a high-quality chocolate bar. Markets for these varieties have received substantial attention over the last decade (Daniels et al., 2012; Gockowski et al., 2011), as global demand for high-quality chocolate is on the rise. Given a gourmet chocolate bar can be pricey—reaching hundreds of dollars— it is commonly believed that fine and flavor cacao varieties receive significant price premia in international markets, and, producers enjoy better rents when compared to those producing ordinary or bulk varieties (Ricketts et al., 2014). Cacao producers, whether they grow ordinary or fine and flavor varieties, commonly undertake postharvest practices as a means of capturing more value-added. Nonetheless, the varied application of postharvest processing causes heterogeneity in prices received and hinders the objective assessment of prices received for certain varieties.

In this study, we explore the contributions of the variety grown and use of Postharvest practices to differences in prices received by smallholder cacao farmers. We use household survey data including observations on farmers' behavior and prices received from a highly representative cacao region in Ecuador (Barrera et al., 2018). These data allow the study of determinants of prices received by farmers and the degree of postharvest processing.

As it is well-known, distortions in commodity markets can prevent producers of raw materials from reaping the benefits of increased quality (Calo & Wise, 2005; Ronchi, 2006). Explanations for this lack of price transmission vary depending on the country and crop context and include poor transportation infrastructure, high transportation costs (Negi et al., 2018), cooperatives not distributing the benefits directly to members (Kumar et al., 2018), and market power for buyers (Ola & Menapace, 2020). The transmission of quality-related price premia to producers is the main focus of this paper, as it is not clear if smallholder farmers are enjoying benefits for producing fine and flavor cacao varieties. This is of economic interest for a number of reasons.

First, the international development community considers the market for fine and flavor cacao, as an integrated development strategy for boosting the income of cacao producers (Abbott et al., 2018). Ordinary or bulk cacao production is not widely considered to be highly profitable for smallholder farmers, and the private sector conducts relatively little research and development for this crop (Naseem et al., 2010). Cacao producers in West Africa, where most of the world's bulk cacao is produced, tend to be very poor. In the Ivory Coast—the world's largest producer of bulk cacao—only 7% of cacao farmers currently earn a living income[1] (Fair Trade International, 2018). Their participation in the bulk market has not provided adequate social protection (Jäckering et al., 2021) or broad-based benefits. Higher-valued varieties might be a path toward higher earnings for many producers.

Second, fine and flavor cacao price expectations might be based on overstated premiums that only accrue to a small share of the market. Some premium cacao beans have been reported to command up to $10,000 per metric ton, but the high-end share of the market is said to be less than 12,000 tons annually, less than 0.25% of the world market (Confectionery, 2016).

Third, various studies have assessed quality-related price premiums—including Fair Trade, Organic, and other sustainability certifications and standards—and their impact on smallholders in developing countries and found mixed results (Meemken et al., 2019; Sellare et al., 2020). Even though some have found positive impacts, there is

[1]Living Income is the net annual income required for a household in a particular place to afford a decent standard of living for all members of that household (The Living Income Community of Practice, 2021).

growing evidence showing that transmission of price premiums to producers is marginal or nonexistent (Cepeda et al., 2013; de Janvry et al., 2015; Melo & Hollander, 2013; Minten et al., 2018; Nelson & Martin, 2013; van Rijsbergen et al., 2016; Waarts et al., 2016). To the best knowledge of the authors, previous studies on cacao price transmission and their impact on farmers have not analyzed the case of fine and flavor varieties, nor the role of postharvest processing.

We contribute to the body of literature on crop varieties and postharvest practices in developing countries' value chains in two important ways. First, we employ econometric techniques to test the relationship between variety produced, postharvest practices, and producers' prices. Most studies of postharvest practices and food value chains in developing countries to date have been highly descriptive in nature (e.g., Gómez et al., 2011; Maertens et al., 2012; Reardon et al., 2009; Reardon, 2015; Swinnen & Maertens, 2007; Zilberman et al., 2017). For this, we apply various empirical strategies to explore the robustness of our results: (i) we use the classic approach of controlling for relevant confounding covariates; (ii) we use an instrumental variable (IV) approach to address potential endogeneity concerns; and (iii) we estimate bias-adjusted effects and causal bounds of our core findings to test for the potential impact of omitted variable bias on our results (Altonji et al., 2005; Oster, 2017).

Second, given the quality of the product obtained after the application of postharvest practices is inherently endogenous to a variety of farmer and farm characteristics—including access to different technologies and training/knowledge—we also explore heterogeneity in the relationship between producers' price and postharvest practices.

With various policy implications, this study is the first empirical analysis of fine and flavor cacao prices received by farmers. Overall, our results suggest that, contrary to the common belief of the international development community, production of fine and flavor cacao varieties might not necessarily lead to higher prices for small-scale producers. Findings suggest that recommending cacao farmers to perform postharvest practices may lead to substantial price responses irrespective of the variety grown. We also find evidence that suggests that the strength of the relationship between cacao producers' price and postharvest practices may partly depend on the total amount of cacao produced by a farmer.

The remainder of this article proceeds as follows. Section 2 provides background on cacao varieties, postharvest practices, and price premiums in Ecuador. Section 3 presents the theoretical framework. Section 4 describes the data and summary statistics. Section 5 presents the empirical framework, including the strategy used to assess the role of varieties and postharvest practices on producers' prices. Section 6 presents and discusses the empirical results as well as an exploration of heterogeneity in the relationship between cacao producers' prices and postharvest practices. In section 7, we conclude and discuss policy recommendations for cacao programs as well as directions for future research.

## 2 | BACKGROUND

### 2.1 | Differentiation in cacao varieties

Two cacao bean categories are found in world markets: (i) "fine and flavor" cacao beans, also known as specialty cacao and (ii) "bulk" or ordinary cacao beans. Fine and flavor cacao beans are produced from *Criollo* or *Trinitario* cacao trees varieties. Bulk (or ordinary) cacao beans come from *Forastero* trees. Exceptions to this generalization are (1) *Nacional* trees from Ecuador (considered to be *Forastero* type trees) that are classified as producing fine and flavor cacao beans, and (2) *Trinitario* type trees from Cameroon, that are classified as producing bulk cocoa beans (International Cacao Organization [ICCO], 2019a).

In international markets, the difference between fine and ordinary beans is considered to reside in the flavor rather than in other quality factors, such as genetic origin, morphological characteristics, chemical characteristics, or physical attributes (Amores et al., 2007). This makes the assessment of the quality of fine and flavor cacao to be subjective and complicates efforts to improve the marketing position of fine and flavor producers. An objective means of measuring whether beans have fine characteristics has yet to be formulated.

Ecuador is the world's largest exporter of fine and flavor cacao, accounting for around two-thirds of global production. The Ecuadorean fine variety is called “Nacional” or “Arriba” and is mostly recognized in international markets for its use in the production of gourmet chocolate (Cadby et al., 2021). Nacional trees are mostly cultivated by smallholder farmers (typically with less than 5 ha) and account for 80% of the total cacao area planted in the country. This variety needs shade for proper growth and is normally grown using agroforestry systems which decrease the planting densities (Abbott et al., 2018). Ecuador also produces a bulk or ordinary variety developed during the 1960s called CCN-51 (Colección Castro Naranjo). CCN-51 is a high-yielding hybrid[2] that accounts for 20% of the total cacao area planted in the country (Vicepresidencia del Ecuador, 2015). It is more resistant to cacao diseases, but with lower organoleptic quality (US Department of Agriculture, Foreign Agricultural Service, 2015). It is grown by smallholders and also by much larger farms as a monocrop with little shade and relatively high planting densities (Abbott et al., 2018).

These differences cause plantation management to differ among Nacional and CCN-51 cacao varieties. Nacional plantations tend to be far older than CCN-51 and are less intensively managed. Few Nacional farmers use fertilizers, pesticides, or irrigation, and trees are rarely pruned. Nacional trees are much taller (as much as 10 meters in height) and broader than CCN-51 (Alwang, 2019). Differences in age and agronomic practices cause many Nacional plantations to produce more heterogeneous bean sizes, and more variability in other attributes.

Despite its inferior flavor and being considered as ordinary cacao, CCN-51 is an attractive alternative to increase producer incomes due to its high productivity. According to some authors, it yields four times as much per hectare as the Nacional variety (Abbott et al., 2018; Nieburg, 2018). However, studies have shown that after controlling for planting densities, yield differences only occur under nonirrigated systems. When better agronomic management practices are used, including irrigation and pest and disease control, Amores et al. (2011) found no statistical yield differences between Nacional-type clones and the CCN-51 variety.

The combination of higher yields, partly due to lower disease susceptibility and more homogeneous beans appears to give an economic advantage to the production of CCN-51 over Nacional, at least in markets that are more focused on physical rather than organoleptic characteristics. This resonates with large-scale chocolate manufacturers who dominate purchases in international markets, as they are less concerned about flavor than are gourmet chocolate producers. Lack of interest by industrial chocolate producers in fine cacao is explained by the processing innovations allowing companies to preserve the taste of chocolate products despite the lower quality of the cacao beans (ICCO, 2019b). For large manufacturers, the Ecuadorian CCN-51 can compete with bulk beans from other countries.

## 2.2 | Postharvest practices

Fermentation and drying are among the most common postharvest practices applied to cacao. Carefully controlled fermentation and drying protocols are essential to obtain the aroma and flavor notes of the cacao beans. These postharvest practices represent a means of increased capture of value-added and are commonly performed by farmers in most cacao-producing countries such as Ivory Coast, Ecuador, Dominican Republic, Peru, and so forth (Hamrick & Fernandez-Stark, 2018; Meemken et al., 2019; Nelson & Martin, 2013).

Ecuadorean farmers also sell their cacao beans without them being dried or fermented. When farmers sell their beans in this condition, normally the cooperatives, collection centers, or intermediaries do the drying and fermentation. It is uncommon for farmers to perform only fermentation or only drying; they either do both practices or

[2]Population structure analysis shows the genetic ancestry of CCN-51 to be primarily of Iquitos, Criollo, and Amelonado (Forastero) genetic type (Boza et al., 2014).

**TABLE 1** Cacao production and prices during 2015

| Cacao type | Annual production (tons) | Market price (USD/ton) |
|---|---|---|
| Ultrapremium fine | 12,000 | 5,000 – 10,000+ |
| Fine | 230,000 | 3,700 – 5,000 |
| Bulk certified | 600,000 | 3,100 – 3,700 |
| Bulk | 3,200,000 | 3,000 – 3,500 |

*Note*: Data for annual production and market price from Martin (2017).

neither. In some cases, intermediaries or manufacturers especially concerned with quality might buy beans before fermentation to achieve desired characteristics with custom fermentation and drying.

Good application of postharvest practices can improve the quality of the cacao bean, regardless of variety (Camu et al., 2008; Jespersen et al., 2005; Schwan & Wheals, 2004). Likewise, poor control of postharvest processing can ruin the flavor of even the best beans (Daniels et al., 2012). In Ecuador, fermentation and drying have attracted considerable interest, especially from CCN-51 producers as they can improve its presumed poorer flavor and aroma (Díaz et al., 2012; Eskes et al., 2012; Hue et al., 2016; Jentzsch et al., 2016).

## 2.3 | Prices and premiums

Bulk cacao beans are traded at the London (The New York Stock Exchange–The London International Financial Futures and Options Exchange—British Pound Sterling [NYSE LIFFE-GBP]) and New York (U.S. Dollar Index [ICE-USD]) futures markets. Futures contracts are the benchmark for setting bulk cacao prices worldwide (World Cacao Foundation, 2014). Like other agricultural commodities, cacao price variations are determined by demand and supply forces. The international demand for cacao has experienced sustained growth during the last decade due to population and income growth mainly driven by Asia and other emerging markets (Tothmihaly & Ingram, 2019). Most of the bulk cacao supply comes from West Africa and global price fluctuations are driven by factors affecting this region, including political instability and conflict, weather, crop diseases, labor shocks, logistics, and so forth. Political instability and conflict have led to supply shortfalls over multiple years (Karbuz & Jumah, 1995; Woods, 2003). Price volatility has also been influenced by speculation in futures markets.

Higher prices in niche and international markets have been reported for the Ecuadorean fine variety "Nacional" or "Arriba." Companies that buy fine cacao use their own pricing models, including floor prices and premiums based on the quality of the bean—which can be subjective as previously discussed. The lack of industry standards for defining fine cacao makes the availability and verifiability of its pricing data a challenge (Martin, 2017). Some buyers have specific suppliers with contracts for particular types of cacao. Aidenvironment (2018) reported a case study about the different pricing models used by companies buying fine and flavor cacao during 2015. Examples of these pricing models included (i) fixed prices, (ii) New York market price plus a fixed quality premium of 300 USD/ton, and (iii) New York market price plus a minimum quality premium of 500 USD/ton.

Table 1 shows rough estimates for market prices of fine and flavor cacao presented by ICCO during a forum[3] in 2015. To this day, it represents the only officially collected data by the ICCO on fine and flavor cacao prices (Martin, 2017) and is widely used by the international community for discussions about price premiums of fine cacao. According to this data, prices for the fine category have exceeded bulk prices by up to 2000 USD/ton (more than 60% of the base price) and this difference is even larger for ultrapremium fine cacao.

[3]These statistics were cited by the ICCO Executive Director at the Foro Cacao in Nicaragua in November 2015 (Martin, 2017).

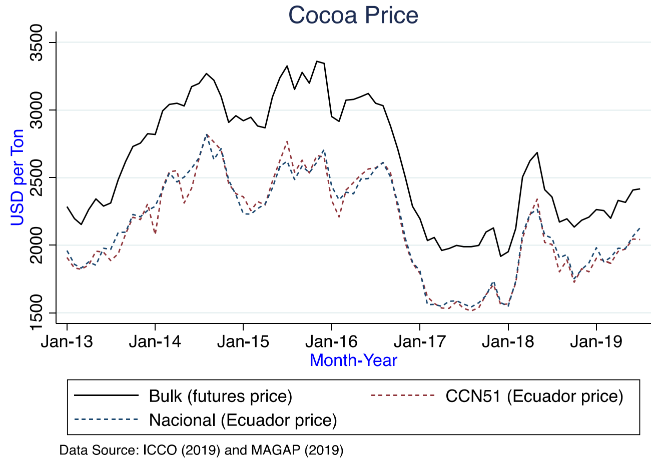


**FIGURE 1** Cacao monthly prices (*Data Source*: ICCO, 2019; MAGAP, 2019)

Bulk cacao price data are available for the London and New York futures markets, and the ICCO publishes monthly averages of these daily prices for bulk cacao futures.[4] Figure 1 displays the ICCO prices for bulk cacao futures and average price for CCN-51 and Nacional varieties in the principal markets of Ecuador obtained from the Ministry of Agriculture (MAGAP). These prices represent cacao beans that have already been fermented and dried. Although local prices for CCN-51 and Nacional cacao varieties are not directly comparable to the ICCO bulk cacao futures prices, Figure 1 shows prices in Ecuador follow the future market trend.

Moreover, given CCN-51 is considered as a bulk type of cacao, the gap between its price and the ICCO price can be interpreted as the profit share of intermediaries and traders in the bulk cacao value chain. Interestingly, according to the data provided by MAGAP, the differences among local prices of CCN-51 and Nacional are very small, and counterintuitive, especially given the widespread perception that Nacional is a better-quality product. Over the last 7 years, average monthly price for Nacional has been about 2141 USD/ton, while for CCN-51 it has been about 2130 USD/ton. This leaves a difference of merely 11 USD/ton (less than 1% of the price) between what is considered fine and flavor and bulk cacao varieties. In some months this difference increased to 210 USD/ton (about 10% of the price), but for some months, CCN-51 received higher prices than Nacional by as much as 145 USD/ton. This evidence suggests fine and flavor cacao price premiums received by Ecuador's producers are not large.

In Ecuador, prices for cacao beans vary by variety and degree of postharvest elaboration. On the basis of monthly price data reported by MAGAP, during the last 7 years the Nacional variety received on average 100 USD/ton more than their CCN-51 counterparts when sold without fermentation and drying. Interestingly, Figure 2 shows this average difference between varieties falls to about 11 USD/ton when sold after fermenting and drying. Occasionally CCN-51 prices have exceeded Nacional prices, particularly when the product is fermented and dried.

This evidence suggests that the impact of postharvest practices on prices received is larger for CCN-51 compared to Nacional. This phenomenon raises two competing hypotheses: (i) CCN-51 producers have access to better training or technologies for drying and fermenting and this affects the quality of the end product or (ii) Ecuador markets are more oriented towards physical characteristics rather than organoleptic attributes. These differences in prices are further explored in the next sections.

[4]This average represents the quotations of the nearest three active futures trading months on ICE Futures Europe (London) and ICE Futures US (New York) at the time of London close (ICCO, 2019).

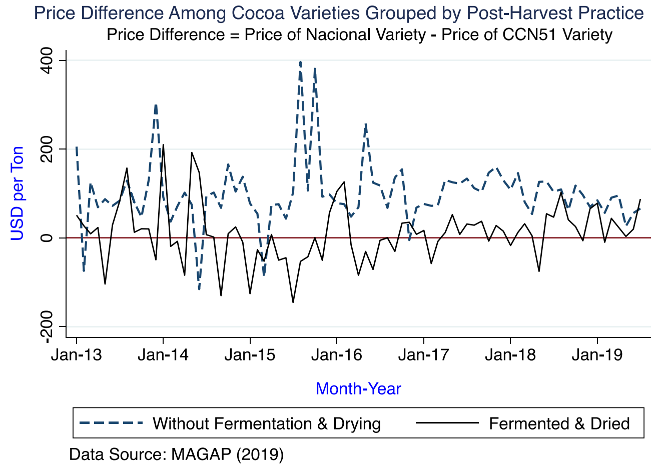


**FIGURE 2** Monthly price difference of cacao varieties (*Data Source*: MAGAP, 2019)

## 3 | THEORETICAL FRAMEWORK

To motivate our subsequent empirical analysis, we use the theoretical model developed by Lancaster (1966) and present a methodology that is analogous to Minten et al. (2018). We consider the cacao beans as a food item $i$ with a set of intrinsic properties or attributes $x_i = \{x_i^0, x_i^1, \ldots, x_i^N\}$, where $x_i^k$ represents the level of attribute $k$ in good $i$. Individuals derive positive utility from these intrinsic properties or attributes such that $U = U(x^0, x^1, \ldots, x^N)$ with $\partial U/\partial x^k \geq 0$, where $U$ is measured in monetary units. When two food products $i$ and $j$, differing only in attribute $k$, are offered in the market, their price difference adjusts accordingly to make consumers indifferent between the two food products such that:

$$U(x_i^0, \ldots, x_i^k, \ldots, x_i^N) - p_i = U(x_j^0, \ldots, \tilde{x}_j^k, \ldots, x_j^N) - p_j, \tag{1}$$

$$p_i - p_j \approx \frac{\partial U}{\partial x^k}(x_i^k - \tilde{x}_j^k). \tag{2}$$

The price differential between the two food products (Equation 2) is then considered as the implicit price of attribute $k$. This theoretical model assumes agricultural producers have identical production possibility frontiers $H(x, l) \leq 0$, where $l$ is the vector of inputs required to produce a vector of attributes[5] $x$. Then, the social planner maximization problem is represented by:

$$\max_{\{x,l\}} U(x^0, x^1, \ldots, x^N) - \sum_{n=1}^{M} p_n l_n \tag{3}$$

subject to $H(x^0, x^1, \ldots, x^N; l_1, l_2, \ldots, l_M) \leq 0$.

At the optimum, it follows that:

$$\frac{dp}{dx^k} = \frac{\partial U}{\partial x^k} = p\frac{\partial H}{\partial x^k}. \tag{4}$$

[5]Positive values of $G$ represent inefficient input/output combinations.

At an efficient equilibrium, the price premium associated with attribute *k* will be equal to the marginal utility of that attribute—expressed in monetary units—and is equal to the marginal cost of producing that attribute (Carlucci et al., 2013). By assuming each attribute has a constant marginal utility and a constant implicit price, a hedonic price regression can be estimated. In this study, we will estimate a hedonic price regression where the cacao price is a function of the attributes of the cacao beans which—as previously discussed—are determined by a particular variety and/or the application of postharvest practices, among many other controls. As stated above, this model assumes an "efficient equilibrium," hence one of its limitations is that it does not take into account other market frictions relevant in the context of the country (e.g., high transactions costs and price discrimination).

## 4 | DATA AND DESCRIPTIVE STATISTICS

Data come from a survey of 386 cacao farmers conducted in 2018 in the province of Manabí—a highly representative cacao region that accounts for 21% of the total cacao area planted in Ecuador (Corporación Financiera Nacional, 2018). The survey included questions on household demographics, farming and postharvest practices, marketing, household borrowing, and sources of nonfarm income (Barrera et al., 2018). Given the differences in attributes between producers of different varieties, summary statistics are divided by variety produced: (i) farmers who produce cacao from Nacional trees, and (ii) farmers who produce cacao from CCN-51 trees.[6]

Table 2 shows producers of Nacional have much older trees and more experience producing cacao compared to those producing CCN-51. Cacao association membership rates indicate that most of the CCN-51 producers market their cacao beans individually, which might be associated with larger production volumes. Typical farm cacao bean production—already adjusted for moisture content—is about 50% higher for CCN-51 compared to Nacional (2.70 vs. 1.83 tons). CCN-51 appears to yield twice as much as Nacional varieties (0.80 vs. 0.44 tons/ha). Nonetheless, CCN-51 plantations are typically cultivated at higher densities and on average have 25% more trees per hectare compared to Nacional plantations.[7] Taking into account planting densities, productivity measured on a yield per tree basis shows CCN-51 trees produce only about 39% more cacao beans than Nacional trees (0.82 vs. 0.59 kg/tree). The difference in planting densities among CCN-51 and Nacional is driven by Nacional trees requiring protective shade for their correct development during the early years. This factor limits the planting density of Nacional varieties.

Table 3 shows crop management practices by variety planted. CCN-51 producers are more likely to prune their trees, use fertilizers, and ferment and dry their cacao beans compared to Nacional producers. Fertilization and pruning are generally viewed as good management practices and, as a result, yields are likely to be higher on CCN-51 plantations.[8] The difference in certification rates relates to the differences in association membership, as some associations[9] promote production of certified organic cacao. Intercropping is also more common among Nacional producers, where the most common trees planted with cocoa being plantain and orange. This is related to Nacional trees requiring some protective shade for their correct development during the early years, hence motivating intercropping practices among producers of this variety. Intercropping also helps farmers with additional sources of income. In contrast, CCN-51—due to not needing shade for its development—is more densely planted, leaving little incentives for intercropping practices.

[6]In our sample, 46 farmers planted both varieties. These were dropped from the analysis as it is not possible to determine if prices received were driven by the Nacional or CCN-51 variety.

[7]Average planting density of Nacional is close to a tree distance of 3 × 4 m (833 trees/ha). Average planting density of CCN-51 is close to a tree distance of 3 × 3 m (1111 trees/ha).

[8]The higher prevalence of pruning CCN-51 may be related to their smaller trees, but the difference (10 percentage points) is relatively small (Alwang, 2019).

[9]Cacao producers' associations in Ecuador are not related to the classic concept of farmers cooperatives pooling resources and farming jointly. Instead, these associations mainly work as facilitators of production training and marketing.

**TABLE 2** Summary statistics: Household and farm characteristics by cacao variety planted

| Variable | Description of variable | Nacional Mean | Nacional SD | CCN-51 Mean | CCN-51 SD | *p* value |
|---|---|---|---|---|---|---|
| Household Characteristics | | | | | | |
| Experience | Years of experience in cacao farming for household head | 29.00 | 16.23 | 18.11 | 15.29 | 0.00 |
| Gender | Gender of the head of household (Male = 1 and Female = 0) | 0.85 | 0.36 | 0.92 | 0.28 | 0.07 |
| Association membership | Household head (HH) is member of a producer's association (Yes = 1 and No = 0) | 0.34 | 0.48 | 0.05 | 0.22 | 0.00 |
| Cacao training | HH has received any cacao training (Yes = 1 and No = 0) | 0.51 | 0.50 | 0.32 | 0.47 | 0.00 |
| Farm Characteristics | | | | | | |
| Farm size | Total size of farm (ha) | 14.40 | 28.60 | 14.53 | 27.03 | 0.97 |
| Cacao trees age | Age of the cacao trees (years) | 29.33 | 19.00 | 6.66 | 4.89 | 0.00 |
| Cacao area | Size of cacao lot (ha) | 3.81 | 5.56 | 3.40 | 4.65 | 0.49 |
| Cacao production[a] | Cacao beans produced (tons) | 1.83 | 3.71 | 2.70 | 3.51 | 0.04 |
| Planting density | Planting density of cacao trees (trees/ha) | 814 | 14.60 | 1020 | 15.17 | 0.00 |
| Production per area | Cacao beans produced per hectare (ton/ha) | 0.44 | 0.13 | 0.80 | 0.15 | 0.00 |
| Production per tree | Cacao beans produced per tree (kg/tree) | 0.59 | 0.02 | 0.82 | 0.02 | 0.00 |
| Observations | | 221 | | 119 | | |

*Note*: The *p* value in the final column refers to the test of equality of outcomes by variety planted.
Abbreviation: CCN-51, Colección Castro Naranjal 51.
[a]Cacao production reported without fermentation and drying was adjusted for moisture content to make it comparable to dried cacao beans.

CCN-51 and Nacional farmers in our sample employ slightly different marketing methods. CCN-51 producers are somewhat more likely to sell their beans at the farmgate and to wholesaler warehouses than Nacional producers. Conversely, selling the beans to associations and/or having a purchase contract is more common for Nacional producers, which is also related to association membership as these often require members to sell their products back to the association. In addition, Nacional producers travel shorter distances to sell their beans and this is associated with having lower transportation costs (about 50% less). Curiously, about equal percentages of Nacional and CCN-51 farmers sell their beans at local markets and exporter warehouses and claim to know the market price before selling their products.[10]

## 4.1 | Producer prices

Respondents from 15 different sublocations across the province of Manabí reported the average price received for their cacao during the survey reference period (June–August of 2018). Average prices received at the different

[10]See Appendix A for complete summary statistics of all the variables in our data set.

**TABLE 3** Summary statistics: Farm management, postharvest, and marketing practices by cacao variety planted

| Variable | Description of variable | Nacional Mean | Nacional SD | CCN-51 Mean | CCN-51 SD | *p* value |
|---|---|---|---|---|---|---|
| On-Farm Management Practices | | | | | | |
| Pruning | Plantation is pruned (Yes = 1 and No = 0) | 0.71 | 0.45 | 0.81 | 0.40 | 0.05 |
| Fertilization | Farmer applies fertilizers (Yes = 1 and No = 0) | 0.19 | 0.39 | 0.45 | 0.50 | 0.00 |
| Any certification | Farmer has any type of certification (Yes = 1 and No = 0) | 0.13 | 0.34 | 0.00 | 0.00 | 0.00 |
| Intercropping | Farmer intercrops cacao trees (Yes = 1 and No = 0) | 0.33 | 0.47 | 0.22 | 0.41 | 0.03 |
| On-Farm Postharvest Practices | | | | | | |
| Fermentation and drying | Farmer ferments and dries cacao (Yes = 1 and No = 0) | 0.65 | 0.03 | 0.80 | 0.04 | 0.00 |
| Marketing practices | | | | | | |
| Farmgate | Farmer sells cacao beans at the farmgate (Yes = 1 and No = 0) | 0.02 | 0.13 | 0.06 | 0.24 | 0.04 |
| Sell to association | Farmer sells cacao beans to an association (Yes = 1 and No = 0) | 0.26 | 0.44 | 0.01 | 0.09 | 0.00 |
| Use of contract | Farmer sells cacao beans under a contract (Yes = 1 and No = 0) | 0.13 | 0.34 | 0.04 | 0.20 | 0.01 |
| Distance to buyer | Distance from farm to buyer (km) | 14.94 | 17.49 | 21.63 | 48.37 | 0.07 |
| Transportation costs | Average transportation costs (USD/ton) | 44.80 | 4.79 | 80.50 | 19.40 | 0.01 |
| Average Income from Cacao Activities (USD/year) | | 615 | | 1188 | | |
| Observations | | 221 | | 119 | | |

*Note*: The *p* value in the final column refers to the test of equality of outcomes by variety planted.
Abbreviation: CCN-51, Colección Castro Naranjal 51.
[a]Cacao production reported without fermentation and drying was adjusted for moisture content to make it comparable to dried cacao beans.

sublocations varied from 1166 to 1562 USD/ton.[11] Figures 3a and 3b illustrate the distribution of prices for each cacao variety and with and without drying and fermenting, respectively. The density of prices for the CCN-51 variety is distinct to the right of that of the Nacional variety. Likewise, the density of prices of fermented and dried beans is to the right of raw beans. In both cases, this indicates significant mean differences at the farmer level.[12]

Table 4 shows the producer's price grouped by variety and postharvest processing. The average price per ton received by farmers for the CCN-51 variety was 87 USD higher than that for Nacional cacao (1485 vs. 1398 USD/ton). Average prices between June and August of 2018 reported by MAGAP were 1943 USD/ton for CCN-51 and 2011 USD/ton for Nacional. ICCO average price for bulk varieties was 2313 USD/ton for that same period. Cacao fermentation and drying add, on average, 144 USD/ton, to the price received. As shown in Table 3, the survey data suggest that more than two-thirds of cacao farmers in Manabí ferment and dry their cacao. The practice of

[11]See Appendix B for details.
[12]The average price per variety was found statistically different when measured with a $t$ test ($t = 4.51$; $\Pr(|T| > |t|) = 0.00$). The average price per application of postharvest practices was also found statistically different when measured with a $t$ test ($t = -7.57$; $\Pr(|T| > |t|) = 0.00$).

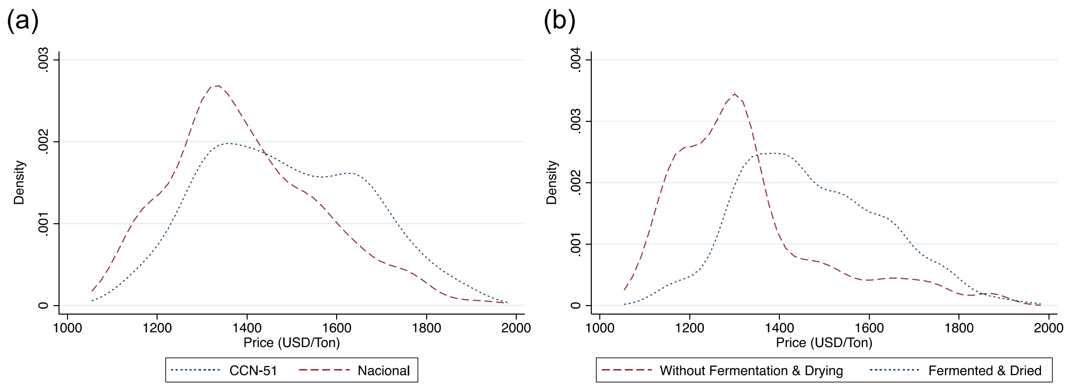


**FIGURE 3** Cacao prices by variety (a) and by application of postharvest practices (b)

**TABLE 4** Mean values of cacao producers' price (June–August 2018) grouped by variety and postharvest practices in USD/ton

| | Postharvest practice | | |
|---|---|---|---|
| **Variety** | **Without fermentation and drying** | **Fermented and dried** | **Pooled** |
| CCN-51—ordinary variety (USD/ton) | 1425 | 1500 | 1485 |
| Nacional—premium variety (USD/ton) | 1297 | 1453 | 1398 |
| Pooled (USD/ton) | 1327 | 1471 | |

Abbreviation: CCN-51, Colección Castro Naranjal 51.

fermentation and drying has on average a premium of 156 USD/ton for Nacional producers compared to only 75 USD/ton for producers of CCN-51.

The average farm gross income per hectare generated by cacao activities is estimated to be about 1188 USD/year for CCN-51 producers and 615 USD/year for Nacional producers. These comparisons of summary statistics can be misleading in light of the many factors influencing cacao prices received. In addition to varieties and postharvest practices, geographic factors, and farm management practices might also affect quality and price received; a multivariate regression framework is required.

## 5 | EMPIRICAL FRAMEWORK

In this section, we present the details for the strategies used to examine the relationship between cacao producer's prices and the use of specific varieties and postharvest practices. Each of these estimation strategies depends on distinct identification assumptions and leads to limited empirical findings.

### 5.1 | Ordinary least square (OLS) and IV regressions

Our baseline estimation is mainly based on Minten et al. (2018) and follows from the theoretical framework discussed above. A simple model, where the cacao beans are a function of their intrinsic properties or characteristics can be represented as:

$$P = \sum_{k=0}^{N} \beta_k X_k + \varepsilon, \tag{5}$$

where $P$ is the price of the food product, $X_k$ represents attribute $k$, $\beta_k$ is the implicit price of attribute $k$, and $\varepsilon$ is a well-behaved error term.

In this study, the attributes of main interest are the type of cacao variety and the practice of fermentation and drying. To assess whether a specific variety and the use of postharvest practices affect the price received, we employ a setup where price outcomes are observed for the two cacao varieties with and without the application of postharvest practices. As discussed above, price premiums depend on the superior quality of the beans, including flavors and aromas. These flavors and aromas have been shown to be closely related to the variety grown and postharvest practices (Díaz et al., 2012). To accurately estimate the effect of the variety and postharvest practices, additional factors influencing the price received were controlled for. The empirical model for the generic cacao price per ton received by a farmer of any variety using any postharvest practice can be written as:

$$P_i = \alpha + \lambda V_i + \eta T_i + \boldsymbol{\beta X}_i + \boldsymbol{\psi W}_i + \boldsymbol{\theta}_l + \varepsilon_i, \tag{6}$$

where $P_i$ is the price per ton received by farmer $i$. $V_i$ is a binary variable equal to one for farmers producing Nacional cacao. $T_i$ is a binary variable equal to one to represent the application of fermentation and drying.

$\boldsymbol{X}_i$ is a vector of observable personal and farm-level characteristics that may influence the received price. These include age, gender, education, years of experience in cacao farming, ownership of a cellphone, age of the cacao trees, and altitude of the farm. $\boldsymbol{W}_i$ is a vector of farm management controls that represent observable management practices that may influence the quality of the cacao beans and the price received. These include whether the farmer is aware of factors affecting quality, whether the farmer has any type of certification, whether the farmer prunes, applies fertilizers, uses irrigation, or controls weeds. Pruning and weed control specifically help against fungus-related diseases that later affect the fermentation of the beans (Mejía et al., 2008).

We also control for whether the farmer has received cacao production training, has access to an extension agent, is part of a producer's association, and whether the farmer intercrops the cacao trees with other crops. Specifically controlling for any type of certification helps to identify the price effect of the Nacional variety, as most producers with organic certification in our sample grow Nacional trees and the observed price might be the result of a specific variety–certification combination.

The study region can be divided into three major production zones, each with different climate features, so $\boldsymbol{\theta}_l$ is a vector of indicator variables controlling for production zones' fixed effects, namely, Coastal Zone, Central Zone, and Hillsides Zone. Controlling for these helps capture the effect of climate on the flavor and aroma of the beans that can influence the price received by producers.[13] $\varepsilon_i$ is an error term with zero mean. Standard errors are clustered by sublocation, as this is the level at which sampling occurred, and because some sublocations from the province of Manabí were not sampled (Abadie et al., 2017).

An alternative specification of Equation (6) was also estimated:

$$P_i = \alpha + \lambda V_i + \eta T_i + \boldsymbol{\beta X}_i + \boldsymbol{\psi W}_i + \boldsymbol{\varphi M}_i + \boldsymbol{\theta}_l + \varepsilon_i. \tag{7}$$

Equation (7) includes additional variables (vector $\boldsymbol{M}_i$) related to marketing practices, including sales channels, use of contracts, whether farmer knows the market price before the sales, distance to buyer, and transportation costs. It also includes cacao production, the number of people hired to work in the cacao farm, and days per week worked on the farm (family plus hired). The variables represented by vector $\boldsymbol{M}_i$ might have an effect on the price received by a farmer but can also be affected by the price received. Due to the possible concerns of endogeneity, we treat this alternative regression as a robustness check and exclude the possibly problematic regressors in Equation (6), our main regression.

[13]These fixed effects also help cleaning the error term of its correlation with the control variables that do not vary within a region.

The variable of interest “cacao variety” $V_i$ might cause endogeneity concerns related to simultaneity. However, it is important to mention that after being planted, cacao trees require at least 4–5 years to produce pods and beans. Thus, a farmer's cacao variety that is harvested and sold at a given year is not correlated to the price observed during that same year. A cacao variety harvested and sold at a given year might be correlated to its price observed 4 or 5 years ago, nonetheless, unobservables may persist for many years.

“Postharvest practices” $T_i$ can also raise endogeneity concerns related to simultaneity. However, it is important to note that price premiums are not simultaneously determined with postharvest practices, as price premiums are only observed after the postharvest practices are performed. Performing good fermentation and drying of the cacao beans is not straightforward for farmers with limited access to technology and training/knowledge of postharvest practices. In our sample, only 25% of the farmers performing postharvest practices claimed to know the factors that affect the quality of the cacao beans. This, combined with the subjective evaluation of flavor and aroma, does not necessarily guarantee better prices for farmers performing postharvest practices on their cacao beans.

As a second method, and to address the potential endogeneity concern related to postharvest practices, we present an IV estimation where we use “access to a canopy” as an instrument for “postharvest practices.” Access to a canopy is highly correlated with the use of Postharvest practices in our study region, especially with drying, as a canopy helps protect the cacao when sun drying is interrupted by unpredictable rains. Sun drying predominates in Ecuador, especially among small-scale producers. In our sample, more than half of farmers performing postharvest practices claimed to have access to a canopy, while this is reported by only 2% of those not fermenting and drying. The variable “access to a canopy” is an appropriate instrument[14] and it is likely to meet exclusion restriction as its influence on the price received by cacao farmers comes only through its effect on postharvest practices.

This IV approach consists of a two-stage procedure. In the first stage, using the below equation, “postharvest practices $T_i$” is predicted by regressing the observations of this variable on the explanatory variables and the instrument $Z_i$:

$$T_i = \alpha + \lambda V_i + \boldsymbol{\beta X}_i + \boldsymbol{\psi W}_i + \boldsymbol{\varphi M}_i + \tau Z_i + \boldsymbol{\theta}_l + \varepsilon_i. \tag{8}$$

In the second stage, the predicted values for postharvest practices $\hat{T}_i$, obtained from the first stage, are used instead of the observed values in the estimation of the empirical model for the generic cacao price.

Conditional on the IV identification and given that we clustered the standard errors, we report the regression-based test of exogeneity to further explore if the potential endogenous regressor $T_i$ is in fact exogenous. In the same fashion, we report the test for weak instruments to explore the relevance of the excluded exogenous variable as a valid instrument.[15] We report the *F* statistic and the *p* value of the *F* statistic for the significance of the instrument coefficient in Table 5. Other endogeneity concerns related to omitted variable bias and unobserved heterogeneity are addressed next.

## 5.2 | Unobservable selection and coefficient stability

As in any empirical application, it is impossible to control for all factors. Thus, unobserved heterogeneity might cause our estimation strategy to suffer from additional endogeneity problems, leading our estimates to not be clearly identified. For example, risk preferences may make farmers more willing to ferment and dry; at the same time, risk preferences may also allow farmers to obtain better prices (Iyer et al., 2020), which might lead to biased

[14]Angrist and Krueger (2001) argue that the ultimate choice of instruments should be based on economic intuition and theory. Moreover, Angrist and Pischke (2008, 2014) further emphasize that the optimal choice of instruments should be based on how likely they are to meet the exclusion restriction.
[15]The correlation of the potentially endogenous variable “postharvest practices” $T_k$ and the instrument “access to a canopy” is 0.4850.

**TABLE 5** Regression results: Estimates of the effect of varieties and postharvest practices on the mean price received by cacao producers

| Variable | Model specification (1) OLS | (2) OLS[a] | (3) IV |
|---|---|---|---|
| Dependent variable: Natural Log of Cacao Price Received by Farmers (USD/ton) | | | |
| Variety (Farmer uses Nacional = 1) | −0.050*** | −0.026** | −0.034*** |
| | (0.013) | (0.010) | (0.012) |
| Postharvest practices (Farmer ferments and dries = 1)[b] | 0.077*** | 0.069*** | 0.148*** |
| | (0.030) | (0.029) | (0.052) |
| Cacao production (ton) | No | 0.012*** | 0.012*** |
| | - | (0.003) | (0.003) |
| Farmer and farm characteristics control variables | Yes | Yes | Yes |
| Farm management control variables | Yes | Yes | Yes |
| Marketing practices control variables | No | Yes | Yes |
| Production zones fixed effects | Yes | Yes | Yes |
| Observations | 340 | 340 | 340 |
| $R^2$ | 0.243 | 0.451 | 0.403 |
| Tests of Exogeneity (Ho: $T_i$ is exogenous) | | | |
| Robust regression *F* statistic (1, 14) (Adjusted for 15 clusters) | - | - | 2.461 |
| *p* value of the *F* statistic | - | - | 0.139 |
| Test of Weak Instrument | | | |
| Robust *F* statistic (1, 14) | - | - | 26.726 |
| *p* value of the *F* statistic | - | - | 0.000 |

*Notes*: Standard errors clustered at the sublocation (town/city) level in parenthesis. Complete regression results with all control variables are shown in Appendix C. First stage regression results of the instrumental variable (IV) estimation are shown in Appendix D.

Abbreviations: IV, instrumental variable; OLS, ordinary least square.

[a]Regression in column (2) includes additional control variables.

[b]Instrumented value.

*Significance at the 10% levels.

**Significance at the 5% levels.

***Significance at the 1% levels.

and inconsistent estimates of our parameter of interest. Like risk preferences, measurement error,[16] and other unobserved factors could create bias in our estimates and result in concerns related to our identification strategy.

To assess the potential influence of omitted variable bias on our results, we examine the robustness of our main coefficients of interest by applying the method developed by Oster (2017).[17] Using the information on the

[16]Classical measurement error leads to attenuated coefficient estimates (Griliches, 1986; Levi, 1973; Theil, 1965). Although measurement error is plausible in this study, this is minimized by the use of data collectors with expertise in cacao production working at INIAP.

[17]This method is based on the assumption that bias from observed covariates is informative about bias from unobserved covariates (Altonji et al., 2005).

movements in the coefficients and the $R^2$ values—when additional controls are added—Oster (2017) assesses unobservable selection bias and coefficient stability by estimating bias-adjusted effects and causal bounds. Formally, an approximation of the bias-adjusted effect $\beta*$ can be estimated as follows:

$$\beta* \approx \tilde{\beta} - \delta[\ddot{\beta} - \tilde{\beta}]\frac{R_{Max} - \tilde{R}}{\tilde{R} - \ddot{R}}. \quad (9)$$

In Equation (9), $\delta$ is the degree of the selection on unobservables relative to selection on observables.[18] $\tilde{\beta}$ and $\tilde{R}$ are the coefficient estimate and $R^2$ values from the regression "with" additional controls, and $\ddot{\beta}$ and $\ddot{R}$ are the coefficient estimate and $R^2$ values from the regression "without" additional controls. $R_{Max}$ represents the hypothetical maximum possible $R^2$ value of the specification.[19] $\delta$ and $R_{Max}$ are unknown parameters and, therefore, assumptions must be made about their values. For $\delta$, we will assume a value[20] of $\delta = 1$; for $R_{Max}$, we will present a suite of results associated with different values recommended in the literature.[21]

## 6 | RESULTS

Overall, the estimation of Equations (6) and (7) provide a preliminary robustness check on the empirical results presented in Table 4, but it does not allow us to make a causal statement about the average treatment effect (ATE) of different variety choices and postharvest practices on prices. Furthermore, our IV estimation only addresses the endogeneity of the use of postharvest practices, but it does not address this concern for cacao variety choice. Also, it only recovers local average treatment effects (LATE) rather than ATE (Imbens & Angrist, 1994). Results from these estimations should be interpreted with caution.

### 6.1 | OLS and IV estimation results

OLS results from the estimation of Equations (6) and (7) and the IV approach are presented in Table 5. For these estimations, we used the natural log of the dependent variable (price), and hence the estimated coefficients of the continuous variables can be interpreted as the percentage change in the price received by cacao farmers caused by a one-unit change in the independent variable. In what follows, we mostly focus on our OLS results (i.e., columns 1 and 2 of Table 5) and on the estimated coefficients for variety and postharvest practices.

In line with the data shown in Figure 1, where CCN-51 commanded higher prices in some years, results in Table 5 show the sign on the coefficient estimate for variety is negative and statistically significant across all three model specifications. This signals that the Nacional variety is associated with lower prices for producers after we control for factors such as postharvest practices and zone of production. The estimated decrease in price associated with using the Nacional variety ranges from 2.6% to 5% depending on model specification (1) or (2). These results show that despite the common belief that Nacional cacao commands higher prices than CCN-51, producers are not rewarded by the market from its use in our study region.

The sign on the coefficient estimate for postharvest practices is positive and statistically significant across all three model specifications. Controlling for the type of variety grown, producers who ferment and dry their cacao

[18]A value of $\delta = 2$, for example, suggests that unobservables are twice as important as the observables.
[19]$R_{Max}$ is bounded between the $R^2$ in the regression "with" additional controls $\tilde{R}$ and 1.
[20]In empirical settings, a value of $\delta = 1$ is normally considered as researchers typically focus their data collection efforts (or their choice of regression controls) on the controls they believe ex-ante are the most important (Angrist & Pischke 2010; Oster, 2017).
[21]Oster (2017) sets $R_{Max} = 1.3 \times \tilde{R}$, being this the least conservative approach. The most conservative approach sets $R_{Max} = 1$ and assumes measurement error does not exist. Bellows and Miguel (2009) set $R_{Max} = \tilde{R} + (\tilde{R} - \ddot{R})$. Gonzalez and Miguel (2015) set $R_{Max} = 2.2 \times \tilde{R}$.

beans receive, on average, higher prices than those who do not (about 6.9%–14.8% higher). In summary, these findings suggest that producers of the Nacional variety do not receive price premiums. They also hint that by fermenting and drying, farmers are able to add value and capture extra benefits from their production. Hence, by performing both practices farmers can place their cacao beans in a better position in the value chain. On the basis of our sample, 30% of farmers do not ferment and dry their cacao. This implies that only about two-thirds capture benefits from adding value postharvest. These patterns suggest markets in which there is a relatively weak transmission of price premiums to producers of fine and flavor cacao.

In addition, the estimated coefficient for quantity of cacao production is positive and statistically significant at the 1% level. In aggregate terms, each additional ton of cacao produced by a farmer is associated with a 1.2% increase in the price received. Although cacao production can be considered to be an endogenous variable in our estimation, it is widely discussed in the development literature that selling directly to formal markets is more likely to happen when the quantity sold is large and the market is close by (Fafchamps & Hill, 2005). The relation between quantity sold and cacao prices is explored in the next sections.

IV results presented in column 3 lead to the same conclusions with regard to the use of the Nacional variety and postharvest practices. In this estimation, the magnitude of the effect (LATE) of the use of postharvest practices on increasing prices is even larger. Nonetheless, it is important to point out that test results for this estimation do not reject the null hypothesis that "postharvest practices" are exogenous at conventional significance levels ($p = 0.139$).

Overall, the results are consistent with the increasing use and production of CCN-51 in Ecuador during the last decade as producing Nacional does not represent a clear advantage for the farmers. As discussed earlier, CCN-51 is more intensively managed, especially when it comes to pruning and fertilization applications. These crop management activities will likely increase the price received via yield effects, but they also increase production costs. Production costs differences between varieties are not explored in this article; likewise, the costs of fermenting and drying are not considered.

### 6.2 | Coefficient stability results

To address concerns related to our identification strategy, we assess the potential influence of omitted variable bias on our results. As discussed in the previous sections, we use the method developed by Oster (2017) and estimate a plausible identification set for the estimated relationship between producers' price and the use of specific varieties or postharvest practices.

Table 6 reports the results: Panel (a) shows estimates of the variety effect on producers' price Panel (b) shows estimates of the postharvest effect on producers' price. The first column shows treatment effects, standard errors, and $R^2$ values without additional controls. Column 2 shows similar values with the full control set. Columns 3 through 6 show the bias-adjusted treatment effects ($\beta^*$) under the assumption that $\delta = 1$ while varying values of $R_{\text{Max}}$. They also show the values of $\delta$ such that $\beta = 0$. Finally, column 7 shows the bounding set of the effect, using $\delta = 1$. In Panel (a), the identified set is bounded below by $\tilde{\beta}$[22] and above by $\beta^*$. In Panel (b) the identified set is bounded below by $\beta^*$ and above by $\tilde{\beta}$. In both cases, $\beta^*$ is based on $R_{\text{Max}} = 1$, which is the most conservative approach, assumes measurement error does not exist and causes the largest adjustments.

To argue for a level of stability consistent with randomized treatment, researchers should consider whether the identified set excludes zero or, equivalently, that the $\tilde{\delta}$ that would produce $\beta = 0$ exceeds 1 (Oster, 2017). Results from column 7 in Table 6 show the bounding set on the variety coefficient includes zero. If we use the rule of accepting the effect as causal only if the identified set excludes zero, this result leads to the conclusion of no

[22] $\tilde{\beta}$ is equivalent to the value of $\beta$ delivered when $R_{\text{Max}} = \tilde{R}$ or $\delta = 0$.

**TABLE 6** Coefficient stability and effect bounds

| | (1) Baseline effect | (2) Controlled effect | (3) $R_{Max} = 1.3 \times \tilde{R} = 0.586$ | (4) $R_{Max} + \tilde{R} + (\tilde{R} - \ddot{R}) = 0.659$ | (5) $2.2 \times \tilde{R} = 0.992$ | (6) $R_{Max} = 1$ | (7) Identified set |
|---|---|---|---|---|---|---|---|
| (a) Variety effect estimate | | | | | | | |
| $\beta$ | −0.050*** | −0.026** | −0.008 | 0.002 | 0.058 | 0.059 | (−0.026, 0.059) |
| | (0.013) | (0.010) | | | | | |
| $\tilde{\delta}$ for $\beta = 0$ given $R_{Max}$ | | | 1.396 | 0.920 | 0.359 | 0.354 | |
| (b) Postharvest effect estimate | | | | | | | |
| $\beta$ | 0.077*** | 0.069*** | 0.063 | 0.058 | 0.029 | 0.028 | (0.028, 0.069)[a] |
| | (0.030) | (0.029) | | | | | |
| $\tilde{\delta}$ for $\beta = 0$ given $R_{Max}$ | | | 4.421 | 3.113 | 1.322 | 1.305 | |
| Additional controls | No | Yes | | | | | |
| Observations | 340 | 340 | | | | | |
| $R^2$ | 0.243 | 0.451 | | | | | |

*Notes*: This table shows the validation results for the analysis of the relationship between varieties and postharvest practices with prices received by cacao producers. Baseline effects relate to Equation (6), and controlled effects relate to Equation (7) presented in this paper. Standard errors clustered at the sublocation (town/city) level in parenthesis.

[a]Identified set excludes zero.

*Significance at the 10% levels.

**Significance at the 5% levels.

***Significance at the 1% levels.

causality. In contrast, the bounding set on the postharvest coefficient excludes zero, suggesting that the result on postharvest practices is qualitatively robust to the inclusion of omitted variables. The calculated values of $\tilde{\delta}$ that would produce $\beta = 0$ confirm these results. For the case of postharvest effects, $\tilde{\delta}$ exceeds 1 for all the values of $R_{\text{Max}}$ considered, while for the case of variety effects, $\tilde{\delta}$ exceeds 1 only when $R_{\text{Max}} = 1.3 \times \tilde{R}$.

In general, these results imply that postharvest effects are highly robust to potential unobserved heterogeneity, while variety effects are not. It is important to note that results from columns 1 and 2 in Table 6 show significant variety effects, hence, interpreting these results in a naïve way would lead one to wrongly conclude that variety has a significant link with producers' price.

### 6.3 | Heterogeneity in the relationship between cacao producers' price and postharvest practices

Motivated by the results from the coefficient stability analysis, and to explore additional dimensions of heterogeneity, we examine the relationship between producers' price and the use of postharvest practices among various subgroups of producers. We first test the finding from our summary statistics that suggest that price premiums associated with fermenting and drying are different for Nacional producers compared to CCN-51 producers. Next, we examine heterogeneity influenced by total cacao production. The rationale is that farmers that produce larger quantities of cacao obtain larger incomes, can invest in better postharvest technologies, and hence obtain better prices. We also assess heterogeneity driven by experience in cacao farming, access to an extension agent, having received cacao production training, and being part of a producers' association. The rationale is that these attributes can help farmers apply better techniques or procedures at the time of performing postharvest practices and hence obtain better prices.

To assess if these dimensions of heterogeneity find support in the data, we follow the approach to heterogeneity presented in Bandiera and Rasul (2006) and allow the effect of the application of postharvest practices to vary according to farmer characteristics described above. Consequently, we estimate an augmented version of our fully controlled specification (Equation 7) represented as:

$$P_i = \alpha + \gamma_1 [T_i \times G_{1i}] + \gamma_2 [T_i \times G_{2i}] + \boldsymbol{\beta X}_i + \boldsymbol{\psi W}_i + \boldsymbol{\varphi M}_i + \boldsymbol{\theta}_l + \varepsilon_i, \tag{10}$$

where $G_1$ and $G_2$ identify in our sample the subgroup of farmers with the characteristics of interest described above. Our interest is to establish whether, in the empirical specification above, the marginal effect of the application of postharvest practices differs or not among the subgroups of farmers, that is if $\gamma_1 - \gamma_2 = 0$.

For characteristics represented by continuous variables, we used the next criteria to sort farmers: total production was divided into “large” and “small,” with large production defined as producing more than 10 tons/year; experience was divided into “long” and “short”, where long experience is defined as having more than 15 years of experience in cacao farming. Table 7 reports estimates of Equation (10) for each of the six potential dimensions of heterogeneity along with the subgroup of farmers. For ease of exposition, only the coefficients ($\gamma_1$, $\gamma_2$) are reported but all individual characteristics included in Equation (7) are controlled for.

Two main results arise from this analysis. First, columns (1), (3), (4), (5), and (6), report positive and statistically significant marginal effects for all subgroups of farmers by variety, experience, extension, training, and association, respectively. Nonetheless, in these columns the difference in the price received by farmers across subgroups is relatively small (approximately 1%) and is not statistically significant (confirmed by a simple Wald test reported at the bottom of Table 7). Second, column (2) reports heterogenous and statistically significant postharvest effects by total cacao production. The results in column (2) suggest that applying postharvest practices produce greater benefits for larger farmers when compared to small farmers (an increase in price of 19.7% vs. an increase in price of 6.7%). This difference, of approximately 13% points, is statistically significant confirmed by a Wald test.

**TABLE 7** Heterogeneity

| Dependent variable: Natural Log of Cacao Price Received by Farmers (USD/ton) | | | | | | |
|---|---|---|---|---|---|---|
| | **(1) Variety $G_1$ = Nacional $G_2$ = CCN-51** | **(2) Production $G_1$ = Large $G_2$ = Small** | **(3) Experience $G_1$ = Long $G_2$ = Short** | **(4) Extension $G_1$ = Yes $G_2$ = No** | **(5) Training $G_1$ = Yes $G_2$ = No** | **(6) Association $G_1$ = Yes $G_2$ = No** |
| $G_1$ × Postharvest | 0.063*** | 0.197*** | 0.072*** | 0.079*** | 0.073*** | 0.063*** |
| | (0.018) | (0.039) | (0.015) | (0.017) | (0.019) | (0.021) |
| $G_2$ × Postharvest | 0.076*** | 0.067*** | 0.063** | 0.065*** | 0.067*** | 0.071*** |
| | (0.020) | (0.020) | (0.025) | (0.019) | (0.019) | (0.022) |
| Additional controls | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 340 | 340 | 340 | 340 | 340 | 340 |
| $R^2$ | 0.447 | 0.359 | 0.452 | 0.452 | 0.451 | 0.45 |
| Test of equality (Ho: $\gamma_1 - \gamma_2 = 0$) | | | | | | |
| $F(1, 14)$ | 0.96 | 11.02 | 0.5 | 2.65 | 0.27 | 0.08 |
| Prob > $F$ | 0.343 | 0.0051 | 0.4894 | 0.1259 | 0.6131 | 0.7822 |

*Notes*: Column (2) defines large production as producing more than 10 tons/year of cacao beans. Column (3) defines long experience as having more than 15 years of experience in cacao farming. Additional controls refer to Equation (9), which is based on Equations (6) and (7). Standard errors clustered at the sublocation (town/city) level in parenthesis.

Abbreviation: CCN-51, Colección Castro Naranjal 51.

*Significance at the 10% levels.

**Significance at the 5% levels.

***Significance at the 1% levels.

In addition to the rationales provided before, another possible explanation for these results is that buyers may segment the cacao market by volume. Therefore, they reward the careful application of postharvest practices more when volumes are larger. Larger volumes of high-quality cacao offered by producers might facilitate the subsequent trade between intermediaries and processors of gourmet chocolate—who look for the consistency of specific flavors and aromas present in the beans to prepare their products. Likewise, larger volumes of high-quality cacao can also help exporters working in the high-end cacao market to reach minimum exportable quantities. Small quantities of high-quality cacao might not reach processors or exporters in pure form, as most likely, intermediaries would need to mix these beans with others to meet minimum tradeable quantities. The mixing of high-quality with low-quality beans affects the overall perceived quality of the cacao, driving it to the "ordinary" category. Thus, this might incentivize buyers to pay lower prices for small quantities of beans traded. At the same time, this problem might further disincentivize small producers to perform a careful application of postharvest practices.

## 7 | CONCLUSIONS AND DISCUSSION

Using actual observations on farmers' behavior and prices received, we study the effects of producing Nacional and CCN-51 cacao varieties in combination with the use of the postharvest practices of fermentation and drying. We find evidence that suggests that prices received by farmers for the fine and flavor variety Nacional are not higher compared to those received by producers of the ordinary variety CCN-51—controlling for other price-related practices. Indeed, our results suggest that farmers who ferment and dry their cacao beans receive higher prices compared to those who do not. These findings hint that at least some market segments of Ecuador—the world's main exporter of fine and flavor cacao—are focused on physical characteristics. Organoleptic attributes, the trademark of fine and flavor cacao varieties, on average are not being rewarded. A plausible explanation for these results is that price premiums may only accrue to farmers who are well organized and sell large quantities of high-quality beans. As mentioned before, small quantities of high-quality cacao might get mixed with bulk beans along the supply chain—to meet minimum tradeable quantities—and this mixing incentivizes buyers to pay lower prices. Although the Nacional variety is used for manufacturing gourmet chocolates, nothing prevents them from being used to manufacture mass consumptions chocolates.

The high-quality chocolate value chain has grown rapidly and now likely exceeds 12,000 tons (Table 1). Nonetheless, this market is still a very small share of the global cacao market. Other efforts in this value chain that may earn premiums include (i) very careful chocolate manufacturing and (ii) good marketing strategies (that may use, i.e., denomination of origin). These premiums generally accrue to agents well along the value chain, and only in some instances to farmers. A recent study conducted by FAO and the Bureau for the Appraisal of Social Impacts (BASIC), finds that 70% of the total value of chocolate products in the French market accrues to brands and retailers—the final two actors in the chain. Upstream, it is estimated that only 18.6% of total value is accrued by actors in cocoa-producing countries—from cocoa cultivation up to bean exports (FAO and BASIC, 2020).

Increased production of the Nacional variety will benefit smallholders only if (i) price premiums exist and (ii) the benefits of the price premiums are transmitted to producers. In the particular case of Ecuador, promoting production of the Nacional variety based on (i) the relatively higher prices of gourmet chocolate bars and (ii) the assumed variety-related price premiums does not guarantee higher prices to farmers for two reasons. As discussed in this paper, focusing on the production of Nacional variety as means of distinguishing farmers as fine and flavor cacao producers, ignores problems in the markets where price premiums fail to reach farmers. Intermediaries, associations, and other buyers do not necessarily pay price premiums for the Nacional variety. In addition, our results suggest that only by fermenting and drying the cacao beans are farmers able to capture price premiums. Access to technology and farmer expertise in postharvest processes play important roles in the outcomes.

Changes in global markets, with demands for credence attributes including food safety, organic production, carbon-neutral and carbon-sequestering production, fair trade, and environmental sustainability may open new opportunities to cacao producers. However, opportunities to harvest value out of credence attributes come with additional costs as they need to be independently verified to ensure the validity of such claims.

### 7.1 | Policy implications

The common belief that fine and flavor cacao varieties command price premiums has shaped policy choices aimed at promoting the local cacao sectors in various Latin-American countries during the last decade. The Government of the Dominican Republic with the support of the United Nations Development Program launched in 2015 the National Cacao Action Plan for the Sustainable Development, focused on the renovation of cacao farms. The Government of Perú in collaboration with the United States Agency for International Development and local private institutions, launched the Peru Cacao Alliance, focused on supporting smallholder farmers to leave illicit crops and plant cacao.

In Ecuador, the local government launched the Fine and Flavor Cacao Reactivation Program (FFCRP) in 2012 focused on revitalizing production among small-scale producers. The FFCRP was intended to benefit smallholder producers and expand exports of high-valued cacao. By using input subsidies, increasing the access to credit, the rehabilitation of older nonproductive plantations, and promoting enhanced farm management, the Ecuadorian government seeks to stimulate the production of the fine and flavor variety Nacional in approximately 284,000 ha of current cacao plantations. Nonetheless, this program disregards that for farmers producing CCN-51, the costs of shifting to an alternative variety may be overwhelming.

This study has important implications for current and future program interventions in the region aimed at (i) increasing cacao farmers' revenue and income and (ii) improving price transmission. Programs like the FFCRP in

Ecuador, that promote the production of fine and flavor cacao varieties alone, are misguided but can be improved by training farmers in more modern processing techniques. Indeed, we found evidence suggesting that recommending to farmers that they perform both, fermentation and drying practices, may lead to substantial price responses irrespective of the variety grown. Training on postharvest practices should complement cacao program interventions, as it can benefit larger segments of cacao farmers, not only producers of certain varieties. Farmers' associations can play important roles as facilitators of this training. Farmers that currently do not perform postharvest practices will likely need access to capital to invest in improved drying and training in how to meet local moisture standards. Likewise, program interventions can also provide technical assistance to help farmers determine the most appropriate practices and factors to account for when fermenting cacao beans.

Because the total volume of cacao production was found to be significantly associated with better prices received, improvements in farm productivity will likely increase returns to cacao farming. From a distributional point of view, if farmers receiving higher prices are large-scale producers, then policies focusing on increasing productivity, such as input subsidies, will overly benefit this group. Targeting program interventions to smaller-scale producers might reduce inequalities in the distribution of prices received by farmers.

## 7.2 | Limitations and future research

As with any other empirical analysis, our results have limitations. We focus on building up the credibility of our estimation by using different estimation techniques, but we cannot make any causal statements. The association between volume and better prices received might indicate high transactions costs along the value chain and hence buyers prioritizing and incentivizing large volume transactions. This suggests that the local cacao markets in Ecuador are not competitive and that buyers and intermediaries may exercise market power and segment the market by volume, which deserves further scrutiny. Moreover, this phenomenon raises the question of the reasons why small-scale cacao producers fail to associate and sell in volume. Further research on industrial organization and the impact of association or cooperative membership on the prices received by cacao farmers should clarify this.

The study presented here did not address how price premiums are affected by transactions costs incurred by other members alongside the value chain. Research focusing on the effectiveness of the various links along the value chain will complement these findings. As our research focused exclusively on price received by producers, we did not explore the possibility that premiums are diminished along the value chain by other costs including customs and logistics.

### ACKNOWLEDGMENTS

We are grateful for constructive feedback from Philip Abbott, Jorge Sellare, Ling Yao, Marc Bellemare, and Jeffrey Bloem. We are also thankful for useful comments and suggestions from participants of the 2019 Agricultural and Applied Economics Association (AAEA) Meetings in Atlanta, GA, and the 2020 Southern Agricultural Economics Association (SAEA) in Louisville, KY, as well as seminar participants in the Online Agricultural and Resource Economics Seminar OARES and Innsbruck University. Comments received from three anonymous reviewers and the editor of this journal are gratefully acknowledged. All remaining errors are ours.

### DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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## PEER REVIEW

The peer review history for this article is available at https://publons.com/publon/10.1002/agr.21730

## REFERENCES


Abadie, A., Athey, S., Imbens, G. W., & Wooldridge, J. (2017). *When should you adjust standard errors for clustering?* (Working paper no. 24003), National Bureau of Economic Research.

Abbott, P. C., Benjamin, T. J., Burniske, G. R., Croft, M. M., Fenton, M., Kelly, C. R., Lundy, M., Rodriguez Camayo, F., & Wilcox, M. D. (2018). *An analysis of the supply chain of cacao in Colombia* (p. 208). United States Agency for International Development (USAID).

Aidenvironment. (2018). Pricing mechanisms in the cacao sector: Options to reduce price volatility and promote farmer value capture. Retrieved May 15, 2019, from http://www.aidenvironment.org/wp-content/uploads/2018/02/Pricing-mechanisms-in-the-cacao-sector.Oct2018.pdf

Altonji, J. G., Elder, T. E., & Taber, C. R. (2005). Selection on observed and unobserved variables: Assessing the effectiveness of catholic schools. *Journal of Political Economy*, *113*(1), 151–184.

Alwang, J. (2019). *Cacao value chains and producer well-being in Manabí, Ecuador*. Mimeo.

Amores, F., Butler, D., Ramos, G., Sukha, D., Espin, S., Gómez, A., Zambrano, A., Hollywood, N., van Loon, R., & Seguine, E. (2007). *Project to determine the physical, chemical and organoleptic parameters to differentiate between fine and bulk cacao* (EX/134/10, pp. 1–15). Instituto Nacional Autonomo de investigaciones agropecuarias.

Amores, F., Vasco, S., Eskes, A., Suarez, C., Quiroz, J., Loor, R., & Teran, M. (2011). On-farm and on-station selection of new cacao varieties in Ecuador. Final Report of the CFC/ICCO/Bioversity International Project on "Cacao Productivity and Quality Improvement: A Participatory Approach (technical paper 59), pp. 59–72.

Angrist, J. D., & Krueger, A. B. (2001). Instrumental variables and the search for identification: From supply and demand to natural experiments. *Journal of Economic Perspectives*, *15*, 69–85.

Angrist, J. D., & Pischke, J. S. (2008). *Mostly harmless econometrics: An empiricist's companion*. Princeton University Press.

Angrist, J. D., & Pischke, J.-S. (2010). The credibility revolution in empirical economics: How better research design is taking the con out of econometrics. *Journal of Economic Perspectives*, *24*, 3–30.

Angrist, J. D., & Pischke, J. S. (2014). *Mastering 'metrics: The path from cause to effect*. Princeton University Press.

Bandiera, O., & Rasul, I. (2006). Social networks and technology adoption in Northern Mozambique. *The Economic Journal*, *116*(514), 869–902.

Barrera, V., Alwang, J., Casanova, T., Domínguez, J., Escudero, L., Loor, G., Peña, G., Párraga, J., Arévalo, J., Quiroz, J., Tarqui, O., Plaza, L., Zambrano, F., Rodríguez, G., García, C., & Racines, M. (2018). La Cadena de Valor del Cacao y El Bienestar de los Productores en la Provincia de Manabí-Ecuador. *INIAP*. Libro Técnico No. 171. ARCOIRIS Producciones Gráficas. Quito, Ecuador. p. 160.

Bellows, J., & Miguel, E. (2009). "War and local collective action in Sierra Leone". *Journal of Public Economics*, *93*, 1144–1157.

Boza, E. J., Motamayor, J. C., Amores, F. M., Cedeno-Amador, S., Tondo, C. L., Livingstone, D. S., & Gutiérrez, O. A. (2014). Genetic characterization of the cacao cultivar CCN 51: Its impact and significance on global cacao improvement and production. *Journal of the American Society for Horticultural Science*, *139*(2), 219–229.

Cadby, J., Araki, T., & Villacis, A. H. (2021). Breaking the mold: Craft chocolate makers prioritize quality, ethical and direct sourcing, and environmental welfare. *Journal of Agriculture and Food Research*, *4*, 100122.

Calo, M., & Wise, T. A. (2005). *Revaluing peasant coffee production: Organic and fair trade markets in Mexico*. Global Development and Environment Institute, Tufts University.

Camu, N., Winter, D., Addo, T., Takrama, S. K., Bernaert, J. S., H., & de Vuyst, L. (2008). Fermentation of cacao beans: Influence of microbial activities and polyphenol concentrations on the flavour of chocolate. *Journal of the Science of Food and Agriculture*, *88*(13), 2288–2297.

Carlucci, D., Stasi, A., Nardone, G., & Seccia, A. (2013). Explaining price variability in the Italian yogurt market: A hedonic analysis. *Agribusiness: An International Journal*, *29*(2), 194–206.

Cepeda, D., Pound, B., Nelson, V., Kajman, G., Cabascango, D., Martin, A., & Ojeda, A. (2013). *Assessing the poverty impact of sustainability standards: Ecuadorian Cacao*. University of Greenwich Natural Resources Institute Publications.

Confectionery. (2016). Premium chocolate 'Leg Up': How to win Fine Flavor Cacao status. Retrieved March 15, 2019, from https://www.confectionerynews.com/Article/2016/05/10/Everything-you-need-to-know-about-fine-flavor-cacao#targetText=The%20ICCO%20estimates%20fine%20flavor,%2410%2C000%20per%20MT%2C%20it%20says

Corporación Financiera Nacional. (2018). Ficha Sectorial: Cacao y Chocolate. Retrieved March 30, 2019, from https://www.cfn.fin.ec/wp-content/uploads/2018/04/Ficha-Sectorial-Cacao.pdf

Daniels, S., Laderach, P., & Paschall, M. (2012). *Reaching high-value markets: Fine Flavor Cacao in Ghana*. International Institute for Environment and Development/Sustainable Food Lab, London. Retrieved March 01, 2019, from https://pubs.iied.org/pdfs/16036IIED.pdf

Díaz, S., Pinoargote, M., & Castillo, P. (2012). Análisis de las características organolépticas del chocolate a partir de cacao CCN-51 tratado enzimáticamente y tostado a diferentes temperaturas. Retrieved March 15, 2019, from http://www.dspace.espol.edu.ec/xmlui/bitstream/handle/123456789/31050/D-79697.pdf?sequence=-1%26isAllowed=y

Eskes, A., Ahnert, D., Garcia Carrion, L., Seguine, E., Assemat, S., Guarda, D., & Garcia, R. (2012, October 15–20). Evidence on the Effect of the Cacao Pulp Flavour Environment During Fermentation on the Flavour Profile of Chocolates. *17th International Cacao Research Conference (COPAL): Improving the profitability of small and medium-sized farms: the principal key to a global sustainable cacao economy*. Yaoundé, Cameroun. Retrieved March 01, 2019, from https://agritrop.cirad.fr/568108/1/document_568108.pdf

Fafchamps, M., & Hill, R. V. (2005). Selling at the farmgate or traveling to market. *American Journal of Agricultural Economics*, *87*(3), 717–734.

Fair Trade International. (2018). Cacao farmer income: The household income of cacao farmers in Côte d'Ivoire and strategies for improvement. Retrieved March 01, 2019, from https://www.fairtrade.net/fileadmin/user_upload/content/2009/resources/2018-04_Report_Fairtrade_Cacao_Farmer_Income.pdf

FAO and BASIC. (2020). Comparative study on the distribution of value in European chocolate chains, Executive Summary. Retrieved May 24, 2021, from https://lebasic.com/wp-content/uploads/2020/07/BASIC-DEVCO-FAO_Cocoa-Value-Chain-Exec-Summary_Advance-Copy_June-2020.pdf

Gockowski, J., Afari-Sefa, V., Sarpong, D. B., Osei-Asare, Y. B., & Dziwornu, A. K. (2011). Increasing income of Ghanaian cacao farmers: Is introduction of Fine Flavour Cacao a viable alternative. *Quarterly Journal of International Agriculture*, *50*(2), 175–200.

Gómez, M. I., Barrett, C. B., Buck, L. E., de Groote, H., Ferris, S., Gao, H. O., & Reardon, T. (2011). Research principles for developing country food value chains. *Science*, *332*(6034), 1154–1155.

Gonzalez, F., & Miguel, E. (2015). War and local collective action in Sierra Leone: A comment on the use of coefficient stability approaches. *Journal of Public Economics*, *128*, 30–33.

Griliches, Z. (1986). Economic data issues. *Handbook of Econometrics*, *3*, 1465–1514.

Hamrick, D., & Fernandez-Stark, K. (2018). *Belize in the cacao global value chain*. Duke Global Value Chains Center, Duke University. Retrieved March 30, 2019, from https://gvcc.duke.edu/wp-content/uploads/2018_07_02_Belize-Cacao-GVC_FINAL_PUBLIC.pdf

Hue, C., Gunata, Z., Breysse, A., Davrieux, F., Boulanger, R., & Sauvage, F. X. (2016). Impact of fermentation on nitrogenous compounds of cacao beans (Theobroma Cacao L.) from various origins. *Food Chemistry*, *192*, 958–964.

ICCO. (2019a). Fine and flavor cacao. Retrieved March 30, 2019, from https://www.icco.org/about-cacao/fine-or-flavour-cacao.html

ICCO. (2019b, May). 2019 quarterly bulletin of cacao statistics. Retrieved July 01, 2019, from https://www.icco.org/about-us/icco-news/408-may-2019-quarterly-bulletin-of-cacao-statistics.html

Imbens, G. W., & Angrist, J. D. (1994). Identification and estimation of local average treatment effects. *Econometrica: Journal of the Econometric Society*, *62*, 467–475.

Iyer, P., Bozzola, M., Hirsch, S., Meraner, M., & Finger, R. (2020). Measuring farmer risk preferences in Europe: A systematic review. *Journal of Agricultural Economics*, *71*(1), 3–26.

Jäckering, L., Meemken, E. M., Sellare, J., & Qaim, M. (2021). Promoting written employment contracts: Evidence from a randomised awareness campaign. *European Review of Agricultural Economics*, *48*, 1007–1030.

de Janvry, A., McIntosh, C., & Sadoulet, E. (2015). Fair trade and free entry: Can a disequilibrium market serve as a development tool? *Review of Economics and Statistics*, *97*(3), 567–573.

Jentzsch, P. V., Ciobotă, V., Salinas, W., Kampe, B., Aponte, P. M., Rösch, P., & Ramos, L. A. (2016). Distinction of Ecuadorian varieties of fermented cacao beans using Raman spectroscopy. *Food Chemistry*, *211*, 274–280.

Jespersen, L., Nielsen, D. S., Hønholt, S., & Jakobsen, M. (2005). Occurrence and diversity of yeasts involved in fermentation of West African cacao beans. *FEMS Yeast Research*, *5*(4–5), 441–453.

Karbuz, S., & Jumah, A. (1995). Cointegration and commodity arbitrage. *Agribusiness: An International Journal*, *11*, 235–243.

Kumar, A., Saroj, S., Joshi, P. K., & Takeshima, H. (2018). Does cooperative membership improve household welfare? Evidence from a panel data analysis of smallholder dairy farmers in Bihar, India. *Food Policy*, *75*(C), 24–36.

Lancaster, K. (1966). New approach to consumer theory. *Journal of Political Economy*, *74*(2), 132–157.

Levi, M. D. (1973). Errors in the variables bias in the presence of correctly measured variables. *Econometrica (pre-1986)*, *41*(5), 985.

MAGAP. (2019). SIPA Sistema de Información Pública Agropecuaria del Ecuador, Ministerio de Agricultura Ganaderíá Acuacultura y Pesca. Retrieved August 10, 2019, from http://sipa.agricultura.gob.ec/index.php/sipa-estadisticas/estadisticas-economicas

Maertens, M., Minten, B., & Swinnen, J. (2012). Modern food supply chains and development: Evidence from horticulture export sectors in Sub-Saharan Africa. *Development Policy Review*, *30*(4), 473–497.

Martin, C. (2017). *Sizing the craft chocolate market*. Fine Cacao and Chocolate Institute. Retrieved April 15, 2019, from: https://chocolateinstitute.org/blog/sizing-the-craft-chocolate-market/

Meemken, E., Sellare, J., Kouame, C., & Qaim, M. (2019). Effects of fairtrade on the livelihoods of poor rural workers. *Nature Sustainability*, *2*, 635–642.

Mejía, L. C., Rojas, E. I., Maynard, Z., Bael, S. V., Arnold, A. E., Hebbar, P., Samuels, G. J., Robbins, N., & Herre, E. A. (2008). Endophytic fungi as biocontrol agents of Theobroma cacao pathogens. *Biological Control*, *46*(1), 4–14.

Melo, C. J., & Hollander, G. M. (2013). Unsustainable development: Alternative food networks and the Ecuadorian Federation of Cacao Producers, 1995–2010. *Journal of Rural Studies*, *32*, 251–263.

Minten, B., Dereje, M., Engida, E., & Tamru, S. (2018). Tracking the quality premium of certified coffee: Evidence from Ethiopia. *World Development*, *101*, 119–132.

Naseem, A., Spielman, D. J., & Omamo, S. W. (2010). Private-sector investment in R&D: A review of policy options to promote its growth in developing-country agriculture. *Agribusiness: An International Journal*, *26*(1), 143–173.

Negi, D. S., Birthal, P. S., Roy, D., & Khan, M. T. (2018). Farmers' choice of market channels and producer prices in India: Role of transportation and communication networks. *Food Policy*, *81*, 106–121.

Nelson, V., & Martin, A. (2013). *Final technical report: Assessing the poverty impact of sustainability standards*. Natural Resources Institute University of Greenwich Publications.

Nieburg, O., (2018). Cities of fine and flavor cacao. Retrieved January 15, 2019, from https://www.foodnavigator-latam.com/Article/2018/10/29/Cities-of-fine-flavor-cacao-and-lost-varieties-never-found-in-chocolate

Ola, O., & Menapace, L. (2020). Smallholders' perceptions and preferences for market attributes promoting sustained participation in modern agricultural value chains. *Food Policy*, *97*, 101962.

Oster, E. (2017). Unobservable selection and coefficient stability: Theory and evidence. *Journal of Business and Economic Statistics*, *37*(2), 187–204.

Reardon, T. (2015). The hidden middle: The quiet revolution in the midstream of agrifood value chains in developing countries. *Oxford Review of Economic Policy*, *31*(1), 45–63.

Reardon, T., Barrett, C. B., Berdegué, J. A., & Swinnen, J. F. (2009). Agrifood industry transformation and small farmers in developing countries. *World Development*, *37*(11), 1717–1727.

Ricketts, D. K., G. Turvey, C., & I. Gómez, M. (2014). Value chain approaches to development: Smallholder farmer perceptions of risk and benefits across three cacao chains in Ghana. *Journal of Agribusiness in Developing and Emerging Economies*, *4*(1), 2–22.

van Rijsbergen, B., Elbers, W., Ruben, R., & Njuguna, S. N. (2016). The ambivalent impact of coffee certification on farmers' welfare: A matched panel approach for cooperatives in central Kenya. *World Development*, *77*, 277–292.

Ronchi, L. (2006). *Fairtrade and market failures in agricultural commodity markets*. The World Bank.

Schwan, R. F., & Wheals, A. E. (2004). The microbiology of cacao fermentation and its role in chocolate quality. *Critical Reviews in Food Science and Nutrition*, *44*(4), 205–221.

Sellare J., Meemken E.-M., Kouamé C., & Qaim M. (2019). Do sustainability standards benefit smallholder farmers also when accounting for cooperative effects? Evidence from Côte d'Ivoire. *American Journal of Agricultural Economics*, *102*(2), 681–695. http://doi.org/10.1002/ajae.12015

Swinnen, J. F., & Maertens, M. (2007). Globalization, privatization, and vertical coordination in food value chains in developing and transition countries. *Agricultural Economics*, *37*, 89–102.

The Living Income Community of Practice. (2021). The concept. Retrieved May 23, 2021, from https://www.living-income.com/the-concept

Theil, H. (1965). *Economic Forecasts and Policy* (2nd ed.). North Holland Publishing Company.

Tothmihaly, A., & Ingram, V. J. (2019). How can the productivity of Indonesian cocoa farms be increased? *Agribusiness: An International Journal*, *35*(3), 439–456. http://doi.org/10.1002/agr.21595

US Department of Agriculture, Foreign Agricultural Service. (2015). Ecuador cacao update and outlook. Retrieved January 15, 2019, from https://gain.fas.usda.gov/Recent%20GAIN%20Publications/Ecuador%20Cacao%20Update%20and%20Outlook_Quito_Ecuador_2-18-2015.pdf

Vicepresidencia del Ecuador (2015). *Diagnóstico de la cadena productiva del cacao en el Ecuador*. Ecuador: Secretaría Técnica del Comité Interinstitucional para el Cambio de la Matriz Productiva. Recuperado de http://www.vicepresidencia.gob.ec/wp-content/uploads/2015/07/Resumen-Cadena-de-Cacao-rev.pdf

Waarts, Y., Ingram, V., Liderhof, V., Puister-Jansen, L., van Rijn, F., & Aryeetey, R. (2016). *Impact of UTZ certification on cacao producers in Ghana, 2011 to 2014*. LEI, Wageningen UR.

Woods, D. (2003). The tragedy of the cocoa pod: Rent-seeking, land and ethnic conflict in Ivory Coast. *Journal of Modern African Studies*, *41*, 224–241.

World Cacao Foundation. (2014). Cacao market update. Retrieved January 15, 2019, from http://www.worldcacaofoundation.org/wp-content/uploads/Cacao-Market-Update-as-of-4-1-2014.pdf

Zilberman, D., Lu, L., & Reardon, T. (2017). Innovation-induced food supply chain design. *Food Policy*, *83*, 289–297.

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**How to cite this article:** Villacis, A. H., Alwang, J. R., Barrera, V., & Dominguez, J. (2022). Prices, specialty varieties, and postharvest practices: Insights from cacao value chains in Ecuador. *Agribusiness*, 1–33. https://doi.org/10.1002/agr.21730

## APPENDIX A

Table A1.

**TABLE A1** Summary statistics: Household characteristics, farm management practices, and marketing practices by cacao variety planted

| Variable | Description of variable | Variety | | Observations | *p* value |
|---|---|---|---|---|---|
| | | Nacional | CCN-51 | | |
| Household Characteristics | | | | | |
| Household Size | Total number of household members | 3.68 | 3.50 | 340 | 0.36 |
| Age (years) | Age of the head of the household in years | 57.83 | 56.07 | 340 | 0.26 |
| Education (years) | Education of the head of household (years) | 7.41 | 6.74 | 340 | 0.19 |
| Experience (years) | Years of experience in cacao farming | 29.00 | 18.11 | 340 | 0.00 |
| Gender | Gender of the head of household (Male = 1 and Female = 0) | 0.85 | 0.92 | 340 | 0.07 |
| Cellphone | Head of household owns cellphone (Yes = 1 and No = 0) | 0.94 | 0.93 | 340 | 0.76 |
| Additional Employment | Head of household has additional job outside his farm (Yes = 1 and No = 0) | 0.23 | 0.16 | 340 | 0.15 |
| Access to Credit | Head of household has access to credit (Yes = 1 and No = 0) | 0.20 | 0.21 | 340 | 0.88 |
| Association Membership | Head of household is part of a producer's association (Yes = 1 and No = 0) | 0.34 | 0.05 | 340 | 0.00 |
| Cacao Training | Household has received any cacao production training (Yes = 1 and No = 0) | 0.51 | 0.32 | 340 | 0.00 |
| Access to Extension Agent | Household has access to an extension agent (Yes = 1 and No = 0) | 0.32 | 0.21 | 340 | 0.04 |
| Farm Characteristics | | | | | |
| Farm Size (ha) | Total size of farm (ha) | 14.40 | 14.53 | 340 | 0.97 |
| Time to Lot (min) | Time required to get from the household to the cacao lot (min) | 7.05 | 4.74 | 340 | 0.37 |
| Cacao Trees Age (years) | Age of the cacao trees (years) | 29.33 | 6.66 | 340 | 0.00 |
| Cacao Area (ha) | Size of cacao lot (ha) | 3.81 | 3.40 | 340 | 0.49 |

**TABLE A1** (Continued)

| Variable | Description of variable | Variety: Nacional | Variety: CCN-51 | Observations | *p* value |
|---|---|---|---|---|---|
| Cacao Production (ton) | Cacao beans produced (tons) (already adjusted for moisture)[a] | 1.83 | 2.70 | 340 | 0.04 |
| Planting Density (tress/ha) | Planting density of cacao trees (tree/ha) | 814.79 | 1020.64 | 340 | 0.00 |
| Production per Area (ton/ha) | Cacao beans produced per hectare (ton/ha) | 0.44 | 0.80 | 340 | 0.00 |
| Production per Tree (kg/tree) | Cacao beans produced per tree (kg/tree) | 0.59 | 0.82 | 340 | 0.00 |
| Pruning | Farmer prunes the cacao plantation (Yes = 1 and No = 0) | 0.71 | 0.81 | 340 | 0.05 |
| Fertilization | Farmer applies fertilizers in the cacao plantation (Yes = 1 and No = 0) | 0.19 | 0.45 | 340 | 0.00 |
| Irrigation | Farmer uses irrigation in the cacao plantation (Yes = 1 and No = 0) | 0.17 | 0.24 | 340 | 0.13 |
| Weed control | Farmer controls weeds in the cacao plantation (Yes = 1 and No = 0) | 0.90 | 0.94 | 340 | 0.25 |
| Knowledge of Quality Factors | Farmer claims to know the factors affecting the quality of the cacao beans (Yes = 1 and No = 0) | 0.30 | 0.24 | 340 | 0.25 |
| Any Certification | Farmer has any type of certification (Yes = 1 and No = 0) | 0.13 | 0.00 | 340 | 0.00 |
| Intercropping | Farmer intercrops the cacao trees with other crops (Yes = 1 and No = 0) | 0.33 | 0.22 | 340 | 0.03 |
| On-Farm Postharvest Practices | | | | | |
| Fermentation & Drying | Farmer ferments and dries cacao (Yes = 1 and No = 0) | 0.65 | 0.80 | 340 | 0.00 |
| Drying Technologies | | | | | |
| Wood Pallets | Farmer uses wood pallets to dry the cacao beans (Yes = 1 and No = 0) | 0.24 | 0.21 | 340 | 0.53 |
| Concrete Floor | Farmer uses concrete floor to dry the cacao beans (Yes = 1 and No = 0) | 0.21 | 0.31 | 340 | 0.05 |
| Roadside | Farmer uses the sides of the roads to dry the cacao beans (Yes = 1 and No = 0) | 0.02 | 0.03 | 340 | 0.88 |
| Marquee | Farmer uses marquees to dry the cacao beans (Yes = 1 and No = 0) | 0.05 | 0.06 | 340 | 0.59 |
| Plastic Canvas | Farmer uses plastic canvas to dry the cacao beans (Yes = 1 and No = 0) | 0.10 | 0.16 | 340 | 0.11 |

(Continues)

**TABLE A1** (Continued)

| Variable | Description of variable | Variety | | Observations | *p* value |
|---|---|---|---|---|---|
| | | Nacional | CCN-51 | | |
| Marketing Practices | | | | | |
| Farmgate | Farmer sells cacao beans at the farmgate (Yes = 1 and No = 0) | 0.02 | 0.06 | 340 | 0.04 |
| Local Market | Farmer sells cacao beans at the local market (Yes = 1 and No = 0) | 0.49 | 0.56 | 340 | 0.19 |
| Wholesaler Warehouse | Farmer sells cacao beans to a wholesaler warehouse (Yes = 1 and No = 0) | 0.28 | 0.39 | 340 | 0.05 |
| Exporter Warehouse | Farmer sells cacao beans to an exporter warehouse (Yes = 1 and No = 0) | 0.00 | 0.02 | 340 | 0.25 |
| Sell to Association | Farmer sells cacao beans to an association (Yes = 1 and No = 0) | 0.26 | 0.01 | 340 | 0.00 |
| Use of Contract | Farmer sells cacao beans under a contract (Yes = 1 and No = 0) | 0.13 | 0.04 | 340 | 0.01 |
| Know Market Price | Farmer knows cacao market price before sales (Yes = 1 and No = 0) | 0.53 | 0.55 | 340 | 0.83 |
| Distance to Buyer (km) | Distance from cacao farm to buyer (km) | 14.94 | 21.63 | 340 | 0.07 |
| Transportation Costs (USD) | Average transportation costs (USD/ton) | 44.80 | 80.50 | 340 | 0.01 |

*Note*: The *p* value in the final column refers to the test of equality of outcomes by variety planted.

[a]Cacao production reported en baba was adjusted for moisture content to make it comparable to dried cacao beans.

## APPENDIX B

Figure B1.

| Location Name | Average Price |
|---|---|
| 24 de Mayo | 1562 |
| Bolívar | 1354 |
| Chone | 1397 |
| El Carmen | 1473 |
| Flavio Alfaro | 1505 |
| Jama | 1452 |
| Junín | 1408 |
| Pedernales | 1326 |
| Pichincha | 1495 |
| Portoviejo | 1456 |
| Rocafuerte | 1320 |
| San Vicente | 1166 |
| Santa Ana | 1491 |
| Sucre | 1379 |
| Tosagua | 1293 |
| **Total** | **1428** |

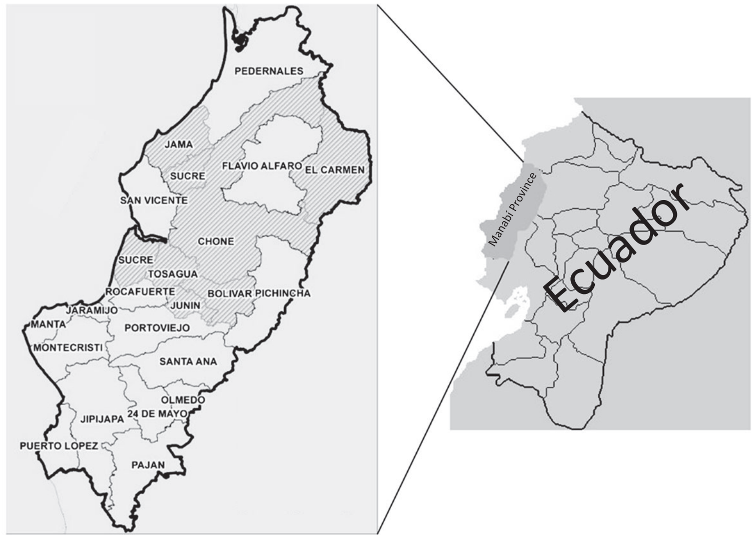


**FIGURE B1** Average price received by cacao farmers in the province of Manabí, Ecuador (USD/Ton)

## APPENDIX C

Table C1.

**TABLE C1** Regression results: Estimates of the effect of varieties and postharvest practices on the mean price received by cacao producers

| Variable | Model Specification (1) OLS | (2) OLS[a] | (3) IV |
|---|---|---|---|
| Dependent variable: Natural log of Cacao Price Received by Farmers (USD/ton) | | | |
| Variety (Farmer uses Nacional = 1) | −0.050*** | −0.026** | −0.034*** |
| | (0.013) | (0.010) | (0.01) |
| Postharvest Practices (Farmer ferments & dries = 1)[b] | 0.077*** | 0.069*** | 0.148*** |
| | (0.017) | (0.018) | (0.05) |
| Age (years) | −0.001 | −0.003 | −0.003 |
| | (0.003) | (0.002) | (0.00) |
| Age squared | 0 | 0 | 0 |
| | (0.000) | (0.000) | (0.000) |

(Continues)

**TABLE C1** (Continued)

| Variable | Model Specification (1) OLS | (2) OLS[a] | (3) IV |
|---|---|---|---|
| Gender of the Head of Household (Male = 1) | 0.019 | 0.007 | 0.003 |
| | (0.018) | (0.016) | (0.01) |
| Education of the Head of Household (years) | 0 | 0.001 | 0.002* |
| | (0.001) | (0.001) | (0.00) |
| Experience (years of experience in cacao farming) | 0 | 0 | 0 |
| | (0.000) | (0.000) | (0.000) |
| Cellphone (Head of household owns cellphone. Yes = 1) | 0.012 | −0.001 | −0.012 |
| | (0.020) | (0.016) | (0.02) |
| Cacao Trees Age (years) | 0.001** | 0.001 | 0.001 |
| | (0.000) | (0.000) | (0.000) |
| Farm Altitude (m) | 0 | 0 | 0 |
| | (0.000) | (0.000) | (0.000) |
| Central Production Zone = 1[c] | 0.025 | 0.028* | −0.01 |
| | (0.018) | (0.016) | (0.03) |
| Hillside Production Zone = 1[c] | 0.039** | 0.056*** | 0.006 |
| | (0.017) | (0.018) | (0.04) |
| Knowledge of Quality Factors (Yes = 1) | −0.015 | −0.018 | −0.021 |
| | (0.017) | (0.018) | (0.02) |
| Any Certification (Farmer has any type of certification. Yes = 1) | 0.003 | 0.01 | 0.03 |
| | (0.021) | (0.017) | (0.02) |
| Pruning (Farmer prunes the cacao plantation. Yes = 1) | 0.014 | 0.013* | 0.011 |
| | (0.016) | (0.007) | (0.01) |
| Fertilization (Farmer applies fertilizers in the cacao plantation. Yes = 1) | 0.021 | 0.016 | 0.011 |
| | (0.015) | (0.015) | (0.01) |
| Irrigation (Farmer uses irrigation in the cacao plantation. Yes = 1) | 0.003 | −0.007 | −0.007 |
| | (0.019) | (0.013) | (0.01) |
| Weed Control (Farmer controls weeds in the cacao plantation. Yes = 1) | 0.040*** | 0.022 | 0.02 |
| | (0.013) | (0.013) | (0.01) |
| Cacao Training (Household has received any cacao production training. Yes = 1) | 0.01 | 0 | 0.002 |
| | (0.011) | (0.010) | (0.01) |
| Access to Extension Agent (Household has access to an extension agent. Yes = 1) | −0.003 | 0.006 | 0.002 |
| | (0.009) | (0.006) | (0.01) |
| Association Membership (Head of household is part of a producer's association Yes = 1) | −0.015 | −0.017 | −0.017 |
| | (0.021) | (0.025) | (0.02) |

**TABLE C1** (Continued)

| Variable | Model Specification (1) OLS | (2) OLS[a] | (3) IV |
|---|---|---|---|
| Intercropping (Farmer intercrops the cacao trees with other crops. Yes = 1) | −0.005 | −0.01 | −0.008 |
| | (0.018) | (0.017) | (0.02) |
| Cacao Production (ton)[b] | | 0.012*** | 0.012*** |
| | | (0.003) | (0.00) |
| Farmgate (Farmer sells cacao beans at the farmgate. Yes = 1) | | −0.009 | −0.002 |
| | | (0.040) | (0.04) |
| Local Market (Farmer sells cacao beans at the local market. Yes = 1) | | −0.026 | −0.029 |
| | | (0.020) | (0.02) |
| Wholesaler Warehouse (Farmer sells cacao beans to a wholesaler warehouse. Yes = 1) | | −0.017 | −0.019 |
| | | (0.020) | (0.02) |
| Exporter Warehouse (Farmer sells cacao beans to an exporter warehouse. Yes = 1) | | −0.024 | −0.038 |
| | | (0.076) | (0.08) |
| Sell to Association (Farmer sells cacao beans to an association. Yes = 1) | | −0.045* | −0.009 |
| | | (0.022) | (0.02) |
| Use of Contract (Farmer sells cacao beans under a contract. Yes = 1) | | 0.037* | 0.037** |
| | | (0.018) | (0.02) |
| Know Market Price (Farmer knows cacao market price before sales. Yes = 1) | | 0.013 | 0.005 |
| | | (0.013) | (0.01) |
| Distance to Buyer (km) | | 0 | 0 |
| | | (0.000) | (0.000) |
| Transportation Costs (USD) | | 0.001* | 0.001 |
| | | (0.001) | (0.00) |
| Days worked per week in the cacao farm | | 0 | 0.002 |
| | | (0.004) | (0.00) |
| Number of people hired to work in the cacao farm | | 0.000*** | 0.000*** |
| | | (0.000) | (0.000) |
| Constant | 7.146*** | 7.206*** | 7.191*** |
| | (0.115) | (0.069) | (0.08) |
| Observations | 340 | 340 | 340 |
| $R^2$ | 0.243 | 0.451 | 0.403 |

*Note*: Standard errors clustered at the sublocation (town/city) level in parentheses.

Abbreviations: IV, instrumental variable; OLS, ordinary least square.

[a]Regression in column (2) includes additional marketing practices control variables that might affect the price but also may cause endogeneity problems.

[b]Instrumented value.

[c]Coastal Production Zone is the omitted category.

*, **, and ***Significance at the 10%, 5%, and 1% levels, respectively.

## APPENDIX D

Table D1.

**TABLE D1** IV estimation: First-stage regressions

| Variable | Coefficient | SE | *t* | *p* > \|t\| |
|---|---|---|---|---|
| Dependent variable: Postharvest Practices (Farmer ferments & dries = 1) | | | | |
| Variety (Farmer uses Nacional = 1) | 0.086 | 0.050 | 1.730 | 0.085 |
| Age (years) | −0.001 | 0.009 | −0.120 | 0.908 |
| Age squared | 0.000 | 0.000 | −0.150 | 0.884 |
| Gender of the Head of Household (Male = 1) | 0.041 | 0.045 | 0.920 | 0.360 |
| Education of the Head of Household in years | −0.004 | 0.005 | −0.750 | 0.453 |
| Experience (Years of experience in cacao farming) | 0.000 | 0.001 | 0.160 | 0.872 |
| Cellphone (Head of household owns cellphone. Yes = 1) | 0.109 | 0.070 | 1.570 | 0.118 |
| Cacao Trees Age (years) | −0.001 | 0.001 | −0.520 | 0.600 |
| Farm Altitude (m) | 0.000 | 0.000 | 1.130 | 0.258 |
| Central Production Zone. *b* = 1[a] | 0.372 | 0.087 | 4.300 | 0.000 |
| Hillside Production Zone. *b* = 1[a] | 0.533 | 0.070 | 7.640 | 0.000 |
| Knowledge of Quality Factors (Yes = 1) | 0.009 | 0.018 | 0.510 | 0.609 |
| Any Certification (Farmer has any type of certification. Yes = 1) | −0.216 | 0.068 | −3.180 | 0.002 |
| Pruning (Farmer prunes the cacao plantation. Yes = 1) | −0.017 | 0.045 | −0.380 | 0.705 |
| Fertilization (Farmer applies fertilizers in the cacao plantation. Yes = 1) | 0.043 | 0.047 | 0.910 | 0.366 |
| Irrigation (Farmer uses irrigation in the cacao plantation. Yes = 1) | −0.007 | 0.064 | −0.120 | 0.908 |
| Weed Control (Farmer controls weeds in the cacao plantation. Yes = 1) | −0.038 | 0.077 | −0.490 | 0.622 |
| Cacao Training (Household has received any cacao production training. Yes = 1) | −0.035 | 0.038 | −0.950 | 0.345 |
| Access to Extension Agent (Household has access to an extension agent. Yes = 1) | 0.031 | 0.046 | 0.670 | 0.503 |
| Association Membership (Head of household is part of a producer's association Yes = 1) | 0.026 | 0.053 | 0.500 | 0.617 |
| Intercropping (Farmer intercrops the cacao trees with other crops. Yes = 1) | −0.039 | 0.033 | −1.190 | 0.235 |
| Cacao Production (ton)[b] | −0.003 | 0.004 | −0.740 | 0.461 |
| Farmgate (Farmer sells cacao beans at the farmgate. Yes = 1) | 0.004 | 0.111 | 0.040 | 0.968 |
| Local Market (Farmer sells cacao beans at the local market. Yes = 1) | 0.070 | 0.092 | 0.770 | 0.443 |
| Wholesaler Warehouse (Farmer sells cacao beans to a wholesaler warehouse. Yes = 1) | 0.064 | 0.088 | 0.720 | 0.469 |
| Exporter Warehouse (Farmer sells cacao beans to an exporter warehouse. Yes = 1) | 0.167 | 0.133 | 1.260 | 0.209 |
| Sell to Association (Farmer sells cacao beans to an association. Yes = 1) | −0.371 | 0.116 | −3.200 | 0.002 |
| Use of Contract (Farmer sells cacao beans under a contract. Yes = 1) | 0.010 | 0.029 | 0.340 | 0.733 |

**TABLE D1** (Continued)

| Variable | Coefficient | SE | *t* | *p* > \|t\| |
|---|---|---|---|---|
| Know Market Price (Farmer knows cacao market price before sales. Yes = 1) | 0.108 | 0.031 | 3.480 | 0.001 |
| Distance to Buyer (km) | −0.001 | 0.001 | −1.690 | 0.093 |
| Transportation Costs (USD) | 0.003 | 0.002 | 1.760 | 0.079 |
| Days worked per week in the cacao farm | −0.015 | 0.013 | −1.140 | 0.254 |
| Number of people hired to work in the cacao farm | 0.000 | 0.000 | −0.860 | 0.390 |
| Canopy Use (Yes = 1)[b] | 0.304 | 0.059 | 5.160 | 0.000 |
| Constant | 0.183 | 0.174 | 1.050 | 0.293 |

*Note*: Number of observations = 340. No. of clusters = 15. $F(14, 305) = 209.15$. Prob > $F$ = 0.0000. $R^2$ = 0.5378. Adj.$R^2$ = 0.4863. Root mean square error = 0.3289.

[a]Coastal production zone is the omitted category.

[b]Instrument.