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IZA DP No. 18335

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ISSN: 2365-9793

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# ABSTRACT

## Quality Upgrading in Global Supply Chains: Evidence from Colombian Coffee*

Do the returns to quality upgrading pass through supply chains to primary producers? We explore this question in the context of Colombia's coffee sector, in which market outcomes depend on interactions between farmers, exporters (which operate mills), and international buyers, and contracts are for the most part not legally enforceable. We formalize the hypothesis that quality upgrading is subject to a key hold-up problem: producing high-quality beans requires long-term investments by farmers, but there is no guarantee that an exporter will pay a quality premium when the beans arrive at its mills. An international buyer with sufficient demand for high-quality coffee can solve this problem by imposing a vertical restraint on the exporter, requiring the exporter to pay a quality premium to farmers. Combining internal records from two exporters, comprehensive administrative data, and the staggered rollout of a buyer-driven quality-upgrading program, we find empirical support for the key theoretical predictions. The results are consistent with the hypotheses that quality upgrading can provide a path to higher incomes for farmers, but also that it is unlikely to be viable under standard market conditions in the sector.

**JEL Classification:** O12, F61, L23, Q12, Q13

**Keywords:** quality upgrading, relational contracts, vertical restraints, buyer-driven voluntary standards

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* This paper combines and supersedes two previously circulated papers, Macchiavello and Miquel-Florensa (2019) and De Roux et al. (2022). Without implicating them, we thank Oscar Bernal, Nancy Gonzalez, José Leibovich, and Yair Soto and the two unnamed exporters for facilitating data access. For comments and suggestions, we thank Rodrigo Adao, Pol Antras, David Atkin, Jie Bai, Lauren Falcao Bergquist, Daniel Björkegren, Laura Boudreau, Lorenzo Casaburi, Arnaud Costinot, Dave Donaldson, Marcela Eslava, Thibault Fally, Andrew Foster, Peter Hull, Michael Kremer, Gianmarco León, Farbizio Leone, Pierre Mérel, Suresh Naidu, Paulina Oliva, Patrick Rey, Martin Rotemberg, Chad Syverson, Chris Udry, Jose Vasquez, Sujata Visaria, and seminar participants at ASSA (x2), Banco de la República (CEARN), Banco de Mexico, Barcelona Summer Forum, Berkeley, Bocconi, BREAD, Brown, BU, Cambridge, Chicago, Columbia, Dartmouth, FAO, FIMAD, Harvard, HBS, HKU, IEA, IGC Firms/Trade/Development, Imperial, LSE, Lyon, Maryland, Michigan, MIT, Naples, Northwestern, Nottingham, Notre Dame, NYU, Penn State, Roma III, SciencesPo, Southampton, Syracuse, Tilburg, Toronto, TSE, U. de Los Andes, UBC, UCSD, UNIVPM, USC, US Census Bureau, Yale, World Bank, and WUSTL. Cristhian Acosta, Miguel Fajardo, Kyle Coombs, Yusuke Kuroishi, Sergio Montoya, Suanna Oh, Juan Quicana, and Pablo Warnes provided excellent research assistance. Funding from the ERC (Grant 818767), a SIPA faculty grant, and the IGC is gratefully acknowledged. All errors remain our own.

# 1 Introduction

A widely held view among policy-makers and development practitioners is that quality upgrading in agriculture is an effective way to reduce poverty. For instance, the International Coffee Organization (2020), the main international consortium of coffee producers, writes in its annual report, "Upgrading facilitates producers' access to high-value coffee markets and is often associated with higher farm income, since consumers pay a price premium for the higher quality." This view presumes both that there are rents from high-quality production — in the sense that the additional revenues exceed the additional production costs — and that these rents are shared with farmers. If this view is correct, then quality upgrading in agriculture has the potential to lift millions out of poverty, given that about 75% of the world's poor live in rural areas and earn their livelihood in agriculture.

In this paper, we evaluate this view in the context of the Colombian coffee sector. Market outcomes depend on a complex interaction between farmers (and their cooperatives), exporters (which operate mills to de-husk and sort beans), and international buyers (who purchase from the exporters), in a setting in which contracts over quality are for the most part not legally enforceable. We argue that quality upgrading in the sector is potentially subject to a hold-up problem: producing high-quality beans requires a set of long-term investments by farmers, but there is no guarantee that exporters will pay a premium for quality to farmers once the beans arrive at the mill gate. As a result, farmers may be reluctant to invest in raising quality. At the same time, the hold-up problem may be resolved if an international buyer is sufficiently willing to pay for a reliable supply of high-quality coffee. We develop a theoretical model with these features. A potential solution involves the buyer imposing a *vertical restraint* (Rey and Tirole, 1986) on the exporter, dictating not only the price at which the buyer purchases high-quality beans from the exporter but also the quality premium that the exporter pays to farmers. There exists a set of parameter values under which, in normal circumstances, an exporter would not be able to credibly promise a quality premium to farmers, but under which an international buyer could impose a self-enforcing vertical restraint that would ensure pass-through of quality premia and induce upgrading. Under such a vertical restraint, not only is there be greater production of high-quality coffee, but farmer incomes and welfare are higher than under standard market conditions.

Empirically, we assemble evidence from various sources, including the internal records of two large exporters, that the theoretical predictions — both the "negative" prediction that hold-up may prevent quality upgrading and the "positive" prediction that under certain circumstances the hold-up problem can be overcome by a contract involving a vertical restraint — are borne out in the data. Consider first the "negative" prediction. One of the exporters, which we refer to as Exporter 1 (E1), operates in a way that has long been standard among Colombian exporters. Although the company sells some coffee of the highest quality grade (referred to as *Supremo* in Colombia) and some coffee with special characteristics (e.g., organic, single-origin), it mostly sells what is known as *Usually Good Quality (UGQ)* coffee, which until 2016 was the minimum quality that could be exported from the country.[1] The internal records from the company allow us to track the price it pays farmers for the main input into its mills — "parchment" coffee (with dried hulls that must be removed, *pergamino* in Spanish) — as well as the shares of beans from each load of parchment that end up in exports of different quality levels and the prices of the export shipments. Using this information, we can calculate price/cost margins separately by quality grade. We show that the exporter's price/cost margins are indeed higher for higher-quality coffee but that it does not pay more for higher-quality parchment, conditional on being at least UGQ-grade. That is to say, the price premium for high-quality coffee is not passed through to farmers. Under such circumstances, farmers have no incentive to incur the additional costs required to produce *Supremo*-grade beans, even though those costs are below the quality premium paid for *Supremo* on international markets.

Turning to the "positive" prediction of how to overcome the hold-up problem, we examine the Sustainable Quality Program (hereafter "the Program"), which was implemented by a large international buyer ("the Buyer") and another Colombian exporter, which we refer to as Exporter 2 (E2). Exporter 2 mainly operates in a way similar to Exporter 1, and generally does not pay a premium for parchment quality above that required for UGQ. But beginning in 2007, Exporter 2 and the Buyer launched the Program, which provided training, seedlings and other inputs, required farmers to improve and

[1] UGQ, the standard export quality in Colombia, is already perceived as good relative to the exports of other countries and earns a "Colombia" premium on world markets.

certify their quality-management practices, and offered a quality premium to farmers for high-quality, *Supremo*-grade parchment. The Program was scaled up in two regions in the south of the country (Cauca and Nariño) beginning in 2008. The involvement of the Buyer — and the vertical restraint imposed on Exporter 2 by the Buyer — arguably made the commitment to pay the quality premium more credible than a commitment made just by an exporter would have been.

We evaluate the effects of the Program in two ways. First, we estimate simple difference-in-differences regressions using the timing of the Program rollout, comparing eligible areas to non-eligible areas — including non-eligible areas in the two regions where the Program was implemented. We bring together internal firm records from Exporter 2 (and an affiliated cooperative) and administrative data on the sector as a whole, which allow us to observe sales to and by Exporter 2, aggregate exports disaggregated by quality grade and region of origin, and production variables from the universe of Colombian coffee farms over a 10-year period. We find that Exporter 2 indeed paid a premium for *Supremo*-grade parchment, that the supply of *Supremo*-grade parchment in eligible areas increased, that farmers in eligible areas increased long-term investments in quality, and that the investments were undertaken especially by farmers with better and larger farms. Second, we estimate a dynamic discrete choice model in which a farmer decides whether to upgrade and join the Program. The model incorporates the main elements of the theoretical framework, is calibrated to the context, and shows that the mechanisms we highlight are quantitatively plausible explanations for the reduced-form patterns. The structural estimation also allows us to quantify the gains from the Program and how they are distributed between farmers and Exporter 2. We estimate that the Program increased surplus along the Colombian coffee chain by 8-18%, with farmers capturing 36-62% of those gains.[2]

Combining the reduced-form results from Exporter 1 and Exporter 2 and the results from the structural estimation, our findings point to two main conclusions. First, quality upgrading has the potential to raise farmer incomes; our estimates suggest that the Program spurred farmer upgrading and increased farmer welfare. Second, despite this potential, the empirical patterns from Exporter 1 suggest that quality upgrading is un-

[2] Although the Program was a bundle of interventions including farmer training and extension services, our calculations suggest that the vertical restraint is responsible for at least a third of the farmers' gains from the Program.

likely to be viable under standard market conditions in the sector, in the absence of a large international buyer with high willingness to pay for quality.

Our study contributes to several literatures. One is the literature on quality upgrading in developing countries, which includes Verhoogen (2008), Kugler and Verhoogen (2012), Artopoulos et al. (2013), Atkin et al. (2017a), Bai (2025) and, in agriculture, Saenger et al. (2014), Bernard et al. (2017), Bold et al. (2022), and Park et al. (2025). (See Saitone and Sexton (2010) and Verhoogen (2023) for reviews of the agricultural and non-agricultural literatures, respectively.) Our paper is distinctive in that we directly observe price premia and margins by quality and are able to document the lack of pass-through of quality premia along the chain under normal conditions. We also introduce a novel mechanism through which an international buyer's willingness to pay for quality can reduce distortions in the domestic portion of supply chains, helping to understand the mechanics of a large-scale quality-upgrading episode. Perhaps the closest paper is Hansman et al. (2020)'s study of vertical integration in the Peruvian fishmeal sector, which also focuses on how organizational arrangements can reduce contracting frictions and support quality upgrading, but through a different mechanism than we emphasize here.[3]

We also contribute to the literature estimating markups and markdowns in imperfectly competitive markets, which includes Atkin and Donaldson (2015), Bergquist and Dinerstein (2020), Rubens (2023), Dominguez-Iino (2024), Leone et al. (2025), and Avignon and Guigue (2022). Unlike traditional approaches (reviewed by De Loecker and Goldberg (2014)), we pursue an "insider econometrics" approach that leverages detailed internal records from two large firms and is closer in spirit to directly eliciting markups using surveys (see, e.g., Atkin et al. (2015)). Moreover, we overcome standard data limitations by directly matching the key variable input (parchment coffee) to the specific output sale. Cajal-Grossi et al. (2023) pursue a similar approach in the apparel sector without focusing on quality.

We also relate to the literature on contractual frictions and relational contracts in international (see, e.g., Macchiavello and Morjaria (2015), Blouin and Macchiavello (2019),

[3] In ongoing work, Bai et al. (2025) study the lack of transmission of quality premia along the coffee chain in Uganda. Through an ingenious combination of field experiments, they untangle the role of buyers' market power from differences in processing costs (especially in sorting beans) across different stages of the chain. Our paper differs in its focus on quality differences above the minimum export quality for Colombia, which is already high relative to typical quality levels in Uganda, and on long-term investments that farmers must make in order to improve bean quality at the high end of the quality spectrum (as opposed to sorting costs).

Antrás and Foley (2015), Startz (2025)), domestic (see, e.g., Brugues (2024)) and agricultural (see, e.g., Macchiavello and Morjaria (2021), Casaburi and Willis (2018), Casaburi and Macchiavello (2019)) supply chains. Our contribution is to interpret a large-scale, buyer-driven upgrading program through the lens of a model of a relational vertical restraint that spans multiple stages of the supply chain.

Finally, our analysis also contributes to the understanding of voluntary sustainable standards (VSSs) and buyer-driven supply-chain programs.[4] Despite their growing importance, there is limited evidence on the impact of such programs. Besides providing one such example, our model also provide a lens to interpret many buyer-driven supply-chain programs as vertical restraints. For example, a logic similar to that of the vertical restraint is at play in buyer-driven initiatives aimed at improving wages and working conditions in supplying factories. (See Boudreau (2024), Amengual and Distelhorst (2020), Distelhorst and Shin (2023) and Boudreau et al. (2023) for discussions.)

The rest of the paper is organized as follows. Section 2 provides background information on the sector. Section 3 describes the datasets we use and presents descriptive statistics. Section 4 presents the model. Section 5 presents reduced-form tests of the predictions of the model. Section 6 presents the structural analysis. Section 7 discusses alternative explanations, and Section 8 offers policy implications and concluding remarks.

# 2 Background

## 2.1 The Colombian Coffee Chain

Coffee is an important sector in Colombia, representing 13% of non-petroleum, non-coal exports. Colombia is the biggest world producer of the Arabica variety of coffee, and the third-largest global coffee producer after Brazil and Vietnam, which produce mainly the Robusta variety.

In Colombia, coffee is cultivated mostly by smallholder farmers — about 550,000 in total — with an average farm size of around 1.67 hectares. When coffee cherries turn red, they are ripe for harvest. The harvested cherries are then depulped and dried to produce "parchment" coffee. In Colombia, this step is undertaken by the farmers themselves. The

[4] See, e.g., De Janvry et al. (2015) and Dragusanu et al. (2022) on the Fair Trade certification in coffee, and Alfaro-Ureña et al. (2022) on the impact of responsible sourcing programs in Costa Rica.

dried parchment is then typically transported via a cooperative or intermediary to a centralized mill, referred to as a "hulling" or "dry" mill, which removes the husks to produce "green" beans. There are approximately 90 registered dry mills in the country, varying in installed capacity. These are typically operated by exporters. Upon arrival at the mill, a small sample is taken for quality analysis and the parchment is warehoused. Once a sales order is received, the parchment is dehusked and the green beans are sorted by size, weight, and defects; in Colombia, the sorting process is typically automated, using sorting machines and optical scanners. The graded coffee is then packed and shipped to a port for export or to domestic buyers.

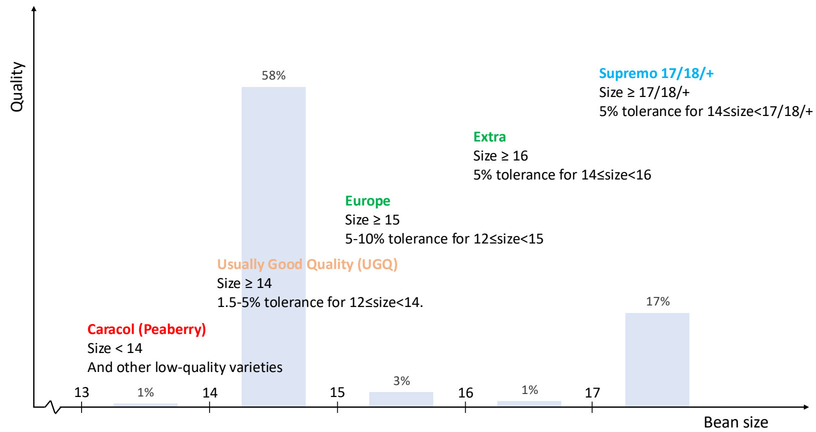
The national coffee federation, the *Federación Nacional de Cafeteros* (FNC), is a private, non-profit, producer-run organization that operates as a parastatal institution, performing public functions and managing public funds for the coffee sector. Some of these functions include price stabilization, quality control, and extension services. The FNC was the only trader and exporter until the collapse of the International Coffee Agreement in 1989, when the market was liberalized (Leibovich and Ocampo, 1985). The commercial arm of the FNC operates a number of mills and exports around 25-30% of all Colombian coffee; it behaves like a private firm. The next three largest private exporters have a combined market share of 25-30%. Together, the 10 largest exporters process about 80% of the production in a given season.

In addition to operating mills of its own, the FNC operates a number of programs. It implements the *Garantía de Compra* ("price guarantee") scheme, which offers all farmers the opportunity to sell parchment coffee at a publicly announced price. The guaranteed price is determined by a formula that links the international coffee price, the exchange rate, and the Colombian quality differential. To access this scheme, coffee can be delivered to one of the many buying points operated by regional cooperatives affiliated with the FNC. The FNC is also in charge of public extension services and agronomic research and manages several Voluntary Sustainability Standards (henceforth, VSSs), such as the Fair Trade and Rainforest Alliance certifications.

## 2.2 Quality Grades

The main "products" offered by Colombian exporters on world markets are grades (or "recipes") of beans that satisfy certain specifications for bean size, humidity, and share

## Figure 1. **Quality Grades**




Notes: The quality grades are taken from Federación Nacional de Cafeteros (2025), shown in Figure A1. Sizes are measured in 64ths of an inch. The bars represent the shares of each recipe in output from Exporter 1.

of defects. Bean size is the key dimension of quality, with bigger beans considered to be of higher quality. Figure 1 presents the main commercial grades for Colombian coffee. Throughout most of the sample period, grades with beans below size 14, often referred to as *Caracol* ("Peaberry"), could only be sold in the domestic market.[5] The most-exported grade is *Usually Good Quality (UGQ)*, with almost all beans of size 14 or larger. Several recipes referred to collectively as *European Preparations (EP)* require most beans to be size 15 or above. The *Extra* grade requires size above 16, and *Supremo* size 17 or above.[6] Note that, while bean size is the key dimension of quality, recipes may differ along other dimensions as well; all commercial grades put strict limits on moisture, but differ in terms of tolerance for defects and/or smaller beans. There is natural variation in bean size, and parchment coffee may have a small share of *Supremo*-grade or *Extra*-grade beans, even when farmers do not incur the higher costs generally required to produce high-quality beans.

As mentioned above, the main input to dry mills is parchment coffee. When a load of parchment first arrives at a mill, the mill takes a small sample (typically 250g) to measure quality. These samples are generally tested for the share of beans of at least size 14 (i.e.,

[5]Before 2016, Colombian regulations did not allow export of sub-UGQ grades. After 2016, their export was permitted, with a label distinct from the standard "Café de Colombia" label. Low-quality grades may also be referred to as *pasilla*, *ripio*, or *chorreado* in Spanish, depending on their contents.

[6]Exporters sometimes use additional recipes for specific buyers. A batch of coffee can also have other characteristics, for instance, organic, from a single origin, or conforming with voluntary sustainability standards (VSSs).

those meeting the minimum export requirement), the moisture content, and the number of defects. Long-standing convention in the industry is not to measure bean size above 14, although doing so would not be particularly costly.[7]

### 2.3 Production Issues

Consistently producing *Supremo*-grade coffee (with beans of size 17 and above) requires careful attention to farm management and harvesting practices.[8] The use of high-yielding Arabica varieties — in Colombia, mostly Bourbon derivatives such as Caturra and Colombia, hybrids bred for disease resistance — is essential, along with proper fertilization and pruning practices that promote uniform cherry development. Optimal shade and water management help to ensure slow and even ripening, contributing to bean size. It is considered best for trees to be between 3 and 8 years of age and for plot density be kept below about 5000 trees/hectare. Beyond routine pruning, farms must engage in regular stumping (cutting trees back to near ground level) and replanting (of new trees). Quality upgrading thus requires farmers to undertake long-term investments, as stumped trees and new trees produce little coffee for several seasons while they mature.[9]

Regarding harvesting practices, selective picking of fully mature cherries, rather than strip-picking (picking all cherries from a branch or tree at once), is critical to ensure that only the densest, largest beans are collected and to avoid harvesting cherries too early or too late, which jeopardizes bean quality. During the 2018-2020 harvest seasons, we conducted extensive interviews with agronomists, who estimated that producing 1 kg (parchment) of UGQ required roughly the following costs:[10] 1,076 Colombian pesos (COP)/kg for inputs (fertilizer, other materials) and plot maintenance labor; 1,546 COP/kg for harvest labor; and 201 COP/kg for post-harvest processing of cherries, which involves labor for drying and sorting and electricity to run the de-pulping machines. Producing one kg of UGQ thus incurred about 2,823 COP in variable costs. The agronomists

[7] This fact has been confirmed by extensive conversations with the two exporters and is widely acknowledged within the industry.

[8] See FAO (2002), TechnoServe (2021) and, specifically for Colombia, Puerta (2001) and Puerta et al. (2016).

[9] *Terroir*, i.e., the combination of soil and micro-climatic conditions, also contributes to bean size. For instance, higher altitude — typically above 1,200 meters — promotes slower cherry maturation, which yields larger and denser beans when combined with good farm management practices. The *terroir* also influences the taste ("cupping") profile of the coffee.

[10] Throughout the paper, monetary values are expressed in (December) 2015 Colombian pesos (COP) unless otherwise indicated. The exchange rate in December 2015 was approximately 3,200 COP/USD.

further estimated that producing *Supremo*-caliber beans required an additional 269 COP/kg in harvest labor and 34 COP/kg in cherry-processing labor. The additional variable cost for *Supremo*-grade production was thus approximately 300 COP/kg.[11]

## 2.4 The Sustainable Quality Program

The Sustainable Quality Program ("the Program") — led by a large international buyer ("the Buyer") — has the stated objectives of ensuring a sustainable supply of high-quality coffee and improving the livelihoods of farmers, while at the same time protecting the environment. Launched in 2003, the Program operated in 18 countries as of 2023 and included 168,500 participating farmers.

The Buyer and Exporter 2 piloted the Program in Colombia in 2004 in one municipality in the Caldas region.[12] In Caldas, a traditional coffee-producing area in the central Andes, the Program focused on upgrading capital-intensive post-harvest equipment on 158 larger farms, financing renovation of on-farm pulpers, fermentation tanks, and drying facilities. The focus of our analysis is the subsequent scale-up in two more remote regions in the Southwest, in Nariño in 2008, and then in Cauca in 2010. There, the Program was rolled out over time in nearly one thousand *veredas* — the smallest administrative unit in Colombia. In contrast to the initial pilot in Caldas, the Program in Cauca and Nariño focused on agronomic upgrading at the plot level, farmer training, and improvements in on-farm practices.

During our study period, the Program exclusively sourced *Supremo*-grade beans. On the supply side, the Program provided training, extension services, and access to seedlings for plot renewal. It also certified farmers who met a set of the relatively stringent conditions on farming practices. On the demand side, the Program included a commitment that Exporter 2 would purchase, at a specified price premium, all the coffee of certified farmers satisfying its quality requirements. The price premium was introduced during the pilot and promised a fixed COP value that the Program would pay above the FNC price-guarantee rate. The price premium was initially set at 400 COP/kg (in 2006, when the average FNC price guarantee rate was 3,727 COP/kg in current COP) and was raised to 600 COP/kg in 2015 (when the average FNC price guarantee rate was 5,731 COP/kg

[11] The agronomists' calculations are based on formal wages and may overstate labor costs for seasonal workers, who are mainly informal or family labor in remote, mountainous regions of Colombia.

[12] A contemporaneous pilot in the Huila region was aborted.

in current COP).The Program premium thus paid farmers around 10% above the guaranteed price, and exceeded the additional costs associated with producing *Supremo*-grade parchment estimated by agronomists described above in Section 2.3.[13] Figure D1 presents a photo of a chart (*pizarra* in Spanish) from a buying point, on which the base price and price premium were communicated to farmers. Program farmers had the option, but not the obligation, to sell to the Program. The Buyer committed to purchase all of the qualifying coffee sold to Exporter 2.[14]

The Program selected eligible *veredas*, comprising on average 70-80 small plots, based on *terroir* conditions. The Program was progressively rolled out in roughly 1,000 *veredas* in 33 municipalities in Cauca and Nariño.[15] (See Figure D2 for a map.) Once the Program was rolled out to a *vereda*, all farmers in the *vereda* were eligible to join the Program. During our sample period, roughly 72,000 plots became eligible to join the Program.[16] By the end of the sample period, 41% of eligible plots had joined. Figure D6 shows that about 30% of eligible plots joined in the first year after their *vereda* became eligible.

## 3 Data and Descriptive Statistics

In this section, we provide an overview of data sources; further details are in Appendix A. We use a variety of sources, in combinations that will be explained below.

1. *Exporter 1 production data:* From Exporter 1 (E1), we have production data that covers 2008-2018 and includes the following: information on purchases of parchment at the gates of the firm's mills (referred to as *entradas* ("entries")) along with the sample characteristics of each purchase; production records that map entries to milling orders (which may combine parchment from several entries) and that map milling

[13] Fluctuations in the base price affected the value of the price premium in proportional terms, but it tended to be near 10% over the sample period. The median value of the premium was 9.5% from 2006-2019.

[14] Regional cooperatives source coffee from farmers, while Exporter 2 is in charge of milling, preparation and export logistics. Together, these entities act as a single (quasi-)vertically integrated exporter. We will think of Exporter 2 and the regional cooperatives together as a single exporter that implements the Program, sourcing directly from farmers.

[15] A municipality in Colombia is an administrative division comprising several *veredas*; it typically has an "urban center" where main administrative and commercial services are located, for example bank branches and small convenience stores. It is also at the municipality center where the cooperatives and other buyers usually have their offices.

[16] Over time, the Program expanded beyond these initial clusters to other coffee-growing regions. These subsequent rollouts occurred after the end of our sample period.

orders to export batches (referred to as *lotes* ("lots") or *salidas* ("exits")); and information on the sale price, quantity, and characteristics of the export batches.

2. *Exporter 2 production data:* From Exporter 2 (E2), we have data on purchases (2006-2014) and prices, quantities, and characteristics of export batches (2006-2013). We also observe the sample characteristics of Exporter 2's purchases from 2009-2014. While Exporter 2's data do not allow us to map specific entries to specific export batches, they have the advantage that they cover the implementation of the Program.

3. *Transaction records from participating cooperative:* From one of the two regional cooperatives that participated in the Program, we have detailed transaction records for the 2015-16 and 2018-19 harvest seasons. These records contain the prices, quantities, and VSS indicators for farmers' sales to the cooperative. The 2015-2016 data are at the farmer-year-buying point level, the 2018-2019 data are at the transaction level.

4. *SICA:* The *Sistema de Información Cafetera (SICA)*, a database maintained by the FNC, contains information for all coffee farms in Colombia for the period 2006–2016. Variables include the location, size, and planted areas of plots, the tenancy status of the owner, the average age of trees, the density of planting (trees per hectare), the varieties planted (including the share that are resistant to coffee leaf rust (*roya*), a prevalent parasitic fungus), the shares of plots that are shaded, and the shares of plots renewed (planted or re-planted) in each year.

5. *PIC:* As part of the *Protección del Ingreso Cafetero (PIC)* Program (Coffee-Farmer Income Protection Program) from late 2012 to early 2014, the FNC collected information on all sales by farmers to cooperatives, traders, or private individuals, including information on prices, quantities and dates.[17]

6. *Export transactions:* For all export transactions, for all exporters, we have information on the selling firm, buying firm, prices, quantities, quality grades, VSS indicators, and dates, for the period 2006-2013.

[17] The PIC was a short-lived scheme implemented to support coffee growers when the guaranteed-purchase price fell below a minimum level. After selling their coffee and obtaining a receipt, farmers could claim a subsidy from the FNC equal to the difference between the transaction price and the scheme's minimum price. See Echavarria et al. (2017) for details.

7. *Mill-to-port transportation records:* The FNC maintains a permit system for domestic shipments from mills to ports. All mills are required to acquire permits, called *guías de tránsito* ("transit guides"), for each shipment. These records include information on the origin and destination of the shipment as well as weight and quality grade.[18] We observe these records for the period 2006-2014 and can match shipments to the export records.

Table 1 presents summary statistics from the internal production records from Exporters 1 and 2 over the 2009-2013 period, when output sales and input purchases, along with sample characteristics, are observed for both. The two exporters are similar in terms of both the composition and prices of their sales and the characteristics and costs of their inputs. *Supremo* accounts for roughly a sixth of E1's output and a fifth of E2's output. The average sale price of E1's green coffee output is slightly lower than that of E2 largely for this reason. When purchasing inputs of parchment coffee, both exporters test for similar bean characteristics, such as the share of beans above size 14 (the minimum requirement for export) and the share of beans with defects. The sample characteristics are similar, though E1 records a lower share of export-grade beans and pays a slightly lower, but comparable, price per kilogram than E2. For E1, we can additionally match inputs to outputs to construct margins earned on each entry of sourced parchment coffee, following the procedure described in Appendix A.2. E1 made an average margin of COP 750 (12%) per kilogram of parchment during the sample period.

## 4 Theoretical Framework

In this section, we present a simple model of the key hold-up problem in the coffee chain and how it can be overcome by a relational contract with a vertical restraint. To upgrade, farmers must undertake long-term investments, but they will not do so unless an exporter can credibly promise a sufficiently high quality premium in the future. We show that, under normal circumstances, the exporter might not be able to commit to a sufficiently high farm-gate premium, despite a substantial quality premium for exports. We then consider the entry of a large buyer with a high willingness to pay for quality; this

[18] The FNC's own shipments are not recorded in the *guías de tránsito*, but comparable information is recorded in the FNC's export records for its own shipments.

Table 1. **Descriptive Statistics, Exporters (2009-2013)**

| | Exporter 1 | | Exporter 2 | |
|---|---|---|---|---|
| | Mean | Sd | Mean | Sd |
| | (1) | (2) | (3) | (4) |
| **Output sales (Batch-level)** | | | | |
| Share Supremo | 0.16 | 0.36 | 0.20 | 0.40 |
| Price per kg (of green coffee) | 9,845 | 2,656 | 9,970 | 2,684 |
| N | 7,031 | | 29,058 | |
| **Inputs purchases (Entry-level)** | | | | |
| Sample share size ≥ 14 | 0.71 | 0.04 | 0.76 | 0.05 |
| Sample share defects | 0.03 | 0.01 | 0.04 | 0.03 |
| Cost per kg (of parchment coffee) | 6,621 | 1,918 | 7,266 | 1,366 |
| N | 23,981 | | 95,641 | |
| **Revenue and Margins (Entry-level)** | | | | |
| Revenues per kg (of parchment coffee) | 7,371 | 1,989 | | |
| Margin (Rpkg - Cpkg) | 750 | 502 | | |
| Margin ((Rpkg - Cpkg) / Cpkg ) | 0.12 | 0.09 | | |
| N | 23,981 | | | |

Notes: Table reports summary statistics for the 2009-2013 period. Monetary values are in December 2015 Colombian pesos (COP); the December 2015 COP/USD exchange rate was approximately COP 3,200/USD.

buyer can discipline the exporter through a vertical restraint, making the promise to pay a quality premium to farmers credible and thereby fostering upgrading.

We present the set-up and notation in Subsection 4.1. In Subsection 4.2, to build intuition, we first consider cases with static, one-shot interactions. We consider three such cases: a case with enforceable contracts and a competitive export market, prior to the entry of the large international buyer (Subsection 4.2.1), a case with enforceable contracts following the entry of the large international buyer (Subsection 4.2.2), and a case without enforceable contracts (Subsection 4.2.3). In Subsection 4.3, we turn to cases with repeated interactions (and without enforceable contracts), first the case with a competitive export market prior to the entry of the buyer (Subsection 4.3.1) and then the case following the entry of the buyer (Subsection 4.3.2). Derivations are in Appendix C.

## 4.1 Set-Up

There are two quality levels: standard and high quality, denoted by superscripts $L$ and $H$ respectively. We assume that the quality of both parchment and green coffee is observable to market participants. There is a unit mass of farmers, indexed by $i$. To produce coffee of standard quality, farmers incur constant unit harvesting and processing costs $c^L$. To produce high quality, farmer $i$ must incur a fixed upgrading cost $F_i \geq 0$ and higher variable cost $c^H = (1+\gamma)c^L$. Farmer $i$ has a plot of size $L_i$ and, for simplicity, produces $Q_i = L_i$ units of coffee. We assume that output per farm does not depend on the quality of beans produced by the farm.[19]

We assume that milling and exporting are undertaken by exporters. We assume that the market for standard coffee is perfectly competitive and that exporters make zero profits in the standard segment. The price of standard coffee in the world market, $p^L$, is taken to be exogenous. Let $\tau$ denote milling, processing, transport, and intermediation costs, as a share of the export price. The price that exporters are willing to pay for standard-grade parchment is then $w^L = (1-\tau)p^L$. We assume that high-quality coffee is traded by a monopsonist exporter. The exporter incurs costs $\tau$ identical to those of standard coffee, and sets a farm-gate price premium $\pi$ over the price of standard parchment, i.e. a farm-gate price $w^H = (1+\pi)w^L$.

The assumption that the market for standard coffee is competitive while the market for high-quality coffee is monopsonistic is stark and merits some discussion. It is plausible that exporters have some monopsony power in both segments, but the standard segment is subject to the *Garantía de Compra* ("price guarantee") mentioned above in Section 2.1, which effectively ensures the transmission of the world price $p^L$ to farmers, net of costs. In this sense, the standard segment seems reasonably well approximated by a competitive market and we believe that the additional insights from modeling both segments as monopsonistic would not be worth the required complications.

## 4.2 Static, One-Shot Interactions

Decisions are assumed to be taken in three stages. At stage $s = 1$, the exporter announces a farm-gate price premium $\pi$. At stage $s = 2$, farmers decide whether to invest and pro-

[19] In practice, when farmers upgrade their plots, both quality and yields tend to increase. For simplicity, we ignore the latter effect in the model, but we will consider it in the calibration below.

duce quality. At stage $s = 3$, harvest and sales are realized, and the exporter pays the farmers the announced price.

#### 4.2.1 Enforceable Contracts, before Entry of Large Buyer

In this case, in which the export market is assumed to be perfectly competitive, the world price of high-quality coffee can be taken as exogenous, $p^H$. Let $\eta^W$ be the corresponding premium relative to standard coffee, such that $p^H = (1+\eta^W)p^L$.

Given the farm-gate premium $\pi$, farmer $i$ upgrades if the total profit from doing so is greater than the total profit from producing standard coffee, that is, if $(w^H - c^H)Q_i - F_i \geq (w^L - c^L)Q_i$. Using the expressions for $w^H$ and $c^H$ from above, this will be the case if

$$F_i \leq (\pi w^L - \gamma c^L)Q_i \tag{1}$$

It is clear that the upgrading condition will be more easily met by farms with either low fixed upgrading costs, $F_i$, or larger areas, $L_i$ (equal to $Q_i$). This insight holds for all upgrading decisions under the various contracting regimes we consider.

Integrating over farmers yields the aggregate quality supply function $\mathbf{Q}(\pi, \vec{\sigma})$, where $\vec{\sigma}$ is a vector that includes $c^L$ and $\gamma$ as well as parameters governing the joint distribution of $F_i$ and $L_i$.[20] Let $\pi^{min} = \gamma c^L / w^L = \gamma c^L/(1-\tau)p^L$ be the minimum farm-gate premium that compensates farmers for the extra variable costs. We assume that $\eta^W > (1-\tau)\pi^{min}$ and $\mathbf{Q}(\pi, \vec{\sigma}) = 0$ for $\pi < \pi^{min}$.

The total profit earned by the exporter is $\mathbf{\Pi}^E = \mathbf{Q}(\pi, \vec{\sigma})p^L(\eta^W - (1-\tau)\pi)$. The quality premium that the exporter pays at the farm gate is the premium that maximizes $\mathbf{\Pi}^E$, i.e., $\pi(\eta^W) = \arg\max_\pi \mathbf{\Pi}^E$. In this case, it can be shown (*i*) that the resulting farm-gate premium, $\pi(\eta^W)$, and exporter's profits, $\mathbf{\Pi}^E(\eta^W)$, are increasing in the export-gate quality premium $\eta^W$, and (*ii*) that the exporter charges a markdown, setting $\pi(\eta^W) < \eta^W/(1-\tau)$, where the right-hand side represents the marginal benefit of one unit of high-quality parchment relative to a unit of standard parchment, i.e. the exporter does not pass through the full export premium to the farm gate.

[20]We assume that the joint distribution $G(F_i, L_i)$ has full support on $(0, \bar{F}]$ and $(0, \bar{L})$, where $\bar{F}$ and $\bar{L}$ are strictly positive upper bounds on fixed costs and land area, respectively.

### 4.2.2 Enforceable Contracts, after Entry of Large Buyer

We now consider the entry of an international buyer who places a value $(1+v)p^L$ on high-quality coffee, with $v > \eta^W$, implying that the buyer is more willing to pay for quality than the rest of the market. We assume that there remains a competitive fringe willing to pay $p^H$ for high-quality coffee. In this case, the buyer chooses an export quality premium, $\eta$, that may be higher than the competitive-fringe premium, $\eta^W$. At an initial stage, $s = 0$, the buyer makes a take-it-or-leave-it offer to the exporter, the exporter accepts or rejects, and then events unfold as in the previous case.

First, consider a constrained contracting space in which the buyer can only offer a linear contract with an export quality premium, $\eta^B$, and the exporter is free to choose the farm-gate quality premium, $\pi^E$. Taking into account the exporter's participation constraint (PC) and incentive constraint (IC), the buyer's problem is:

$$\eta^B = \arg\max_{\eta} \left\{ (v - \eta)\, p^L \mathbf{Q}(\pi^E(\eta)) \right\}$$

$$\text{s.t.} \quad \text{(IC)} \quad \pi^E(\eta^B) = \arg\max_{\pi} \mathbf{\Pi}^E(\cdot) \tag{2}$$

$$\text{(PC)} \quad \eta^B \geq \eta^W \tag{3}$$

The buyer has only one instrument, $\eta^B$, to achieve two goals: to induce upgrading and to extract rent. It can be shown that the resulting farm-gate premium, $\pi^B$, is inefficiently low and that the buyer leaves rents to the exporter (i.e., $\eta^B > \eta^W$).

In this situation, a vertical restraint (Rey and Tirole, 1986) — a contract specifying both an export premium, $\eta^R$, and a farm-gate premium, $\pi^R$ — can help the buyer.[21] The

[21] The European Commission defines vertical restraints as "agreements or concerted practices entered into between two or more companies each of which operates, for the purposes of the agreement, at a different level of the production or distribution chain, and relating to the conditions under which the parties may purchase, sell or resell certain goods or services." See Rey and Vergé (2008) for a review. Two alternative contracts could achieve similar outcomes but seem unlikely in practice. First, the buyer could offer a two-part tariff with a high export gate premium (to induce the exporter to set a higher farm-gate premium $\pi$), and a lump-sum transfer (to extract surplus). In practice, however, the exporter might default on the lump-sum payment, or be liquidity-constrained, and lump-sum payments are rarely used in international transactions (Spencer, 2005). Alternatively, the Buyer could contract on the volume of quality coffee to be delivered. Quantity contracts, however, are less desirable than vertical restraints when there are shocks, such as adverse weather, affecting supply (Rey and Tirole, 1986). In practice, a vertical restraint is a natural arrangement that allows the buyer to induce quality upgrading, circumventing the exporter's monopsony power.

problem becomes:

$$(\eta^R, \pi^R) = \arg\max_{\eta,\pi} \{(v-\eta)p^L \mathbf{Q}(\pi^R(\eta))\} \quad (4)$$
$$\text{s.t.} \quad \text{(PC)} \quad \mathbf{\Pi}^E(\pi,\eta) \geq \mathbf{\Pi}^E(\pi^E(\eta^W), \eta^W)$$

where the IC is removed by the vertical restraint. It can be shown that, by suppressing double marginalization, this contract results in a farm-gate premium $\pi^R$ that is larger than what the exporter would have chosen on its own. Despite having all the bargaining power at the contracting stage, the buyer offers $\eta^R > \eta^W$ to compensate the exporter (i.e., the participation constraint for the exporter (PC) binds).[22]

#### 4.2.3 No Enforceable Contracts

The static case without enforceable contracts needs to be considered only very briefly. In a one-shot interaction, once farmers have invested to produce quality at stage $s = 2$, the exporter can renege on the promised $\pi$ in stage $s = 3$. It follows immediately that the only subgame perfect equilibrium in the one-shot interaction entails no quality premium, $\pi = 0$, and no quality upgrading.

### 4.3 Repeated Interactions

Now suppose that although contracts are not enforceable by courts, interactions are repeated and relational contracts may be self-enforcing. Suppose that there are infinitely many seasons $t = 0, 1, \ldots$ and that all parties have a common discount factor $\delta$ across seasons. Within each season, the timing is as in the one-shot games above. We assume that farmers need to upgrade only once in order to produce high quality in all subsequent periods.

#### 4.3.1 Relational Contracts before Entry of Buyer

In this case, before the entry of the large buyer, the exporter takes the export quality premium, $\eta^W$, as exogenous. Under what conditions can a relational contract between the exporter and farmers be sustained? A relational contract between the exporter and

[22]While other contracts achieve the same outcome for the buyer, they are less desirable once realistic features are considered. See Section 6 for a discussion.

farmer $i$ is a plan that specifies $\mathcal{R}_i = \{\mathbf{I}^t_{H_i}, \pi^t_i\}^{\infty}_{t=0,1,...}$, with $\mathbf{I}^t_{H_i}$ an indicator function specifying whether farmer $i$ produces high quality or not for all future seasons, as a function of the past history of the game, $H^t_i$.[23] We assume perfect public monitoring between the exporter and all farmers.

In this case, a relational contract is self-enforcing if it constitutes a subgame-perfect equilibrium of the repeated game between the exporter and the farmer. We characterize the optimal relational contract that maximizes the exporter's profits. Before the beginning of season $t = 0$, the exporter offers a relational contract to each farmer $i$. Each farmer $i$ independently either accepts or rejects the offer, taking as given the actions of other farmers. If she rejects, both parties earn their outside option forever. If she accepts, the parties enter the relational contract.[24] We focus on the case in which the exporter cannot price discriminate, and at all periods offers $\pi^t_i = \pi^t$ to all farmers $i$. Furthermore, we focus on stationary relational contracts with grim-trigger punishments in which $\pi^t = \pi$ for all seasons $t$; we thus drop the $t$ superscript.

We define outside options for the exporter and for farmer $i$. There are two distinct outside options: before parties enter the relational contract, and following a deviation from either of the two parties after they have entered the relational contract. In both cases, we assume that the parties stop trading quality coffee with each other forever. We assume that if the exporter reneges on one farmer, all farmers punish the exporter. This implies that, if the exporter deviates, he does so by reneging on *all* farmers.

Farmer $i$ decides in season $t = 0$ whether to accept the relational contract and invest $F_i$ and then, conditional on having invested, whether to pay additional variable costs each season to deliver quality. The farmer will do the latter provided $\pi \geq \pi^{min}$. Farmer $i$ accepts the relational contract if $F_i \leq (\pi w^L - \gamma c^L) Q_i / (1 - \delta)$. Analogously to the static case, this yields an aggregate quality supply function $\mathbf{Q}(\pi, \vec{\sigma})$.

Along a stationary equilibrium path with a farm gate quality premium $\pi$, the exporter's per-period profit is equal to $[\eta^W - (1-\tau)\pi] p^L \mathbf{Q}(\pi, \vec{\sigma})$. The condition for the promised premium $\pi$ to be self-enforcing is the following:

$$\frac{1}{1-\delta}(\eta^W - (1-\tau)\pi) p^L \mathbf{Q}(\pi, \vec{\sigma}) \geq \eta^W p^L \mathbf{Q}(\pi, \vec{\sigma}) \tag{5}$$

[23] Note $H^t_i$ evolves within season $t$ as stages $s$ unfold. For simplicity, we omit this from the notation.

[24] When the farmer is indifferent, she is assumed to accept the offer.

where the left-hand side is the present discounted value of the stream of profits under the relational contract and the right-hand side is the current-period value of not paying the quality premium $\pi$. Denoting the per-unit continuation value along the equilibrium path as $\mathbf{V}(\eta^W,\pi) = \frac{\delta}{1-\delta}(\eta^W - (1-\tau)\pi)p^L$, it will be convenient to write the no-deviation condition as:

$$\mathbf{V}(\eta^W,\pi) \geq (1-\tau)\pi p^L \tag{6}$$

The exporter chooses the farm-gate quality premium, call it $\pi^D$, to maximize discounted profits, subject to this constraint:

$$\begin{aligned} \pi^D &= \arg\max_{\pi} \frac{1}{\delta}\mathbf{V}(\eta^W,\pi)\mathbf{Q}(\pi,\vec{\sigma}) \\ \text{s.t.} &\quad \mathbf{V}(\eta^W,\pi) \geq (1-\tau)\pi p^L \end{aligned}$$

We are now in a position to state our first proposition, which characterizes the region of the parameter space (in particular, of the common discount factor, $\delta$) over which relational contracts can be sustained.

**Proposition 1.** *There exist thresholds of the discount factor, $\delta^{\underline{E}}$ and $\delta^{\overline{E}}$, such that for $\delta \geq \delta^{\overline{E}}$, $\pi^D = \pi^E$; for $\delta \in (\delta^{\underline{E}}, \delta^{\overline{E}})$, $\pi^D$ is increasing in $\delta$; and for $\delta \leq \delta^{\underline{E}}$, $\pi^D = 0$.*

We have three cases. First, if players are sufficiently patient ($\delta \geq \delta^{\overline{E}}$), a relational contract is sustainable and the exporter offers the same quality premium as under the static case with enforceable contracts (Subsection 4.2.2). Second, for intermediate degrees of patience ($\delta \in (\delta^{\underline{E}}, \delta^{\overline{E}})$), a positive quality premium is sustainable at a level constrained by the discount factor. Third, if agents are sufficiently impatient ($\delta \leq \delta^{\underline{E}}$), a relational contract with a quality premium paid to farmers is not sustainable; the optimal strategy for the exporter is not to pass through the world quality premium. Intuitively, if the players are sufficiently impatient, the threat of future sanctions is not strong enough to induce the exporter not to renege once the parchment arrives at the mill, a promise to pay a quality premium would not be credible, and the farmer does not upgrade.

Below, in Section 5, we will present evidence that the third case, with $\delta \leq \delta^{\underline{E}}$, appears to be the empirically relevant one. Under business as usual in the sector, farmers are not offered a premium for beans above UGQ quality.

### 4.3.2 Relational Contracts after Entry of Buyer

Consider again the entry of an international buyer with high willingness to pay for quality, as in Subsection 4.2.2, but where now contracts are not externally enforceable and must be self-enforced by repeated interactions. We focus on the case where $\delta \leq \underline{\delta^E}$ and explore whether a relational contract with a vertical restraint between exporter and buyer can sustain high-quality production in this case.

Let $\widetilde{\eta}^R$ and $\widetilde{\pi}^R$ represent the quality premiums offered by the buyer to the exporter and by the exporter to the farmer, analogous to $\eta^R$ and $\pi^R$ in Subsection 4.2.2. We again assume the existence of a competitive fringe willing to pay $\eta^W$. As before, we assume that if the exporter reneges on the promised farm-gate premium in a given period, all farmers punish the exporter by no longer producing high quality (as in Subsection 4.3.1); here we further assume that the buyer punishes the exporter by not paying the promised export premium $\widetilde{\eta}^R$ in that period.[25,26] In addition, we assume that if the exporter decides not to sell to the buyer in season $t$, the buyer refuses to pay the export premium $\widetilde{\eta}^R$ thereafter. Under this assumption, it is straightforward to show that the side-selling deviation will always be less attractive to the exporter than reneging on the farm-gate quality premium; see Appendix C. The exporter's incentive compatibility constraint then becomes:

$$\mathbf{V}(\widetilde{\eta}^R, \widetilde{\pi}^R) \geq ((\eta^W - \widetilde{\eta}^R) + (1-\tau)\widetilde{\pi}^R)p^L \tag{7}$$

The buyer chooses the relational vertical restraint $(\widetilde{\eta}^R, \widetilde{\pi}^R)$ to maximize her discounted profits. Let $\mathbf{Q}(\widetilde{\pi}^R, \vec{\sigma})$ denote the quantity of high-quality coffee delivered when the exporter promises $\widetilde{\pi}^R$ to farmers and the relationship is on the equilibrium path, as above. Denoting the per-unit continuation value for the buyer along the equilibrium path as

[25] The buyer would also be unwilling to pay the export premium in future periods, but the threat is moot once farmers stop producing high quality.

[26] In the empirical application we present below, the buyer deploys personnel in the field and makes announcements at the buying points, implicitly monitoring whether the exporter pays the promised quality premium, $\widetilde{\pi}^R$. While the assumption of perfect monitoring may appear strong, the qualitative insights of the model carry through if the buyer only observes deviations with some positive probability.

$\mathbf{B}(\tilde{\eta}^R, \tilde{\pi}^R) \equiv \frac{\delta}{1-\delta}\Big[\big(v - \tilde{\eta}^R\big)p^L\Big]$, the buyer solves:

$$
\begin{aligned}
(\tilde{\eta}^R, \tilde{\pi}^R) \;\in\; \arg\max_{\tilde{\eta},\tilde{\pi}} \quad & \frac{1}{\delta}\mathbf{B}(\tilde{\eta},\tilde{\pi})\mathbf{Q}(\tilde{\pi}^R, \vec{\sigma}). \\
\text{s.t.} \quad & \mathbf{V}(\tilde{\eta},\tilde{\pi}) \;\geq\; \Big[\big(\eta^W - \tilde{\eta}\big) + (1-\tau)\tilde{\pi}\Big]p^L \qquad \text{(Exporter IC)} \\
& \mathbf{B}(\tilde{\eta},\tilde{\pi}) \;\geq\; \Big[\big(\tilde{\eta} - \eta^W\big)p^L\Big] \qquad \text{(Buyer IC).}
\end{aligned}
\tag{8}
$$

The first constraint (Exporter IC) corresponds to (7) and ensures that the exporter prefers to comply with the relational contract — i.e., pay $\tilde{\pi}^R$ to farmers and sell to the buyer at $\tilde{\eta}^R$ — rather than (i) short-changing farmers or (ii) side-selling at the world premium $\eta^W$. Comparing constraints (6) and (7) reveals that the vertical restraint relaxes the Exporter's commitment problem with the farmers, provided $\eta^W < \tilde{\eta}^R$. The second constraint (Buyer IC) ensures that the buyer is also willing to pay the exporter the promised premium today, rather than reneging on her promise and paying the premium $\eta^W$ but then forfeiting future relational access to high-quality supply.

**Proposition 2.** *There exists a threshold $\delta^R < \delta^{\underline{E}}$ such that, for $\delta \in (\delta^R, \delta^{\underline{E}})$, $\tilde{\pi}^R > \pi_{min}$.*

In other words, if $\delta \in (\delta^R, \delta^{\underline{E}})$, then a relational contract between the exporter and farmers without the buyer is not feasible (since $\delta < \delta^{\underline{E}}$; see Proposition 1), but once the buyer enters a relational contract with positive farm-gate quality premium can be sustained. While no farm-gate premium $\pi \geq \pi_{min}$ can be credibly promised without the buyer, the vertical restraint imposed by the buyer makes possible a farm-gate premium that induces upgrading.

It turns out that the farm-gate quality premium offered under the relational contract with the vertical constraint can be rationalized as the premium that maximizes a weighted average of the exporter's and farmers' payoffs. Let $\vec{\theta}$ be the vector of parameters that are either directly observed or can be estimated. These include the world price $p^L$, the exporter's cost, $\tau$, the parameters governing farmers' supply and upgrading decisions ($\vec{\sigma}$), and the discount factor $\delta$. Then we have:

**Proposition 3.** *In an interior solution, for each export gate premium $\eta$, there exists a $\lambda \in$*

$[0,1]$ *s.t.* $\widetilde{\pi}^R(\vec{\theta}, v) = \pi^*(\vec{\theta}, \lambda, \eta)$ *with:*

$$\pi^*(\vec{\theta}, \lambda, \eta) = \arg\max_{\pi} \left\{ \lambda \mathbf{\Pi}^E(\pi, \eta; \vec{\theta}) + (1 - \lambda) \mathbf{W}^F(\pi; \vec{\theta}) \right\} \tag{9}$$

*where* $\mathbf{\Pi}^E$ *and* $\mathbf{W}^F$ *are the exporter's and farmers' discounted payoffs.*

The parameter $\lambda$ can be interpreted as a conduct parameter that rationalizes the observed $\widetilde{\pi}^R \equiv \pi^*$, given $\widetilde{\eta}^R$, the exporter's profit function, and the farmer's payoff function. This will be useful when we seek an empirical test for the presence of the vertical constraint.

### 4.4 Testable Implications

The simple framework generates a number of testable implications. We focus on the case where $\delta \in (\delta^R, \underline{\delta^E})$, which appears to be the empirically relevant case, in a setting in which contracts are not enforceable. For this range of discount rates, we have the following implications.

**1.** In the business-as-usual regime, the framework predicts:

(***a***) There is a quality premium on the export market that could compensate farmers for higher variable costs of producing high quality, $\eta^W > \pi^{min} > 0$.

(***b***) The exporter does not pay a quality premium to farmers, $\pi^D = 0$.

**2.** Under the (relational) vertical restraint regime, the framework predicts:

(***a***) The exporter receives a larger quality premium from the buyer than on the broader export market, $\widetilde{\eta}^R > \eta^W$.

(***b***) The exporter pays a quality premium to farmers, $\widetilde{\pi}^R > \pi^{min}$.

(***c***) The aggregate supply of high-quality coffee is greater than under the business-as-usual regime.

(***d***) Farmers undertake greater long-term investments than under the business-as-usual regime.

(***e***) Among farmers, those with better (lower $F_i$) and larger (higher $L_i$) farms are more likely to upgrade. (Refer to equation (1).)

(***f***) The farm-gate quality premium maximizes a weighted average of the exporter's and farmers' payoffs ($\lambda < 1$).

These are the testable implications we will take to the data in the remainder of the paper.

# 5 Reduced-Form Evidence

In this section, we draw on the rich combination of datasets we have assembled to present reduced-form evidence on the testable implications of our theoretical framework. In Subsection 5.1, we use data from Exporter 1 to characterize pass-through of quality premia in the business-as-usual regime. In Subsection 5.2, we use data from Exporter 2 and other datasets to examine the impact of the Sustainable Quality Program (the Program), which includes a vertical restraint.

## 5.1 Business-As-Usual Regime

Using data from Exporter 1 (E1), we address two questions: (1) Are margins higher for higher-quality exports (Prediction 1a)? (2) Does the exporter fail to pass the margins through to producers (Prediction 1b)? Drawing on E1's production records, we observe export quality premia directly and can calculate E1's price/cost margins by quality grade. The production records allow us to map from entries of parchment coffee to milling orders and from milling orders to exported batches of green coffee.[27] We observe the quality grade of each export batch. Using this information, we can infer the share of beans of each quality grade in each entry, under an assumption of similar quality composition within the set of entries in each milling order (explained in more detail in Appendix A.2). Through this process, we infer the shares of different quality grades produced and the revenues generated for each of roughly 75,000 entries. We exclude entries with special characteristics (e.g., organic or single-origin), since their more sporadic milling yields a potentially noisier match, leaving us with roughly 54,000 entries, representing 83% of the coffee sourced by weight. (Results are robust to the inclusion of the entries with special characteristics.)

[27] Although the data report a mapping from individual entries to individual milling orders, the information is most reliable when pooled over a short window of time. (Detailed conversations with personnel at the mills support this view.) Hence, when mapping from entries to milling orders to export batches, we treat all parchment milled in a given week as part of the same milling order.

At the entry level, we regress the log of revenue per kilogram, the log of purchase cost per kilogram, and the log of price/cost margin per kilogram — where margin is defined as the ratio of price to cost — on a vector of coffee characteristics.[28] Specifically, we estimate:

$$\ln Y_{esrt} = \beta_0 + \underbrace{\sum_{j \in J} \beta_j R^j_{esrt}}_{\text{Quality Grade \%}} + \underbrace{\sum_{m \in M} \beta_m S^m_{esrt}}_{\text{Sample Characteristics}} + \mu_s + \mu_{rt} + \epsilon_{esrt} \qquad (10)$$

where $\ln Y_{ert}$ is one of the outcomes mentioned in the previous sentence, for entry $e$ sold by supplier $s$ in region $r$ at time $t$. The variables $R^j_e$ reflect the shares of the entry that end up in various quality grades $j \in J$. We report coefficients for *Caracol* (Peaberry), *EP/Extra*,[29] and *Supremo*, with UGQ as the excluded category. The sample characteristics, $S^m_e$, include the measurements taken for each entry at the time it arrives at the mill: the sample share of beans above size 14, the sample share of size between 13 and 14, the sample sample share of size <13, share waste material (husks removed during milling), the sample moisture rate, and the sample disease rate.[30] We also include supplier fixed effects, $\mu_s$, and time-region fixed effects, $\mu_{rt}$, where time corresponds to the year-month (or the exact date) of the output sale. Standard errors are clustered by year-month and supplier in all specifications.

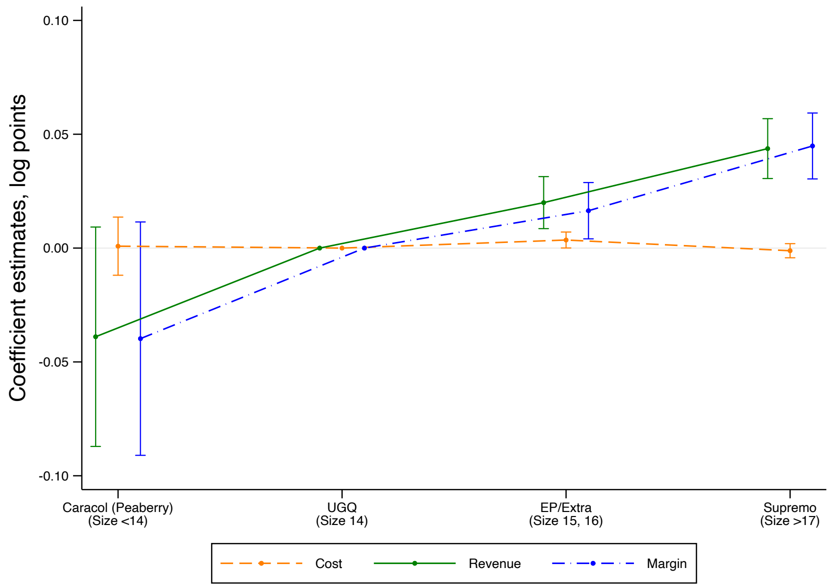
The full estimates of equation (10) are reported in Appendix Table B1. Figure 2 displays the key coefficient estimates, the $\widehat{\beta}_j$ corresponding to different quality shares. The coefficients in green correspond to regressions with E1's revenue per kilogram of each entry as the dependent variable and indicate that quality premia for exports indeed increase with quality grade. Low-quality *Caracol* varieties earn lower revenues than UGQ, *European Preparation (EP)* and *Extra* varieties earn higher revenues, and *Supremo* earns the highest revenues. The estimates in Column 6 of Appendix Table B1 indicate that, on average, E1 earns a premium of 4.5% per kilogram of parchment yielding *Supremo* grade, relative to UGQ grade. We will see below in Subsection 5.2.1 that we estimate a remarkably similar premium for E2.

[28] In this context, margins do not account for other variable costs (e.g., labor and electricity). However, since we are interested in average comparisons across quality grades, those can be safely held constant across different entries, controlling for mill-time fixed effects.

[29] There are relatively few export batches in the European Preparation and Extra grades. We pool recipes with these grades to increase precision.

[30] The sample shares by size and the share waste material sum to 1; we treat the share of beans <13 and the share of waste material together as the excluded category. The moisture rate and disease rate are included separately.

Figure 2. **Prices, Costs, and Price/Cost Margins by Quality Grades**




Notes: The Figure reports estimated coefficients on quality grade shares and 95% confidence intervals from regressions of the form of equation (10), from Columns 3, 6, and 9 of Appendix Table B1. The dependent variables in the regressions are (log) price, cost, and price/cost margin.

The coefficients in orange correspond to regressions with E1's log purchase cost per kg for parchment as the dependent variable. We find no evidence that the cost of parchment coffee to the firm increases with the share of beans of higher-quality grades, conditional on the sample characteristics measured on arrival at the mill. As can be seen in Appendix Table B1, E1 pays higher prices to suppliers for entries that have better sample characteristics: entries with a higher share of beans above size 14 and lower moisture and defect rates are paid more. The F-tests for the joint significance of the coefficient on these measures are about 17-19, depending on the specification. But conditional on the sample characteristics, E1 does not pay higher prices for parchment that ends up in higher-quality grades. The F-tests for the joint significance of the coefficients on the quality shares are approximately 1.5. It is worth noting that E1's purchase costs represent the price paid at the mill gate to the suppliers of parchment coffee. These are predominantly intermediaries, such as cooperatives and traders (91%), rather than farmers (9%). Given that these intermediaries do not receive a price premium for higher-quality beans, it is natural to infer that they do not pay a price premium to farmers.

The coefficients in blue correspond to regression with E1's (log) price/cost margins as the dependent variable. These coefficients are almost exactly equal to the export price coefficients (green) minus the purchase cost coefficients (orange). We see clearly that price/cost margins are higher for higher-quality grades. Note that the quality shares correlate strongly with price/cost margins (F-tests approximately 16), but the sample characteristics (which are already captured in purchase cost) do not (F-tests about 1.2-1.5).

The patterns presented in this subsection are consistent with Predictions 1a and 1b of our model under the business-as-usual regime discussed in Subsection 4.3.1 above. There is clear evidence of a premium for *Supremo* on the export market, $\eta^W$ (Prediction 1a). The premium also appears to be high enough to compensate farmers for the additional variable costs of producing *Supremo*-caliber beans, i.e., $\eta^W > \pi^{min}$ (Prediction 1b). In particular, during the period of Program implementation, the premium earned by E1 was roughly 440 COP per kg of green coffee based on the average sale price in Table 1 (i.e., 9,845*.045).[31] In Subsection 2.3, we reported, based on detailed conversations with agronomists, that the additional variable costs associated with producing *Supremo*-caliber beans are approximately 300 COP per kg of parchment. Once the husk is removed, 1 kg of parchment yields approximately 0.8 kg of green coffee. The additional cost of producing on additional kg of *Supremo* green coffee is thus approximately 375 COP (i.e., 300/.8), which is less that then 440 COP/kg premium we estimate. When coffee prices are low, the 4.5% premium could potentially fall below the level necessary to compensate farmers, but during the period of Program implementation the premium was large enough to support our assumption that $\eta^W > \pi^{min}$.

## 5.2 Program Regime

We now consider reduced-form empirical patterns under the Sustainable Quality Program, which was rolled out by the Buyer and Exporter 2 in two regions (Nariño and Cauca), and included a vertical restraint. We consider quality premia for exported green coffee and for parchment in Subsections 5.2.1 and 5.2.2, the aggregate supply of *Supremo* coffee in Subsection 5.2.3, and farmer-level upgrading responses in Subsection 5.2.4.

[31] We estimate a very similar premium for E2 in Subsection 5.2.1.

### 5.2.1 Export Quality Premia

The information available for Exporter 2 is not exactly the same as the information available for Exporter 1. In particular, we cannot match entries at the mill gate with batches at the export port to compute the price/cost margins earned on each entry. But we do observe transaction data with quality grades at the port, which we can use to measure the export quality premium and test Prediction 2a from above.[32] We also observe transaction-level data of purchases from farmers for one of the two cooperatives that implemented the Program. This allows us to estimate the farm-gate premium under the Program.

Using the transaction-level data on all exports by Exporter 2 for the period 2006-2013, we estimate:

$$ln(P^e_{bctod}) = \beta_0 + \varphi^W S_b + \varphi^R PR_b + \gamma_{my} + \gamma_o + \gamma_d + \gamma_c + \varepsilon_{bcto}, \tag{11}$$

where $P^e_{bctod}$ is the per-kg price for export batch $b$, produced with coffee from origin region $o$, and exported to destination market $d$, in month $m$ or year $y$. The coefficients $\gamma_{my}$, $\gamma_o$, $\gamma_d$ capture month-year, origin, and destination fixed effects. In some specifications, we include contract-terms fixed effects $\gamma_c$, and interactions of $m$ and $y$ fixed effects with $d$ and $o$ fixed effects, to account for potentially heterogeneous seasonality conditions across origins and destination markets. Finally, $\varepsilon_{bctod}$ is an error term which we allow to be arbitrarily correlated across batches exported in a given year from a given origin. The key variables of interest are $S_b$, a dummy that takes the value equal to one for batches of *Supremo* grade, and $PR_b$, a dummy that takes the value equal to one for export batches sold to the Buyer. Recall that the Buyer only buys *Supremo* grade. The coefficient $\varphi^R$ thus captures the premium paid for *Supremo* under the Program above and beyond the market premium for *Supremo*. The overall premium paid by the Buyer relative to UGQ-grade (the omitted category) is thus given by the sum of the estimated coefficients $\varphi^W$ and $\varphi^R$.

Table 2 reports the results. Across specifications that vary in the granularity of included controls, Exporter 2 earned on average a 4% premium for *Supremo* coffee relative to UGQ-grade. This is remarkably similar to the estimate for E1, documented in Section

[32]We also observe entry-level transaction data. These confirm that E2 has a pricing policy similar to E1 for non-Program coffee.

5.1 above. The Program premium reflected the market premium for *Supremo* coffee, the compensation to the exporter for the vertical restraint, and potentially other attributes (e.g., reliability of supply). The Program paid a premium of about 13-14% more than the market premium for *Supremo* coffee — i.e., an overall premium of around $17\%$, relative to UGQ-grade. This estimate is conditional on detailed contractual terms, as well as origin and destination-specific season and seasonality effects.

We also explore whether the Program altered the premium Exporter 2 earned for *Supremo* grade not sold under the Program. One could be concerned that the Program's large demand for *Supremo*-grade coffee altered the price Exporter 2 received from other buyers. For example, other buyers might have paid more (as *Supremo*-grade parchment not committed to the Program became scarcer), or less (as supplying the Program's buyer made it harder for farmers to reliably supply *Supremo*-grade parchment to other buyers and hence to earn a premium for reliability). Column 4 includes an interaction term between the *Supremo* dummy and $post_{ot}$, a dummy that takes the value equal to one for batches exported from Program regions $o$ after its rollout.[33] We find no effect, consistent with the Program having created its own supply of *Supremo*-grade parchment.

### 5.2.2 Farm-Gate Quality Premia and the Program Purchase Commitment

The Program established a vertical restraint: a farm-gate price premium for Program farmers that delivered beans that met the Program's quality requirements and a commitment to buy such beans. To ensure that the exporter in fact conformed with the vertical restraint, several enforcement mechanisms were put in place. For example, large and visible posters at the participating cooperatives' buying points informed farmers of the Program's price premium, while Program extension officers kept regularly in touch with Program farmers, reminding them of the Program's quality requirements and premium. This raised the probability that farmers were aware of the price they were supposed to receive for sales under the Program. Nevertheless, it is an empirical question whether the vertical restraint was honored by Exporter 2. There are two separate aspects to this question: (1) Was the quality premium paid for parchment?, and (2) Was all eligible coffee purchased? We tackle the two questions in turn.

[33] We define rollout as occurring in 2008 in Nariño and 2010 in Cauca, reflecting the timing of the large expansions in these two regions shown in Figure D5)

Table 2. **Export Quality Premia, Exporter 2 Data**

| | Export Gate Price per Kg (log) | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Supremo | 0.051*** | 0.037*** | 0.040*** | 0.041*** |
| | (0.009) | (0.006) | (0.006) | (0.006) |
| Program Batch | 0.210*** | 0.133*** | 0.142*** | 0.148*** |
| | (0.014) | (0.022) | (0.030) | (0.034) |
| Supremo x Post | | | | -0.013 |
| | | | | (0.015) |
| Year-month FE | Yes | Yes | No | No |
| Country FE | Yes | Yes | No | No |
| Mill FE | Yes | Yes | No | No |
| Country-year-month FE | No | No | Yes | Yes |
| Mill-year-month FE | No | No | Yes | Yes |
| Contract conditions | No | Yes | Yes | Yes |
| R2 | 0.81 | 0.82 | 0.87 | 0.87 |
| Obs. | 44,874 | 44,874 | 44,874 | 44,874 |

Notes: Table estimates export premia for *Supremo*-grade (non-Program) batches and for Program batches (which are also *Supremo-grade*) from Exporter 2 internal records. The unit of observation is an export batch and the dependent variable is the (log) export gate price per kg. The sample covers all E2 export transactions over the period 2006-2013, excluding specialty coffee. *Supremo* is a dummy taking the value equal to one if the batch is of *Supremo*-grade. Program Batch is a dummy taking the value equal to one for batches exported under the Program. Post is a dummy taking the value one for batches originating from the Program regions after the Program's rollout (2008 in Nariño, 2010 in Cauca). Contract conditions controls include quantity, transaction volume, exchange rate, port of departure, and terms of payment. Robust standard errors (clustered by year-mill) in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

We use two different sources of data from one of the cooperatives implementing the Program. The first one covers the years 2015 and 2016, and contains aggregate quantities and average prices of yearly sales of standard (i.e., UGQ-grade) parchment, Program-eligible parchment, and parchment sold under other VSSs for each farmer. The second source covers has similar information for 2018 and 2019, but at the *transaction* level.

In 2015-2016, the Program price premium was 600 COP/kg and the FNC base price averaged 6,185 COP/kg (in current COP). In 2018-19, the Program price premium was maintained at 600 COP/kg and the FNC base price averaged 6,114 COP/kg (in current COP). The Program price premium was thus approximately 10% in both periods. The data allow us to directly verify whether Program farmers were paid this higher premium. We estimate a regression of the form:

$$ln(P^f_{sfoy}) = \beta_0 + \pi^R PR_{sfoy} + \gamma_{oy} + \gamma_f + \varepsilon_{sfoy} \quad (12)$$

Table 3. **Farm-Gate Quality Premium**

| | Sample (2015-16) | | | Sample (2018-19) | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Program Sales | 0.092*** | 0.092*** | 0.092*** | 0.107*** | 0.106*** | 0.106*** |
| | (0.008) | (0.009) | (0.010) | (0.007) | (0.008) | (0.009) |
| Origin-year FE | Yes | Yes | Yes | No | No | No |
| Origin-month-year FE | No | No | No | Yes | Yes | Yes |
| Farmer FE | No | Yes | No | No | Yes | No |
| Farmer-year FE | No | No | Yes | No | No | Yes |
| R2 | 0.55 | 0.70 | 0.75 | 0.79 | 0.82 | 0.83 |
| Obs. | 26,942 | 26,942 | 26,942 | 191,526 | 191,526 | 191,526 |

Notes: The data for this table comes from farmer sales to one of the implementing cooperatives. Dependent variable is the log price at the farm gate. Prices are expressed in 2015 COP. Columns 1-3: Unit of observation is farmer-year-buying point-Program status and time period is 2015-2016; sample includes 10,134 farmers. Columns 4-6: Unit of observation is a transaction and time period is 2018-2019; sample includes 34,497 farmers. Robust standard errors (clustered by buying point-year) in parentheses *** p<0.01, ** p<0.05, * p<0.1.

where $Price_{sfoy}$ denotes the per kilo price paid by the cooperative to farmer $f$ for coffee sold under line $s$ delivered at buying point (origin) $o$ in season $y$. The specifications include origin-year fixed effects ($\gamma_{oy}$) or origin-month-year ($\gamma_{omy}$) depending on the sample. Coffee lines $s$ can either be standard sales, sales through the Program, or sales under the various VSSs farmers can sell to (conditional on their certification status). The dummy $PR_{sfoy}$ takes the value 1 for parchment sold under the Program and 0 for non-Program parchment.

Table 3 reports estimates of regressions of the form of equation (12). In Columns 1-3, for 2015-2016, we calculate average prices at the farmer-year-buying point level for Program and non-Program sales and stack observations, so the unit of observation in the regressions is farmer-year-buying point-Program status. In Columns 4-6, for 2018-2019, the data are at the transaction level. Columns 1 and 4 do not control for farmer fixed effects, thus identifying from across-farmer variation; Columns 2 and 5 control for farmer fixed effects; and Columns 3 and 6 controls for farmer-season fixed effects, thus identifying from Program farmers that, in a given season, do not sell all their coffee to the Program. We see that within origin-year (or within origin-month-year) Program sales received approximately 10% higher prices, with the estimates remarkably stable across samples and specifications.

We also verify that, as intended, the Program purchased essentially all of the Program farmers' production. Figure D3 reports the distribution of the share of Program farmers' deliveries sold under the Program, relative to the farmers' total sales to the cooperative. Across farmers, the average share sold under the Program is 86.4% in the 2015-16 sample and 97% in the 2018-19 sample.

Because the data in Table 3 are from one of the implementing cooperatives, they do not include Program farmers' sales to other buyers. One might be concerned that the implementing cooperative did not accept — e.g., because of low quality — a substantial share of Program farmers' deliveries, forcing them to sell to other buyers. Data from the *Protección del Ingreso Cafetero (PIC)* Program captures all farmers' sales during the 2012-2013 growing season, and assuages this concern. Figure D4 shows that Program farmers sold almost their entire production to the implementing cooperative. Numerous conversations in the field suggest that this was indeed the case throughout the Program's implementation. Note that farmers had little incentive to side-sell, given the absence of a farm-gate premium for *Supremo*-caliber parchment in the rest of the market. Note further that the Program gave farmers the option, but not the obligation, to sell to the Program. The Program farm-gate premium provided a lower bound to the gains for the farmers; if Program farmers found it profitable to sell eligible coffee to other buyers, revealed preference suggests that it must have been at a higher price.

Taken together, these results confirm that farmers were able to sell coffee to the Program at the announced price premium, consistent with Prediction 2b from our model. The Program consistently paid a substantial farm-gate premium to farmers and fulfilled its commitment to purchase all eligible production from them. This stands in contrast to most NGO-driven VSSs, for which only a small share of certifiable coffee is generally sold at the corresponding nominal premium. (See De Janvry et al. (2015); Elliott (2018) for a discussion.)

#### 5.2.3 Aggregate Quality Supply from Program Regions

We now test whether the aggregate supply of high-quality coffee increased in areas in which farmers were eligible to join the Program (Prediction 2c). We do this in two ways. First, we consider aggregate sales of coffee by quality category on export markets, using data on transactions for *all* Colombian coffee exports. These data include information on the quality and the region of origin of the exported coffee. This allows us to examine changes in the aggregate production of high-quality coffee across regions over time.

Table 4. **Aggregate Quality in Export Data**

| | | Supremo Exports | | |
|---|---|---|---|---|
| | Exports to Buyer | E2 | Other | Total |
| | (1) | (2) | (3) | (4) |
| Post × Program Region | 2.820*** | 2.921** | -0.279 | 2.642 |
| | (1.085) | (1.260) | (1.573) | (1.937) |
| Year FE | Yes | Yes | Yes | Yes |
| Region FE | Yes | Yes | Yes | Yes |
| Mean 2006 | 0.10 | 0.65 | 4.11 | 4.76 |
| Controls | Yes | Yes | Yes | Yes |
| R2 | 0.86 | 0.82 | 0.94 | 0.94 |
| Obs. | 96 | 96 | 96 | 96 |

Notes: The unit of observation is a region-year. Across columns, the dependent variables are: volume of exports (in million of kgs) bought by the Buyer (which only buys *Supremo*), volume of *Supremo* exports by E2 (including to other buyers), volume of *Supremo* exports by other exporters, and volume of *Supremo* exports by all exporters, respectively. Post × Program Region is a dummy variable that takes value 1 in the years after the Program entered that region. As additional controls, all regressions include a region-specific trend and total production of coffee by region-year. Wild bootstrapped standard errors (1000 repetitions) are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Second, using data from transactions at the farm gate (from one of the cooperatives participating in the Program) and the mill gate (from Exporter 2 internal records), we check that the micro-level patterns are consistent with an aggregate increase in the supply of *Supremo*.

### Aggregate Exports by Quality Category

We take advantage of detailed transaction-level records for the universe of export contracts in Colombia over the period from 2006 to 2013. The data contain detailed information on the commercial grade of the exported coffee, including whether the coffee is of the *Supremo* grade. We were able to merge the export data with administrative records from the "transit guides" system described in Section 3 above. This allows us to observe the quantities of coffee of different quality grades produced in different regions over time. We take advantage of the Program's staggered rollout across the Nariño and Cauca regions to estimate:

$$\mathrm{S}_{rt} = \beta_0 + \beta_1 \times \mathrm{PR}_r \times post_{rt} + \beta_2 Q_{rt} + \gamma_t + \gamma_r + \tau_r \times t + \varepsilon_{rt}, \tag{13}$$

where $S_{rt}$ denotes the volume of *Supremo* coffee exported from region $r$ in year $t$, $PR_r$ is a dummy that takes the value one for the two Program regions, $post_{rt}$ is a dummy that takes value equal to one after 2008 and 2010 for the Nariño and Cauca regions respectively, $\gamma_t$

are year fixed effects, $\gamma_r$ region fixed effects, $\tau_r \times t$ control for region-specific time trends, and $\varepsilon_{rt}$ an error term.[34]

Table 4 reports the results, with outcomes at the region-year level. Column 1 finds that, after the Program's rollout, the volume of coffee exported to the Buyer from the Nariño and Cauca regions took off — from an average of 100 tons of coffee in 2006 to nearly 3,000 tons per year after the Program expansion. Column 2 shows that this spectacular increase roughly matches the overall increase in the volume of *Supremo* coffee exported by E2; total exports of *Supremo* by E2 rose from 650 tons in 2006 to about 3,500 tons per year after the Program expansion. A potential concern is that the increase in E2's exports of *Supremo* coffee may not have been due entirely to increased production. E2 may have, at least in part, diverted *Supremo* coffee previously sourced by other exporters. Column 3, however, finds that the total exports of *Supremo* coffee by other exporters remained stable, at around 4,000 tons. There is no evidence of diversion. Finally, Column 4 considers the total export of *Supremo* coffee from each region. Although the estimate is not statistically significant at conventional levels, the Program is associated with a $2.64/4.76 \approx 55\%$ overall increase in the export of *Supremo* coffee. The large increase in exports of *Supremo* appears to be the result of an increase in the supply of high-quality coffee. In fact, the estimate suggests that the entire increase in exports of *Supremo* coffee from Nariño and Cauca was due to the Program.[35]

### Sample Characteristics at the Mill and Farm Gates

Using internal records from E2 and one of the implementing cooperatives, we can verify that (i) the Program indeed sourced parchment coffee with better sample characteristics (indicative of better coffee), (ii) sample characteristics improved in Program-eligible regions, and (iii) the Program did not divert parchment previously destined to other ex-

[34] Since there are only twelve coffee-producing regions in Colombia, we bootstrap the standard errors to obtain confidence intervals for $\beta_1$, our parameter of interest. Results are robust to alternative bootstrap procedures and to the exclusion of region-specific linear time trends. We also include the total volume of coffee exported from region $r$ in year $t$, $Q_{rt}$, to control for other drivers of coffee production (most notably, the leaf rust that hit the southern regions in the middle of the sample period).

[35] Recall that the Program was piloted at a small scale in Caldas beginning in 2004. Program sourcing from Caldas remained stable at a relatively small scale post-pilot until 2011, when there was a significant increase. This was due to (i) a severe outbreak of coffee leaf rust ("roya") in the southern regions – including Cauca and Nariño – which reduced yields, (ii) the concomitant shift in the buyer's global procurement targets, which aimed at making the Program its dominant supply channel. Caldas — where the Program had already financed post-harvest infrastructure upgrades — was well positioned to increase supply. Table 4 thus *under*estimates the increase in exports of *Supremo* coffee associated with the Program's expansion since Caldas is assigned to the control group.

porters.[36] Starting with the mill gate, we estimate:

$$Q_{eomy} = \beta_0 + \beta_1 \times \text{PR}_{eomy} + \gamma_{omy} + \varepsilon_{bomy} \tag{14}$$

where $Q_{eomy}$ denotes a sample measure of entry $e$ sourced from buying point $o$ in month $m$ of year $y$, and $PR_{eomy}$ is a dummy equal to one for batches sold under the Program. We compare Program entries against entries that the exporter bought at the same time, from the same buying point, by including $\gamma_{omy}$ fixed effects. This specification examines whether Program entries had better sample characteristics, controlling for time-varying, buying-point-specific, seasonal variation. The above specification does not take advantage of the staggered rollout of the Program across buying points to explore whether the overall sample measures of parchment received from origins eligible for the Program improved. We therefore also estimate a staggered differences-in-differences specification:

$$Q_{eomy} = \beta_0 + \beta_1 \times \text{PO}_o \times \text{post}_{omy} + \gamma_{om} + \gamma_{my} + \varepsilon_{bomy}, \tag{15}$$

where the product $\text{PO}_o \times \text{post}_{omy}$ now is equal to one in the years after buying point $o$ becomes eligible for the Program, and zero otherwise. Program eligibility is observable at the year level. The specification controls for month-year $\gamma_{my}$ and buying-point-specific seasonality fixed effects, $\gamma_{om}$.

Panel A of Table D2 reports the results, using the share of beans above the minimum export grade and the share of beans with defects as the outcome variables. Columns 1 and 2 present estimates from equation (14) and find that Program batches had a higher share of export-grade beans and a lower share of defects relative to entries procured at the same time from the same buying point. A potential concern is that Program farmers and/or personnel at the buying points simply sorted better beans into Program batches. To investigate this, Columns 3 and 4 estimate equation (15), exploring how the overall sample characteristics of entries sourced by E2 varied with the Program rollout. Controlling for time ($\gamma_{ym}$) and buying-point-specific seasonality ($\gamma_{om}$), entries sourced from Program origins were better than entries from non-Program origins. Columns 5 and 6 repeat

[36] Recall that both at the mill and farm gates, the standard sample test reveals the share of beans above the minimum export grade and the share of beans with defects, but not the share of *Supremo*-caliber beans. However, data from E1 indicate that these sample measures for parchment coffee correlate with a higher commercial grade for the exported coffee.

the exercise, focusing on the sample of non-Program entries only to investigate potential spillovers. If the difference in Columns 1 and 2 were driven by sorting rather than upgrading, then non-Program entries from Program origins would tend to have lower sample measures than non-Program entries from non-Program origins. On the other hand, it is possible that the Program generated positive spillovers, since its extension services were available to all farmers in eligible locations. In Columns 5 and 6, we find improved sample characteristics even for non-Program entries sourced from Program locations, in line with the positive-spillover hypothesis.[37]

Turning to sample differences at the farm gate, Panel B of Table D2 presents similar specifications as in Panel A. At the farm gate, sample measures are available only for the period 2018-2019, and only from one of the two implementing cooperatives. While this prevents us from exploring staggered difference-in-differences specifications, the results are consistent with the mill-gate analysis In particular, Program entries within buying-points, and entries from Program-eligible buying points, have higher shares of beans meeting export requirements and lower shares of defects (although the latter finding is not statistically significant at conventional levels).

#### 5.2.4 Farmer-Level Upgrading Effects of Program

Finally, we test Predictions 2d and 2e: *(i)* under the vertical-restraint regime, farmers undertake long-term investments to upgrade their plots, *(ii)* among eligible farmers, those with better (lower $F_i$) and larger (higher $L_i$) plots are more likely to upgrade. To test these Predictions, we take advantage of the staggered rollout of the Program across *veredas* and utilize administrative data from the *Sistema de Información Cafetera (SICA)*, an annual panel that provides information on upgrading investments for all coffee farms in Colombia. We focus on the Program's rollout in the Cauca and Nariño regions.

Our empirical analysis compares changes in upgrading investments on the farms, before and after the *vereda* entered the Program, controlling for farm fixed effects and municipality-specific time fixed effects.[38] Detailed conversations with the management

[37]A potential concern is that farmers may have sold lower-quality parchment to other buyers. This is unlikely: as shown in Table 4, other exporters from the same region saw no changes in their exports of *Supremo* coffee. In unreported results, we find that these patterns are also robust to restricting the analysis to VSS batches or to data from the mills in the two Program regions.

[38]Table D1 compares eligible and non-eligible municipalities within the Cauca and Nariño departments. At the municipality level, eligible areas were similar to non-eligible ones. Our specifications control for both

of the cooperatives that implemented the Program indicate that the timing of rollout across eligible *veredas* was mostly based on logistical considerations, rather than changing conditions or trends in farmers' investments. We will check this by examining whether parallel trends held in the pre-treatment period.

### Farm Upgrading

We define our main outcome of interest as a standardized index that combines standardized scores (z-scores) of the (negative) average age of the trees and the share of rust-resistant varieties on the plot. We refer to this index as the "plot index." We estimate:

$$Y_{pvmt} = \beta_0 + \beta_1 \times P_{pvmt} + \gamma_p + \gamma_{mt} + \varepsilon_{pvmt} \tag{16}$$

where $Y_{pvmt}$ denotes the outcome of interest for plot $p$ in *vereda* $v$ of municipality $m$ in season $t$. Depending on specifications, $P_{pvmt}$ is an indicator for participation in or eligibility for the Program. Specifically, in OLS specifications $P_{pvmt} = 1$ once the plot joined the Program, and zero otherwise. In "intent to treat" (ITT) specifications, instead, we set $P_{pvmt} = P_{vmt} = 1$ once the Program was rolled out in *vereda* $v$, and zero otherwise. All specifications include plot fixed effects, $\gamma_p$, and municipality-year fixed effects, $\gamma_{mt}$. We restrict the sample to municipalities where the Program was eventually rolled out, but results are identical when we include all municipalities in the Cauca and Nariño regions. The error term $\varepsilon_{pvmt}$ is allowed to be arbitrarily correlated across plots and over time within each *vereda*.

Table 5 reports the differences-in-differences estimates, comparing OLS and ITT specifications. Column 1 finds that after joining the Program, plots had a 0.174 standard deviation higher plot index. This estimate is, of course, hard to interpret, as it may reflect both actual upgrading as well as plot-level selection into the Program. Column 2 finds that the corresponding ITT estimate is 0.084. Columns 3 and 4 find similar results when taking as dependent variable the share of the plot in productive age (3 to 7 years), while Columns 5 and 6 focus on the expansion of land under coffee cultivation as the outcome. We find an increase in coffee cultivated area of 5% in OLS and of 2% in the ITT specification. We also estimate a version of equation (16) at the *vereda* level, controlling for *vereda* and municipality-year fixed effects (Column 7); we find that Program *veredas* experienced a

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time-invariant characteristics at the plot level and time-varying ones across municipalities.

Table 5. **Plot Upgrading**

| | Plot-level Results | | | | | | Vereda-level Results |
|---|---|---|---|---|---|---|---|
| | Plot Index | | Share Productive Trees | | ln Coffee Area | | ln Coffee Area |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| Program Plot | 0.174*** | | 0.043*** | | 0.053*** | | |
| | (0.012) | | (0.004) | | (0.005) | | |
| Program Vereda | | 0.085** | | 0.026** | | 0.023** | 0.078*** |
| | | (0.037) | | (0.010) | | (0.010) | (0.027) |
| Plot FE | Yes | Yes | Yes | Yes | Yes | Yes | No |
| Vereda FE | No | No | No | No | No | No | Yes |
| Mun-year FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Number of plots/veredas | 71,941 | 71,941 | 71,941 | 71,941 | 71,941 | 71,941 | 997 |
| R2 | 0.60 | 0.60 | 0.24 | 0.24 | 0.85 | 0.85 | 0.97 |
| Obs. | 647,810 | 647,810 | 647,810 | 647,810 | 647,810 | 647,810 | 9,580 |

Notes: Robust standard errors (clustered by *vereda* in Columns 1-6, by municipality in Column 7) in parentheses, *** p<0.01, ** p<0.05, * p<0.1. For Columns 1-6 the unit of observation is a plot-year, for Column 7 the unit of observation is a *vereda*-year. Plot index is a standardized score (z-score) of plot age and share planted with rust-resistant varieties. Share productive trees is the share of the plot in productive age (3 to 7 years). The (log) coffee area is the area of land under coffee cultivation at either the plot (columns 5 and 6) or *vereda* (column 7) level.

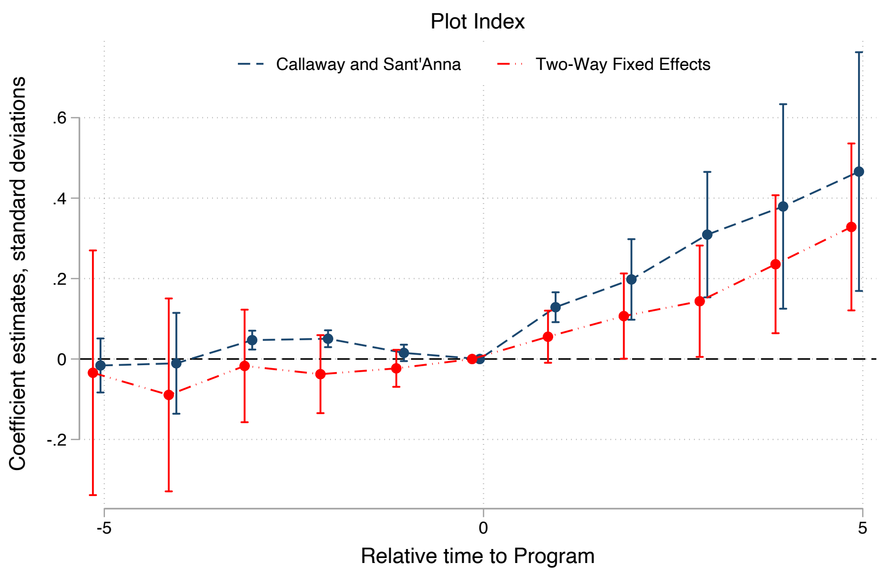
7.8% increase in aggregate land under coffee cultivation.

To get a better sense of the timing, Figure 3 reports two-way fixed effects (TWFE) and Callaway and Sant'Anna (2021) estimates from an event-study specification corresponding to the ITT in equation (16). The figure investigates dynamic patterns in plot upgrading around the time the *vereda* became eligible.[39] It reveals a gradual increase in upgrading in the years after the Program's rollout in the *vereda*, consistent with the take-up patterns shown in Figure D6. The figure shows no evidence of differential trends in upgrading in eligible *veredas* in the years preceding the Program rollout in either the TWFE or Callaway and Sant'Anna (2021) estimates, suggesting that the parallel trends assumption holds.

A potential concern is that the Program might have been rolled out alongside other initiatives that also facilitated upgrading. ITT specifications in Table D3 show that farmers in treated *veredas* were not more likely to receive extension services or other technical assistance programs, to obtain an FNC loan, or to use an identification scheme designed to facilitate access to services offered by the related cooperative. If anything, we find a

[39]The panel starts in 2006, two years before the initial rollout waves in Nariño (and four years before the rollout in Cauca).

Figure 3. **Plot Upgrading**




Notes: The figure reports estimates from event-study specifications adapting the baseline ITT specification in Column 2 of Table 5. The figure shows two-way fixed effects (TWFE) estimates in red and Callaway and Sant'Anna (2021) estimates in blue. The dependent variable is the plot index, a standardized index that combines the (negative) average age of trees and the share of rust-resistant varieties on the plot. The figure displays relatively large standard errors for the TWFE estimates three, four, and five years before the *vereda* becomes eligible because the data begins in 2006 and many *veredas* became eligible in 2008 and 2010 so we have less data 3-5 years before eligibility. We exclude plots in treated *veredas* for which we do not observe at least two observations before treatment. The number of observations in the TWFE estimates is 552,484, while the more restrictive Callaway and Sant'Anna (2021) specification includes 440,420 observations.

small negative impact on credit programs.

### Heterogeneity in Upgrading

To the extent that upgrading entailed fixed costs that did not vary with plot size, one would expect larger plots to have been more likely to take up the Program. Similarly, the costs of upgrading the plot to the Program's required standards were likely lower for plots already in good shape at the time the Program was rolled out in the plot's *vereda*, all else equal. One would also expect such plots to have been more likely to join the Program.

Columns 1 and 2 in Table 6 analyze Program take-up based on pre-Program productive area and plot management. We define an indicator for "large plots" that takes the value 1 if the plot was in the top quartile of plot area in its *vereda* in the year before the *vereda* became eligible. We define an indicator for "well managed" plots that takes the value 1 if the plot was in the top quartile of the plot-index distribution in its *vereda* in the year before the *vereda* became eligible. The evidence supports Prediction 2e: farm-

Table 6. **Heterogeneity in Program Take-up**

| | Program Take-up | |
|---|---|---|
| | (1) | (2) |
| Large area | 0.049*** | |
| | (0.005) | |
| Well managed | | 0.077*** |
| | | (0.005) |
| Vereda FE | Yes | Yes |
| Cohort (mun-eligible year) FE | Yes | Yes |
| R2 | 0.13 | 0.13 |
| Obs. | 49,531 | 49,531 |

Notes: Robust standard errors (clustered by *vereda*) in parentheses, *** p<0.01, ** p<0.05, * p<0.1, + p<0.15. In Columns 1 and 2 the unit of observation is a plot. The dependent variable, Program Take-up, takes the value of 1 if the plot eventually joins the Program. "Large" takes the value of 1 if the plot is in the top quartile of the size distribution within each *vereda* in the year before the *vereda* becomes eligible. "Well managed" takes the value of 1 if the plot is in the top-quartile of the plot-index distribution within each *vereda* in the year before the *vereda* becomes eligible. The plot index is a standardized combination of z-scores for the (negative) average age of trees and the share of trees of rust-resistant varieties.

ers with larger and better-managed plots at the time the Program was rolled out in the *vereda* were more likely to take up the Program. These correlations hold conditional on *vereda* fixed effects and Program cohort effects.

### 5.2.5 Discussion

In sum, we interpret the reduced-form evidence presented in this section as providing strong support for the Predictions 2a-2e of our model. On one hand, the evidence we have presented on Predictions 2a and 2b indicates that, unlike under the "business as usual" regime, the Program passed through the export quality premium to farmers; on the other hand, the evidence on Predictions 2c and 2d indicates that the Program increased the production of high-quality coffee through a process of farm upgrading. In addition, the evidence on which farms take-up the Program provides support for Prediction 2e.

## 6 Structural Analysis

With the reduced-form estimates in hand, we now turn to a structural analysis that simultaneously considers both exporter and farmer behavior. The main goal of this exercise is to examine the plausibility of the assertion that the reduced-form estimates from Section

5 are consistent, in terms of magnitude, with the mechanisms highlighted in the model. We also investigate whether the observed Program premia are consistent with a vertical restraint, reflected by an estimate of $\lambda < 1$, in line with Prediction 2f. We first estimate a dynamic discrete choice model of farmers' decisions to upgrade and join the Program. We then check whether the structure of price premia along the chain is consistent with a vertical restraint and quantify the Program's gains and the distribution of those gains between Exporter 2 and the farmers.

## 6.1 Model Setup

In our model, the unit of analysis is a plot of land, a subset of a farm and the smallest unit observed in our data. Each plot is characterized by three state variables: the age of the coffee trees on the plot, the area of the plot, and Program participation status of the plot (which we treat as equivalent to whether it produces standard or high-quality coffee). In each year, an infinitely lived farmer chooses whether to renew the plot (or not) and whether to join the Program and produce high-quality coffee (or not), aiming to maximize the discounted sum of per-period profits.[40] Renewal refers to replanting or stumping trees, which resets the trees' age, affecting their future productivity. Joining the Program is assumed to be an absorbing state. Plot area is time-invariant and influences both production and costs. Plots that participate in the Program earn a quality premium ($\widetilde{\pi}^R = 10\%$) and may experience productivity gains ($\omega$), consistent with the improved practices and extension support offered by the Program. We estimate the model for values of $\omega$ ranging from 0 to 0.20. (Program agronomists estimate a productivity gain of 20% from the Program.) Consistent with our reduced-form results above, we assume that the exporter earns a quality premium $\widetilde{\eta}^R = 17\%$ for high-quality coffee under the Program, and a world premium $\eta^W = 4\%$ absent the Program.

Given the regenerative nature of renewal and the discrete choice framework, our model and estimation strategy map closely to the classic approach of Rust (1987). Assuming choice-specific Type-I Extreme Value additive shocks, we estimate renewal and joining costs via maximum likelihood. Appendix E provides full model and estimation details, and Table E4 reports the estimates for the structural parameters. We find that

[40] In the interest of tractability, we make the simplifying assumption that the farmer produces high-quality coffee if and only if she joins the Program. This is consistent with our theoretical framework, in which farmers only produce quality if they can be guaranteed a premium.

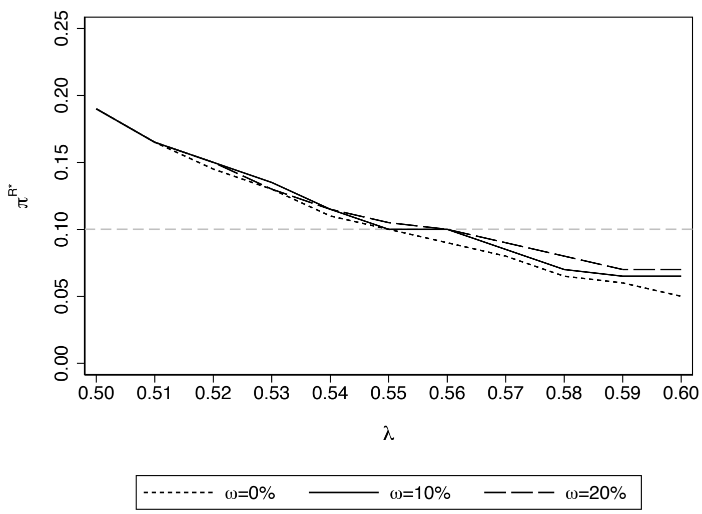
renewing a one-hectare plot costs between 6.9 and 7.5 million 2015 COP (roughly 3,000 USD) across values of $\omega$, in line with agronomists' estimates of 6.9–10.4 million 2015 COP (USDA, 2018). Estimates of the joining cost, for which a benchmark is not available, are sensitive to $\omega$ because, as the Program becomes more attractive, the model requires a higher joining cost to rationalize observed take-up. Figure E3 shows that the model replicates observed behavior well: in particular, it matches the fact that older plots are more likely to renew but less likely to join the Program. We also estimate a simpler version of the model using data from non-eligible plots, which cannot join the Program. (See Table E5 and Figure E4 for the results.) We find that these plots face renewal costs about 5% higher than those of eligible plots, consistent with the Program having subsidized access to seedlings and agricultural inputs (which typically account for 15-20% of the total renovation costs).

### 6.2 Test for Vertical Restraint

Given that the model fit appears to be good, we use it to test Prediction 2f about the vertical restraint. Using the estimated fixed costs, we compute farmers' welfare, $\mathbf{W}^F(\widetilde{\pi}^R, \vec{\sigma})$, and the exporter's profits, $\mathbf{\Pi}^E(\widetilde{\pi}^R, \widetilde{\eta}^R, \vec{\sigma})$, for different levels of the mill-gate premium $\widetilde{\pi}^R$. We then calculate the weighted sum $\lambda \times \mathbf{\Pi}^E(\widetilde{\pi}^R, \widetilde{\eta}^R, \vec{\sigma}) + (1 - \lambda) \times \mathbf{W}^F(\widetilde{\pi}^R, \vec{\sigma})$ for varying values of the weight $\lambda$. For each $\lambda$, we identify the premium $\pi^{R*}$ that maximizes this weighted sum. Figure 4 plots the resulting optimal mill-gate premium as a function of $\lambda$ under different assumptions about $\omega$, the productivity increase associated with joining the Program.

We find evidence consistent with the presence of a vertical restraint. The observed premium of $\widetilde{\pi}^R = 10\%$ is optimal if $\lambda$ is around 0.55-0.56. This implies that, given the export price and the elasticity of aggregate supply of high-quality coffee, the exporter would prefer to set a substantially lower mill-gate premium than the one implemented by the Program, consistent with the logic of a vertical restraint. This estimate of $\lambda < 1$ is consistent with our Prediction 2f.

Figure 4. **Optimal Premium $\widetilde{\pi}^{R*}$ as a Function of $\lambda$**




Notes: The Figure illustrates how the optimal mill-gate premium $\pi^{R*}$ varies with $\lambda$, the weight placed on exporter profits, and $\omega$, the productivity increase that plots get when joining the Program.

## 6.3 Gains from the Program

Finally, we use the model to assess how the Program affected welfare along the supply chain and how the resulting gains were distributed between farmers and the exporter. As a benchmark, we simulate a counterfactual scenario without the Program, where farmers still decide whether to renew their plots, but no high-quality coffee is produced. In this scenario, the exporter earns zero profits, as no high-quality parchment is available for purchase and the exporter must sell in the (perfectly competitive) UGQ segment. We then compare this baseline against various alternatives.

The first set of alternatives we consider assumes that the only benefits of the Program are the price premia (i.e., $\omega$ is assumed to be the same with and without the Program). As before, we conduct the analysis for $\omega$= 0, 10, or 20%. The estimates are presented in Columns 1-3 in Table 7. We find that farmers' welfare increases by 3.0-3.6%. This estimate can be considered a lower bound for the benefits of the Program.

The second set of alternatives we consider assumes that the Program, in addition to providing a price premium, increased productivity only for plots that joined the Program. The estimates are presented in Columns 4-5 of Table 7. Under this assumption, the estimated welfare increase for Program farmers rises to 6.2-8.9%.

The third set of alternatives assumes that the Program lowered renewal costs from $F^H$ to $F^L$. In particular, for the counterfactual scenario without the Program, we now use the higher estimated renewal costs $F^H$ that we obtained for plots in non-eligible *veredas*. The estimates are in Columns 6-8 in Table 7. Under this assumption, if the entire cost difference stemmed from Program support, the Program would raise welfare along the chain and for farmers by an additional 2 percentage points over the second set of alternatives.

Considering the gains in the value chain as a whole, we find welfare increases of 8-18%. The welfare gains for farmers reported above represent between 36-62% of the total gains (indicated by the bottom row of number in the table). Comparing columns 1-3 with columns 6-8 suggests that the Program's vertical restraint accounts for at least a third of farmers' gains from the Program.

As a final exercise, we use the model to characterize the extent of inefficiency in a market equilibrium in which there is no Program and in which the high-quality segment, like the the standard segment, is perfectly competitive. We simulate a counterfactual scenario in which the exporter receives the world premium $\eta^W$ but fully transfers it to farmers, net of transaction costs $\tau$. In this case, farmers would earn a premium of $\pi^M = \eta^W/(1-\tau) = 4.6\% > \pi_{min}$. Model simulations indicate that around 36% of plots would upgrade to high-quality production five years after the exporter begins paying $\pi^M$, compared to 43% under the Program.

Table 7. **Gains from the Program**

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| Program | $\omega$ = 0% | $\omega$ = 10% | $\omega$ = 20% | $\omega$ = 10% | $\omega$ = 20% | $\omega$ = 0%, $F^L$ | $\omega$ = 10%, $F^L$ | $\omega$ = 20%, $F^L$ |
| No Program | $\omega$ = 0% | $\omega$ = 10% | $\omega$ = 20% | $\omega$ = 0% | $\omega$ = 0% | $\omega$ = 0%, $F^H$ | $\omega$ = 0%, $F^H$ | $\omega$ = 0%, $F^H$ |
| $\Delta W$ Chain (COP) | 102.39 | 112.74 | 123.07 | 145.77 | 183.07 | 127.12 | 169.34 | 205.50 |
| $\Delta W$ Chain (%) | 8.46 | 9.28 | 10.06 | 12.34 | 15.73 | 10.73 | 14.62 | 18.01 |
| $\Delta W$ Farmers (COP) | 36.81 | 40.38 | 43.94 | 73.41 | 103.94 | 61.54 | 96.98 | 126.38 |
| $\Delta W$ Farmers (%) | 3.04 | 3.32 | 3.59 | 6.21 | 8.93 | 5.19 | 8.37 | 11.07 |
| % to Farmers | 35.95 | 35.82 | 35.71 | 50.36 | 56.78 | 48.41 | 57.27 | 61.50 |

Notes: The Table presents estimates of welfare gains created by the Program. We compare scenarios with the Program (where farmers who join get a premium $\widetilde{\pi}$ = 10% and the exporter gets a premium $\widetilde{\eta}^R$ = 17%) to one without the Program (with $\pi$ = 0% and no provision of quality coffee). Across Columns 1 to 3, we vary $\omega$ but assume that it is the same with and without the Program. In Columns 4 and 5, instead, we assume that $\omega$ is zero without Program. In Columns 6 to 8, we further assume that without the program renewal costs are equal to those of plots in non-eligible *veredas* ($F^H$), which we estimate to be around 5% higher than renewal costs estimated using plots in eligible *veredas* ($F^L$).

Summing up the results of the structural estimation, we find that the Program generated substantial gains, with between roughly one-third and two-thirds of the gains accruing to farmers. While the Program was a bundle of interventions, it appears that the vertical restraint accounted for a large share of these gains. Although the quality premium paid under the Program (of about 10%) was large, we find that most of the upgrading induced by the Program would also occur were the exporter to pass just the world price premium (of about 4%) on to farmers.

# 7 Discussion: Alternative Mechanisms

We have presented evidence consistent with our hypotheses that a hold-up problem prevents quality premia from being passed through to producers under standard market conditions, and that an international buyer with sufficient willingness to pay for quality can resolve this problem through a vertical restraint. But it is conceivable that other mechanisms may be responsible both for the lack of pass-through of quality premia under normal circumstances and the success of quality upgrading under the Program. In this section, we briefly consider several possible alternative mechanisms.

Firms, even large ones, have been shown to fail to adopt profitable technologies, management practices, cost-saving equipment, and optimal pricing (see, e.g., Atkin et al. (2017b), DellaVigna and Gentzkow (2019)). Is it possible that the exporters we focus on are simply making mistakes by not paying a higher premium for *Supremo*-grade parchment under business as usual? While it is impossible to entirely dismiss this possibility, several considerations lead us to believe that this is unlikely to be the explanation. Both Exporter 1 and Exporter 2 are major, long-standing players in the industry and behave in very sophisticated ways, for instance in how they hedge international price risk through financial instruments. Recall that Exporter 2 has similar sourcing practices as Exporter 1 outside of the Program, conducting essentially identical quality testing at the mill gate. Given the level of sophistication they display on other dimensions, it seems unlikely that they have systematically and persistently failed to optimize their sourcing practices over many years.

The hypothesis that sorting parchment of larger size (which would enable paying a price premium at the mill gate) is too costly relative to the export gate premium is also implausible. Inexpensive equipment for such testing is readily available. A mini-mill (to remove husks) can be purchased for about USD $1,000. At the higher end of the spectrum, a mini-size grader costs about USD $1,500; at the lower end, a set of screens to separate beans of different sizes costs less than USD $400. Given the low cost of determining bean size even before parchment arrives at the mill, it seems unlikely that asymmetric information about bean size can be driving the patterns we observe.

Perhaps exporters coordinate — tacitly, or explicitly — to avoid paying quality premia to suppliers?[41] This is also unlikely to be the case. Colombia has a vigorous antitrust enforcement system. The law explicitly prohibits any tacit or explicit coordinated actions between competitors, and numerous sectors have been investigated for anti-competitive practices. Coordinated pricing is also vulnerable to free-riding and competitors' entry: to emerge, it would require one or more leading firms to coordinate the industry (see, e.g., Byrne et al. (2024); Clark et al. (2024)). To sustain a collusive equilibrium, the FNC (which tightly regulates numerous dimensions of market transactions and has its own commercial arm) would almost certainly need to be involved, and (espcially given its para-statal status) it is very unlikely to be willing to engage in collusive conduct against suppliers.

In short, while it is difficult to rule out other mechanisms definitively, we believe that our hypotheses remain the most plausible explanations for the empirical patterns we have documented.

# 8 Conclusion

Linking smallholder farmers in developing countries to global value chains has the potential to lift millions out of poverty, but often requires quality upgrading. Is quality upgrading a viable path to poverty reduction in such settings? We hope to have made some progress in answering this question in the Colombia coffee chain — a sector that experienced a remarkable episode of quality upgrading.

We have formalized the hypothesis that exporters' inability to commit to long-term quality premia, and the ensuing risk of hold-up, inhibit farmers' long-term quality-upgrading investments. A foreign buyer with a sufficiently high willingness to pay can overcome

[41] In a recent study, Sharma (2024) deploys a pass-through test and finds evidence consistent with garment employers in India colluding to suppress wages. Delabastita and Rubens (2024) document collusion against workers in 19$^{th}$ century Belgian mines.

the hold-up problem, improving the transmission of the quality premium to producers through a vertical restraint with the exporter. A detailed analysis of a rich combination of datasets — internal records from two major exporters, the universe of coffee export transactions, and a panel covering all coffee plots in the country — provides strong empirical support for this hypothesis. Using internal records from an exporter implementing the standard business model in Colombia (Exporter 1), we have documented that margins are substantially higher for higher-quality coffee at the export gate, but that those margins are not passed through to producers. Using internal records from another exporter (Exporter 2) and taking advantage of the staggered rollout of the buyer-driven quality program ("the Program"), we have confirmed that the Program induced eligible farmers to undertake long-term quality-upgrading investments, expanding the aggregate supply of high-quality coffee. Estimating a structural model of farmers' decisions, we find that the Program increased surplus along the Colombian coffee chain by 8-18%, with farmers capturing 36-62% of the gains.

In sum, while the hold-up problem we have identified appears to have limited the poverty-reduction potential of quality upgrading in the sector, the international buyer's demand commitment and the vertical restraint have played a key role in overcoming those barriers and fostering upgrading. Our evidence points to the critical role of guaranteeing stable demand, with adequate price transmission from the export gate to the farm gate, to harness the potential for quality upgrading. The long-term relationship between the multinational buyer and the exporter was critical in overcoming constraints to quality upgrading. Our analysis suggests that strengthening exporters' capabilities to initiate, develop, and sustain long-term relationships with large buyers involved in global value chains would be a useful focus for policy interventions.

Two important questions remain open and would be worthy of further research. One is the consequences of quality upgrading in agricultural value chains for inequality in producing communities. Studies in other sectors have found that differential access to export opportunities might exacerbate inequality.[42] In our context, the Program take-up rates are higher among farmers with larger and better-managed farms. The Program appears to have benefited eligible communities overall, but likely increased dispersion

[42] See, e.g., Verhoogen (2008), or Goldberg and Pavcnik (2007) and Harrison et al. (2011) for reviews.

of incomes among farmers.[43] The impact of the Program on the aggregate amount of land under coffee cultivation could have had effects on welfare in other sectors and, potentially, on food security in the producing communities. At the same time, the Program might have increased labor demand, particularly for seasonal workers who often are among the poorest in rural areas, thereby reducing inequality.[44] The overall Program impact on inequality in rural communities is ambiguous and requires further research.

A second important open question is how generalizable our findings are to other contexts. The Program's success in Colombia may have depended on Colombia-specific factors. Two aspects of the local context may have been particularly relevant: *i*) the local implementer's capacity and relationship with farmers; *ii*) the existence of the FNC price-guarantee scheme. The former might have been key to gaining farmers' trust. The price-guarantee scheme might have protected eligible farmers who did not join the Program. We believe that the hold-up problem we have identified and the ability of international buyer-driven purchase commitments to mitigate it are likely to show up in other settings, but research in other contexts will be required to substantiate that view.

[43] Dragusanu et al. (2022) find positive impact of Fair Trade certification on the income of Costa Rican coffee farmers. Looking at the distributional impact of Fair Trade, they find that the benefits are not evenly distributed: skilled coffee growers benefit, intermediaries are hurt, and unskilled workers are unaffected.

[44] Several studies have documented environmental benefits associated with the practices promoted by the Program (see Ibañez and Blackman (2016), Rueda et al. (2015), Rueda and Lambin (2013)). We do not focus on these potential environmental benefits in this paper.

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# A Further Background and Data Sources

## A.1 Business-as-Usual Operations in Exporting Mills

This subsection describes how coffee processing and trade operate in the business-as-usual regime, based on field visits to exporting mills that are representative of standard practices among large private exporters in Colombia.

Each morning, mill managers receive real-time price updates from the company's headquarters, which track international market movements, the exchange rate, and the differential for Colombian coffee. Purchases are made throughout the day at prices that reflect these parameters and the expected yield of exportable beans. Mills receive parchment from a wide network of intermediaries and farmers. When a truck arrives at the mill, a sample is taken from each lot to measure humidity, defects, and the yield factor (*factor de rendimiento* in Spanish, which is the amount of parchment required to produce seventy kilograms of green coffee of exportable grade). Negotiations with suppliers are based on this factor: a higher yield factor signals lower quality and leads to a lower purchase price.

The sample from each entry is dehusked in a small test machine to produce green coffee, which is then manually sifted through metal screens of different sizes. Beans above a given screen size (typically size 14, which corresponds to 14/64 inch) constitute the exportable portion; smaller beans may potentially be sold in the domestic market. The analysis also records the share of beans affected by diseases and other defects. These measurements determine the price paid and the classification of parchment as UGQ or lower-quality coffee.

Inside the milling plant, parchment coffee is unloaded into silos and passes through a series of machines that clean, hull, and separate the beans by size and weight. The first stage removes impurities such as metal fragments or stones, using magnetic filters and other cleaning devices. After hulling, the green coffee is graded by size (sizes shown in Figure A1), and the process can be repeated when needed to ensure that each fraction corresponds to a consistent range of qualities. Once the beans are separated, they are combined in specific proportions to prepare the commercial grades, or recipes, required by buyers. The by-products from the sorting process (various lower grades of coffee) supply the domestic market and the instant coffee industry. The recipes produced in a given week depend on the mix of orders received, and a given batch of beans may be reprocessed several times to meet the standards of a particular grade.

## A.2 Exporter 1 Data

### A.2.1 Production, Milling, and Sales Data

The data for Exporter 1 cover the 2008–2018 period and consist of three sets of internal records. The first dataset reports the purchases of parchment coffee (entries) at the gates of the firm's mills. For each entry, we observe the sample characteristics from the pre-purchase test of the coffee, the supplier identity and type, the price paid by Exporter 1, the time of purchase, and other details such as whether the entry has special characteristics (for example, single-origin or organic certification).

The second dataset contains information on the sale of batches of green coffee. These records include the recipe or commercial grade produced, the price obtained in the sale, the time and date of shipment, and other transaction-level details. (See the discussion of recipes in Section 2.2.) The third dataset links the two previous ones by recording the timing of milling. Detailed discussions with mill personnel suggest that the dates in the data for a given entry do not necessarily indicate that the entire entry was milled on those days. Instead, tranches of a given entry may be processed separately. A given entry may appear in several consecutive millings, depending on the mix of batches produced in a given week.

To account for this, we match entries to batches based on the weeks when they appear in the milling records, rather than using exact dates. Our key assumption is that all tranches milled within a given week have the same composition in terms of bean size and quality. We use the quality of batches produced in a given week to infer the quality composition of the tranches of entries that enter the milling process in that week. (For example, if in a given week a mill produced 1000 sacks in total, of which 600 were UGQ, 300 were EP or Extra, and 100 were *Supremo*, the corresponding recipe shares for that week are 0.60, 0.30, and 0.10 respectively.) We then average tranches of the same entry milled in multiple weeks, weighting by the recorded weight of each tranche. This procedure allows us to infer the quality composition of each entry in terms of the grades or recipes that can be produced from it. While our assumption of homogeneous quality composition within a given week cannot be directly tested, it is consistent with the operational practices described by mill staff.

Following this matching procedure, we obtain for each entry the shares of different commercial grades produced and the corresponding revenues. The matched dataset includes 74,413 entries. We exclude entries with special characteristics (e.g., organic, single-origin), which represent 17 percent of the firm's output by weight, because their millings are less frequent and therefore less reliably matched. The analysis focuses on the 54,166 entries without special characteristics, though results are robust to their inclusion.

### A.2.2 Construction of Revenues at the Entry Level

To calculate revenues per kilogram of parchment coffee at the entry level, we have to take into account the mix of exportable and domestic-market beans from the entry. For each entry, revenue from exports can be calculated from the firm's data on export sales. Once we have calculated the recipe shares for each entry, we can infer the corresponding revenues from observed prices for the corresponding recipes. For domestic sales (which we do not observe directly), we use the shares from the initial sample (when parchment first arrives at mill) to estimate the share of the entry that ends up in the domestic market. This sample provides the shares of beans that correspond to different potential grades: exportable beans (size 14 and above), beans one size below the export threshold (disaggregated by defect status), small beans below size 13, and the share of husks.[45]

For the domestic grades, we impute prices based on historical average ratios of domestic prices to the export price of UGQ coffee. Specifically, we compute the average ratio of domestic to export prices for each category using records from 2016-2019, and apply these ratios to the observed UGQ export prices in each period. In this way, the total income attributed to each entry reflects both its export and domestic output. An additional adjustment accounts for the share of defective beans due to disease (in particular, *broca*, a coffee pest). The total revenue of the entry is multiplied by one minus the disease share observed in the sample, reflecting the fact that beans affected by disease generate no sellable output. The revenue per kilogram of parchment for an entry

[45] Beans size 13-14 without defects are called *consumo*, beans size 13-14 with defects are called *pasilla*, and beans below size 13 are called *ripio*.

therefore combines: (i) the value of its exportable share at export prices, (ii) the imputed value of lower-grade beans at domestic-market prices, and (iii) a zero value for husks (which represent approximately 20% of the weight of parchment) and diseased beans. The resulting variable, the revenue per kilogram of parchment coffee at the entry level, is the measure used in the paper to estimate margins and quality premia.

## A.3 Sustainable Quality Program and Exporter 2 Data

We have two main sources of data on the Program and Exporter 2: (1) sourcing data from one of the cooperatives for 2015-2016 and 2017-2018, and (2) mill-entry records for 2006-2014 for Exporter 2.

### A.3.1 Farmer Sales: Implementing Cooperative

From one of the implementing cooperative, we have: *a*) data for the 2015 and 2016 harvests at the level of farmer-year–buying point-type of sale (standard or Program), and *b*) transaction-level data for the 2018 and 2019 harvests that records the farmer, type of sale (standard or Program) and a quality measure for each sale to the cooperative. While these data cover only one of the two implementing cooperatives in each of the periods, the fact that they cover Program and non-Program sales enables us to compare within-farmer sales. Moreover, as the 2018-2019 transaction-level data also contains sample characteristics of the batch, they allow us to extend the analysis to within-farmer and between-program differentials in quality control measures and price.

### A.3.2 Batches at Mill Entry

Exporter 2 is a large intermediary exporter that implemented the Program in Colombia. For all Exporter 2 mills, whether or not they source for the Program, we have transaction-level records on all purchases of parchment coffee for the 2006-2014 period. These data include detailed information on the origin of the coffee, its price, sample characteristics and, crucially, an extremely detailed product description. This description indicates whether the coffee is covered by any VSS and other relevant characteristics of the entry. This data allows to compare entries of coffee sourced at the same time from the same narrow locality.

### A.4 Administrative data

We combine several national administrative data sources. These include (1) export data supplemented with records of internal shipments, (2) records on the characteristics of farmer plots, and (3) data covering all farmer sales from late 2012 to early 2014.

#### A.4.1 Batches at Export Gate

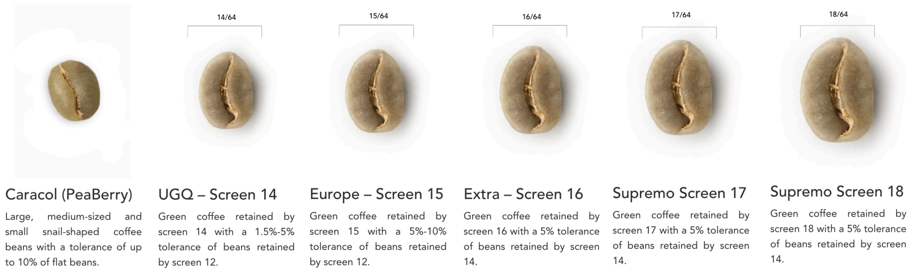
Transaction-level data at the export gate are available for the period 2006-2013. We combine the export data with information from permits required to ship coffee from mills to ports, the *guías de tránsito* ("transit guides"), for each shipment. We observe the shipment data from 2006-2014. Relative to standard transaction-level customs records, these data have the advantages that they include detailed product characteristics, region of origin, quality testing, and contractual terms (e.g., payment conditions). The combined data allow us to observe the aggregate supply of coffee by quality grade at the region level across time during the implementation of the Program.

#### A.4.2 Plot-Farmer Level

At the plot level, we exploit information from the FNC's Coffee Information System (*Sistema de Información Cafetera (SICA)*). This is a continuously updated geo-referenced census of *all* plots cultivating coffee in Colombia. The census contains information on plot characteristics (e.g., location and size) together with information on the coffee plantation (number of trees, average age of trees, cultivated varieties, shade) as well as on any improvements made to the plot over the course of the year. By merging in information from the Program implementer, for each plot we know the year in which it joined the Sustainable Quality Program. Our analysis focuses on the universe of coffee plots in the municipalities in which the Program was implemented in the Cauca and Nariño departments over the 2006-2016 sample period. The annual plot census contains a unique anonymized identifier for the farmer cultivating the plot.[46]

[46]We can thus merge the panel with farmer level information, e.g., the farmer's participation in different FNC programs (technical training, credit, and other socio-economic programs) and farmer sales from the PIC. At any point in time, most farmers only farm one coffee plot. The average share of farmers with one plot only is 67%, and 91% of farmers have two plots or less. When analysis is done at the the farmer level we aggregate plots linked to the farmer. In this case, we attribute to the farmer the location of his/her largest plot. Results of the farmer-level analysis are robust to allocating the farmer to the centroid of his/her plots.

Figure A1. **Commercial Grades**




Notes: The Figure describes the main Colombian commercial grades from the FNC (link: https://federaciondecafeteros.org/wp/productos/green-coffee/?lang=en). Coffee grades are primarily based on the size of the coffee beans, with limited variation in tolerance for beans of other sizes and defects. The usually good quality (UGQ) grade was the minimum grade for export until 2016 and consists of beans larger than size 14 with limited tolerance for smaller beans. Smaller beans may be used in various recipes sold on the domestic market. The highest grades of coffee are the *Supremo* grades, which consist of beans with size greater than 17.

### A.4.3 Farmer Sales: National

The Coffee-Producer Income Protection Program *(Protección del Ingreso Cafetero (PIC))* Program was implemented from late 2012 to early 2014 when the guaranteed purchase price, which is based on a formula that depends on the international coffee price, exchange rate, and Colombian quality differential, fell below a minimum threshold value. The FNC provided a subsidy to farmers while the guaranteed price was low. Farmers could claim this subsidy from the FNC by providing a receipt for each of their sales. Thus, the FNC thus collected information on all sales by farmers to cooperatives, traders, or private individuals, including information on price, quantity, and date, during this period.

Table A1. **Descriptive Statistics, Exporter 1**

| | Mean | SD | p(10) | p(50) | p(90) |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| **Panel A: Initial Sample Characteristics** | | | | | |
| Sample share size ≥ 14 | 0.71 | 0.04 | 0.66 | 0.73 | 0.75 |
| Sample share 13 ≤ size < 14, no defects | 0.04 | 0.02 | 0.02 | 0.04 | 0.08 |
| Sample share 13 ≤ size < 14, with defects | 0.03 | 0.02 | 0.01 | 0.03 | 0.06 |
| Sample share size < 13 | 0.01 | 0.01 | 0.00 | 0.00 | 0.02 |
| Sample share husks | 0.20 | 0.01 | 0.18 | 0.20 | 0.22 |
| Sample moisture rate | 0.12 | 0.01 | 0.11 | 0.12 | 0.13 |
| Sample disease rate | 0.01 | 0.01 | 0.00 | 0.01 | 0.03 |
| **Panel B: Supplier types** | | | | | |
| Cooperative | 0.86 | 0.35 | 0.00 | 1.00 | 1.00 |
| Individual | 0.09 | 0.28 | 0.00 | 0.00 | 0.00 |
| Private Company | 0.06 | 0.23 | 0.00 | 0.00 | 0.00 |
| **Panel C: Production** | | | | | |
| Recipes per entry | 2.37 | 0.79 | 1.00 | 2.00 | 3.00 |
| Caracol (Peaberry) share | 0.01 | 0.05 | 0.00 | 0.00 | 0.00 |
| UGQ share | 0.58 | 0.32 | 0.00 | 0.64 | 1.00 |
| EP/Extra share | 0.24 | 0.29 | 0.00 | 0.14 | 0.71 |
| Supremo share | 0.17 | 0.21 | 0.00 | 0.11 | 0.44 |
| **Panel D: Costs, revenues, margins** | | | | | |
| Cost per kg (of parchment coffee) | 6,229.28 | 1,393.49 | 4,682.97 | 6,011.16 | 8,197.57 |
| Revenues per kg (of parchment coffee) | 6,974.08 | 1,439.42 | 5,311.00 | 6,727.47 | 9,088.20 |
| Margin (Rpkg - Cpkg) | 744.80 | 505.07 | 196.56 | 724.05 | 1,309.48 |
| Margin ((Rpkg - Cpkg) / Cpkg) | 0.13 | 0.10 | 0.03 | 0.12 | 0.23 |

Notes: N = 54,166. This table presents more detailed summary statistics on the entry-level data for Exporter 1. Observations are entry from 2008-2018. Monetary values are in 2015 COP.

## B Quality Premia and Margins

This appendix includes additional results related to our analysis of quality premia using data from Exporter 1. Tables B1 presents estimates of Equation 10 for costs, revenues, and margins per kg of parchment. The coefficients reported in Figure 2 correspond to the specifications in Columns 3, 6, and 9.

Table B1. **Costs/Revenues/Margins by Quality Grade, Exporter 1**

| | Cost per Kg Parchment (log) | | | Revenue per Kg Parchment (log) | | | Margin per Kg Parchment (log) | | |
|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| Caracol (Peaberry) share | 0.005 | 0.005 | 0.001 | -0.041* | -0.041* | -0.039 | -0.047* | -0.046* | -0.040 |
| | (0.007) | (0.007) | (0.006) | (0.022) | (0.022) | (0.024) | (0.024) | (0.024) | (0.026) |
| EP/Extra share | 0.003* | 0.003* | 0.004** | 0.020*** | 0.020*** | 0.020*** | 0.017** | 0.017** | 0.016*** |
| | (0.002) | (0.002) | (0.002) | (0.006) | (0.006) | (0.006) | (0.007) | (0.007) | (0.006) |
| Supremo share | -0.001 | -0.001 | -0.001 | 0.043*** | 0.043*** | 0.044*** | 0.044*** | 0.044*** | 0.045*** |
| | (0.002) | (0.002) | (0.002) | (0.007) | (0.007) | (0.007) | (0.007) | (0.007) | (0.007) |
| Sample share size $\geq$ 14 | 1.145*** | 1.147*** | 1.150*** | 1.179*** | 1.178*** | 1.189*** | 0.035 | 0.031 | 0.039 |
| | (0.159) | (0.160) | (0.170) | (0.016) | (0.017) | (0.016) | (0.157) | (0.157) | (0.167) |
| Sample share 13 $\geq$ size < 14 | 0.520*** | 0.522*** | 0.538*** | 0.665*** | 0.664*** | 0.675*** | 0.145 | 0.141 | 0.137 |
| | (0.116) | (0.117) | (0.123) | (0.025) | (0.026) | (0.025) | (0.114) | (0.114) | (0.121) |
| Sample moisture rate | -0.076 | -0.082 | -0.106* | 0.018 | 0.018 | -0.001 | 0.094 | 0.099 | 0.105 |
| | (0.059) | (0.059) | (0.056) | (0.044) | (0.044) | (0.042) | (0.069) | (0.069) | (0.068) |
| Sample disease rate | -0.736*** | -0.732*** | -0.774*** | -1.005*** | -1.006*** | -1.002*** | -0.269 | -0.274 | -0.229 |
| | (0.169) | (0.169) | (0.165) | (0.034) | (0.033) | (0.036) | (0.166) | (0.166) | (0.163) |
| Cooperative | | 0.005 | | | -0.000 | | | -0.005 | |
| | | (0.004) | | | (0.001) | | | (0.004) | |
| Individual | | 0.005 | | | -0.002 | | | -0.006* | |
| | | (0.004) | | | (0.002) | | | (0.004) | |
| Mill-date effects | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| Supplier effects | N | N | Y | N | N | Y | N | N | Y |
| Mean of dep. var. | 1.80 | 1.80 | 1.80 | 1.92 | 1.92 | 1.92 | 0.12 | 0.12 | 0.12 |
| F - sample characteristics | 17.9 | 17.9 | 18.9 | 4973.1 | 4924.4 | 3916.9 | 1.5 | 1.5 | 1.2 |
| F - recipe shares | 1.6 | 1.5 | 1.5 | 20.0 | 20.0 | 20.4 | 16.1 | 16.1 | 16.4 |
| R2 | 0.97 | 0.97 | 0.97 | 0.99 | 0.99 | 0.99 | 0.72 | 0.72 | 0.72 |
| Obs. | 54,166 | 54,166 | 54,166 | 54,166 | 54,166 | 54,166 | 54,166 | 54,166 | 54,166 |

Notes: Table presents various specifications of equation 10 with the dependent variable of costs per kg of parchment in Columns 1-3, revenues per kg of parchment in Columns 4-6, and margins per kg of parchment in Columns 7-9. The units for all dependent variables are log 2015 COP. Mill-date fixed effects reflect the location where the parchment milled and the date of the output sale. Standard errors are clustered by the year-month of the output sale and supplier in all specifications.

# C Theory Appendix

## C.1 Proofs for Section 4.2.1

### C.1.1 Quality Supply under Enforceable Contracts

Given the announced farm-gate premium $\pi$, farmer $i$ upgrades if:

$$F_i \leq (\pi w^L - \gamma c^L) Q_i, \quad \text{where} \quad w^L = (1-\tau) p^L.$$

Define $\pi^{min} \equiv \gamma c^L / w^L = \gamma c^L / ((1-\tau) p^L)$ as the minimum farm-gate premium that compensates farmers for the higher variable cost of upgrading. Let $G(F_i, L_i)$ denote the joint distribution of fixed costs $F_i$ and plot sizes $L_i$ (equal to $Q_i$). Aggregate quality supply is then

$$\mathbf{Q}(\pi, \vec{\sigma}) = \int_{\{i: F_i \leq (\pi w^L - \gamma c^L) L_i\}} L_i \, dG(F_i, L_i), \tag{C1}$$

where $\vec{\sigma}$ collects $(c^L, \gamma, \tau)$ and the parameters of $G$. By construction, $\mathbf{Q}(\pi, \vec{\sigma}) = 0$ for $\pi < \pi^{min}$ and $\partial \mathbf{Q} / \partial \pi > 0$ for $\pi > \pi^{min}$.

### C.1.2 Exporter Optimization

Exporter profits are

$$\mathbf{\Pi}^E(\pi, \eta^W) = \mathbf{Q}(\pi, \vec{\sigma}) \, p^L \big[ \eta^W - (1-\tau)\pi \big],$$

and the exporter chooses $\pi$ to maximize $\mathbf{\Pi}^E$. If $\mathbf{Q}(\pi, \vec{\sigma})$ is continuously differentiable and strictly increasing in $\pi$, the first-order condition for an interior optimum is

$$\frac{\partial \mathbf{Q}}{\partial \pi}(\pi, \vec{\sigma}) \big[ \eta^W - (1-\tau)\pi \big] = (1-\tau) \, \mathbf{Q}(\pi, \vec{\sigma}). \tag{C2}$$

### C.1.3 Proofs of Statements (i) and (ii)

Rearranging the first-order condition (FOC) yields

$$\eta^W - (1-\tau)\pi = (1-\tau) \frac{\mathbf{Q}(\pi)}{\mathbf{Q}_\pi(\pi)}. \tag{C3}$$

The second-order condition for a local maximum requires $\frac{\partial^2 \mathbf{\Pi}^E(\pi, \eta^W)}{\partial \pi^2} < 0$.

### (i) Comparative Statics in $\eta^W$

Let $\Phi(\pi, \eta^W)$ denote the FOC:

$$\Phi(\pi, \eta^W) \equiv \mathbf{Q}_\pi(\pi)\big[\eta^W - (1-\tau)\pi\big] - \mathbf{Q}(\pi)(1-\tau) = 0.$$

By the Implicit Function Theorem, at an interior optimum $\pi(\eta^W)$ we have

$$\frac{d\pi}{d\eta^W} = -\frac{\partial\Phi/\partial\eta^W}{\partial\Phi/\partial\pi}.$$

We compute

$$\frac{\partial\Phi}{\partial\eta^W} = \mathbf{Q}_\pi(\pi),$$

which is strictly positive whenever an increase in $\pi$ attracts additional upgraded supply. Next, differentiate $\Phi$ with respect to $\pi$:

$$\frac{\partial\Phi}{\partial\pi} = \mathbf{Q}_{\pi\pi}(\pi)\big[\eta^W - (1-\tau)\pi\big] - 2(1-\tau)\mathbf{Q}_\pi(\pi).$$

Using (C3) to substitute out $\eta^W - (1-\tau)\pi$, this becomes

$$\frac{\partial\Phi}{\partial\pi} = (1-\tau)\left[\mathbf{Q}_{\pi\pi}(\pi)\frac{\mathbf{Q}(\pi)}{\mathbf{Q}_\pi(\pi)} - 2\mathbf{Q}_\pi(\pi)\right].$$

Note that

$$\frac{\partial^2\mathbf{\Pi}^E(\pi, \eta^W)}{\partial\pi^2} = p^L\frac{\partial\Phi}{\partial\pi}.$$

Hence, the local second-order condition for a maximum implies $\partial\Phi/\partial\pi < 0$ at the optimum. Combining this with $\partial\Phi/\partial\eta^W = \mathbf{Q}_\pi(\pi) > 0$, we obtain

$$\frac{d\pi}{d\eta^W} > 0.$$

Finally, by the Envelope Theorem,

$$\frac{d\widehat{\mathbf{\Pi}}^E(\eta^W)}{d\eta^W} = \left.\frac{\partial\mathbf{\Pi}^E(\pi, \eta^W)}{\partial\eta^W}\right|_{\pi=\pi(\eta^W)} = \mathbf{Q}(\pi(\eta^W))\,p^L > 0,$$

since $\mathbf{Q}(\cdot) > 0$ whenever some upgraded coffee is produced. Hence, both the exporter's optimal farm-gate premium $\pi(\eta^W)$ and the exporter's maximized profit $\widehat{\mathbf{\Pi}}^E(\eta^W)$ are increasing in $\eta^W$. □

**(ii) Markdown**

Evaluated at the optimum, (C3) implies

$$\eta^W - (1-\tau)\pi = (1-\tau)\frac{\mathbf{Q}(\pi)}{\mathbf{Q}_\pi(\pi)} \quad \Longrightarrow \quad \pi < \frac{\eta^W}{1-\tau}.$$

since the right-hand side is strictly positive whenever $\mathbf{Q}(\pi) > 0$ and $\mathbf{Q}_\pi(\pi) > 0$. That is, the exporter does not pass through the full export-gate premium $\eta^W$ to the farm gate: it pays a premium $\pi$ to farmers strictly lower than the per-unit marginal value of high-quality relative to standard quality at the export gate, $\eta^W/(1-\tau)$. □

## C.2 Proofs for Subsection 4.2.2

The buyer offers $\eta$ to the exporter; the exporter accepts the offer if and only if doing so yields at least its outside-option profit from selling to the competitive fringe at $\eta^W$. After acceptance, the exporter chooses the farm-gate premium $\pi$ to maximize its profit, and then farmers decide whether to upgrade.

### C.2.1 Exporter Behavior

For any given export premium $\eta$, the exporter chooses the farm-gate premium $\pi$ as in Section 4.2.1. Let $\pi^E(\eta)$ denote the exporter's best response. As shown in Appendix C, the exporter's optimal $\pi^E(\eta)$ implies the "markdown" $\pi^E(\eta) < \frac{\eta}{1-\tau}$. Conditional on any given $\eta$, the exporter sets a farm-gate premium that is distorted downward from the buyer's point of view.

### C.2.2 Buyer Behavior

Anticipating $\pi^E(\eta)$, the buyer chooses $\eta$ to maximize its profits from high-quality coffee. The buyer values each upgraded unit at $(1+v)p^L$ with $v > \eta^W$, and pays the exporter $(1+\eta)p^L$ per unit. The buyer's payoff from setting $\eta$ (if the exporter accepts) is therefore

$$\mathbf{\Pi}^B(\eta) = (v-\eta)p^L\,\mathbf{Q}\big(\pi^E(\eta)\big).$$

The exporter will only accept the contract if its profit from trading with the buyer is at least as large as its outside option of selling the same upgraded coffee to the competitive fringe at the competitive premium $\eta^W$. That is, the exporter's participation constraint (PC) requires

$$\mathbf{\Pi}^E(\pi^E(\eta),\eta) \;\geq\; \mathbf{\Pi}^E(\pi^E(\eta^W),\eta^W). \tag{C4}$$

Note that (C4) implies $\eta \geq \eta^W$. Otherwise the exporter would reject and sell to the fringe.

Let $\eta^B$ denote the buyer's optimal choice under this limited contract space, and let $\pi^B \equiv \pi^E(\eta^B)$ be the induced farm-gate premium.

**Claim (i).** The resulting farm-gate premium $\pi^B$ is inefficiently low.

*Proof.* From the buyer's perspective, the efficient farm-gate premium is the one that would maximize *total* surplus created by upgrading (i.e., the value $(1+v)p^L$ per upgraded unit, net of farmers' costs), because higher $\pi$ induces additional upgrading through $\mathbf{Q}(\pi)$. However, the buyer cannot directly choose $\pi$: it can only choose $\eta$, after which the exporter privately chooses $\pi = \pi^E(\eta)$, taking into account her own unit margin $\left[\eta-(1-\tau)\pi\right]$. As shown above, for any given $\eta$ the exporter sets $\pi^E(\eta) < \eta/(1-\tau)$. As a result, the induced premium at the farm gate, $\pi^B = \pi^E(\eta^B)$, is below the level that the buyer would select if it could commit to $(\eta,\pi)$ jointly. □

**Claim (ii).** The buyer leaves rents to the exporter. In particular, $\eta^B > \eta^W$.

*Proof.* Suppose, for contradiction, that the buyer set $\eta^B = \eta^W$. Then by (C4) the exporter would be exactly indifferent between accepting the buyer's offer and selling to the competitive fringe. But if $\eta = \eta^W$, then the buyer's own payoff would be

$$\mathbf{\Pi}^B(\eta^W) = (v-\eta^W)p^L\,\mathbf{Q}\big(\pi^E(\eta^W)\big).$$

Since $v > \eta^W$, the buyer's marginal benefit from inducing more upgrading is higher than the marginal cost of upgrading, which by the exporter's FOC is equal to $(1+\eta^W)p^L$. The only way to expand $\mathbf{Q}(\pi^E(\eta))$ is to raise $\eta$ above $\eta^W$, giving the exporter an incentive to raise $\pi$. Therefore, at the buyer's optimum, we must have $\eta^B > \eta^W$. Because $\eta^B > \eta^W$, the exporter's profit at $(\pi^B,\eta^B)$ strictly exceeds its outside-option profit at $(\pi^E(\eta^W),\eta^W)$; that is, the participation constraint (C4) is slack. The exporter earns positive rents in equilibrium even though the buyer has all the bargaining power in setting $\eta$. □

### C.2.3 Vertical Restraint

We now consider a vertical restraint under which the buyer and the exporter sign a contract that directly specifies both the export-gate premium $\eta$ and the farm-gate premium $\pi$. The timing of events is as before. Under such a contract, the buyer maximizes profits subject only to the exporter's participation constraint:

$$(\eta^R, \pi^R) \in \arg\max_{\eta,\pi} \{(v - \eta)p^L \mathbf{Q}(\pi)\} \quad \text{s.t. } \mathbf{\Pi}^E(\pi, \eta) \ \geq \ \mathbf{\Pi}^E(\pi^E(\eta^W), \eta^W), \tag{C5}$$

where $\mathbf{Q}(\pi)$, $\mathbf{\Pi}^E(\pi, \eta)$ and $\mathbf{\Pi}^E(\pi^E(\eta^W), \eta^W)$ are defined above. Note that under the vertical restraint, the exporter no longer chooses $\pi$: the "incentive compatibility" (IC) constraint from the buyer-only case is removed.

**Claim (i).** The vertical restraint induces a strictly higher farm-gate premium than the exporter would otherwise choose. In particular,

$$\pi^R > \pi^E(\eta^W),$$

and hence

$$\mathbf{Q}(\pi^R) > \mathbf{Q}\big(\pi^E(\eta^W)\big),$$

i.e., the vertical restraint achieves higher upgrading.

*Proof.* Consider first the benchmark without the vertical restraint. When the exporter sells into the competitive fringe at $\eta^W$, it privately chooses the farm-gate premium $\pi$ to maximize its own profit. As shown above, the exporter passes through only part of the competitive fringe premium $\eta^W$ to farmers. Under the vertical restraint, by contrast, the buyer directly chooses *both* $\pi$ and $\eta$ in (C5). The buyer values each upgraded unit at $(1 + v)p^L > (1 + \eta^W)p^L$. Since the buyer now internalizes the effect of $\pi$ on $\mathbf{Q}(\pi)$ directly, and no longer needs to worry that the exporter will under-pass-through (there is no IC constraint on $\pi$), it will choose a $\pi$ that is *strictly higher* than $\pi^E(\eta^W)$ to elicit additional upgrading. Hence, $\pi^R > \pi^E(\eta^W)$, and thus $\mathbf{Q}(\pi^R) > \mathbf{Q}\big(\pi^E(\eta^W)\big)$. □

**Claim (ii).** Even though the buyer has all the bargaining power when offering $(\eta, \pi)$, we must have

$$\eta^R > \eta^W.$$

In equilibrium, the exporter's participation constraint binds, and yet the exporter is still paid an export premium above the competitive fringe level $\eta^W$.

*Proof.* Under the vertical restraint, the buyer cannot simply pay the competitive fringe premium $\eta^R = \eta^W$. The reason is that, to induce the higher farm-gate premium $\pi^R > \pi^E(\eta^W)$ required to expand upgrading, the buyer must simultaneously ensure that the exporter is willing to participate.

From the exporter's perspective, paying $\pi^R$ to farmers is more expensive than paying $\pi^E(\eta^W)$; in particular, $\pi^R > \pi^E(\eta^W)$ raises its unit acquisition cost for upgraded coffee. Holding $\eta$ fixed at $\eta^W$ would therefore *reduce* the exporter's per-unit margin $[\eta - (1 - \tau)\pi]$ below what it obtains in its outside option. This would violate the participation constraint in (C5).

To restore participation, the buyer must raise $\eta$ above $\eta^W$ so that the exporter's total profit from accepting $(\eta^R, \pi^R)$ is at least as large as its outside option. At the optimum, the buyer sets $\eta$ just high enough to satisfy this participation constraint with equality, extracting all (additional) surplus subject to that constraint. Denoting the buyer's optimal choice by $(\eta^R, \pi^R)$, we therefore have:

$$\mathbf{\Pi}^E(\pi^R, \eta^R) = \mathbf{\Pi}^E(\pi^E(\eta^W), \eta^W), \quad \text{with } \eta^R > \eta^W. \qquad \square$$

## C.3 Proof for Subsection 4.3.1

### Proof of Proposition 1

Recall that the exporter solves

$$\pi^D = \arg\max_{\pi} \frac{1}{\delta} \mathbf{V}(\eta^W, \pi)\, \mathbf{Q}(\pi, \vec{\sigma}) \quad \text{s.t.} \quad \mathbf{V}(\eta^W, \pi) \geq (1 - \tau)\pi p^L, \tag{C6}$$

where $\mathbf{V}(\eta^W, \pi) \equiv \frac{\delta}{1-\delta}\left[\eta^W - (1-\tau)\pi\right] p^L$ is the exporter's discounted per-unit continuation value along the equilibrium path. Denote by $\pi^E$ the premium that would be chosen by the exporter in the static benchmark with enforceable contracts (i.e., the unconstrained maximizer of $\mathbf{V}(\eta^W, \pi)\mathbf{Q}(\pi, \vec{\sigma})$), and by $\pi_{\min} > 0$ the minimum premium required to induce any upgrading. The proof proceeds in four steps.

**Step 1. Monotonicity of $\pi^D$ in $\delta$.** Fix two discount factors $0 < \delta' < \delta'' < 1$. For any given $\pi$, note that $\mathbf{V}(\eta^W, \pi)$ is strictly increasing in $\delta$: as $\delta$ rises, the factor $\frac{1}{1-\delta}$ scales up the continuation value from the relationship. Therefore, the left-hand side of the incentive constraint

$$\mathbf{V}(\eta^W, \pi) \equiv \frac{\delta}{1-\delta}\left[\eta^W - (1-\tau)\pi\right] p^L \geq (1-\tau)\pi p^L \tag{C7}$$

is *easier* to satisfy at $\delta''$ than at $\delta'$. In other words, the feasible set of premiums $\pi$ that satisfy the no-deviation condition is weakly larger when $\delta$ is higher.

Since the objective in (C6) is (proportional to) $\mathbf{V}(\eta^W, \pi)\mathbf{Q}(\pi, \vec{\sigma})$, and the feasible set expands with $\delta$, the exporter can never be forced to choose a *lower* premium when $\delta$ increases. Hence the optimal relational premium $\pi^D(\delta)$ is weakly increasing in $\delta$.

**Step 2. The high-$\delta$ region.** Consider the limit $\delta \to 1$. For any fixed $\pi > 0$,

$$\mathbf{V}(\eta^W, \pi) = \frac{1}{1-\delta}\left[\eta^W - (1-\tau)\pi\right] p^L \to \infty \quad \text{as } \delta \to 1,$$

provided that $\eta^W - (1-\tau)\pi > 0$. Therefore, for $\delta$ sufficiently close to $1$, the no-deviation constraint

$$\mathbf{V}(\eta^W, \pi) \geq (1-\tau)\pi p^L$$

is slack at all relevant $\pi$ (the left-hand side diverges, while the right-hand side is finite). When the constraint is slack, (C6) reduces to unconstrained profit maximization. In that case, the exporter chooses exactly the same premium it would choose under full commitment in a static enforceable-contract environment, i.e. $\pi^D(\delta) = \pi^E$ for all $\delta$ sufficiently high. Define $\delta^{\overline{E}}$ as the smallest discount factor at which this happens. For all $\delta \geq \delta^{\overline{E}}$, we have $\pi^D(\delta) = \pi^E$.

**Step 3. The low-$\delta$ region.** Now consider the opposite limit $\delta \to 0$. In this case,

$$\mathbf{V}(\eta^W, \pi) = \frac{\delta}{1-\delta}\left[\eta^W - (1-\tau)\pi\right] p^L \to 0 \quad \text{as } \delta \to 0.$$

To induce any upgrading/participation by farmers, the exporter must offer at least $\pi_{\min} > 0$. But when $\delta$ is arbitrarily small, the left-hand side $\mathbf{V}(\eta^W, \pi)$ is too small to offset this one-shot temptation unless $\pi$ itself is essentially zero. In other words, for $\delta$ sufficiently low, there is *no* positive $\pi \geq \pi_{\min}$ that satisfies the incentive constraint. Hence, for $\delta$ small enough, no relational contract that induces upgrading can be sustained, and the exporter is forced to choose

$$\pi^D(\delta) = 0.$$

Define $\delta^{\underline{E}}$ as the largest discount factor for which even the smallest non-trivial premium $\pi_{\min}$ fails the no-deviation constraint. Then for all $\delta \le \delta^{\underline{E}}$, we must have $\pi^D(\delta) = 0$.

**Step 4. Intermediate $\delta$.** We have shown:

(i) $\pi^D(\delta)$ is weakly increasing in $\delta$ (Step 1);

(ii) for all $\delta \ge \delta^{\overline{E}}$, $\pi^D(\delta) = \pi^E$ (Step 2);

(iii) for all $\delta \le \delta^{\underline{E}}$, $\pi^D(\delta) = 0$ (Step 3).

By monotonicity, as $\delta$ increases from $\delta^{\underline{E}}$ to $\delta^{\overline{E}}$, the optimal relational premium $\pi^D(\delta)$ must rise (weakly) from $\pi_{min}$ toward $\pi^E$. Over this intermediate range, $\delta \in (\delta^{\underline{E}}, \delta^{\overline{E}})$, the incentive compatibility constraint is binding, and the exporter sets the highest premium that can be credibly paid without triggering deviation. This proves Proposition 1. □

## C.4 Proof for Subsection 4.3.2

### Proof of Proposition 2

The proof proceeds in four steps.

**Step 1. Joint enforcement and aggregation of incentive constraints.** The buyer–exporter vertical restraint involves two relational promises: the exporter promises to pay a farm-gate premium $\widetilde{\pi}^R$ to farmers and to sell high-quality output to the buyer; the buyer promises to pay an export premium $\widetilde{\eta}^R$ to the exporter. Both promises must be self-enforced. A standard result in the theory of relational contracts is that under our set up, the pair of incentive constraints can be combined into a single *aggregate* constraint requiring that the *sum* of their continuation values on the equilibrium path is at least as large as the *sum* of their joint one-shot deviation payoffs.[47]

Summing the Exporter's and the Buyer's IC constraints (see equation (8)) yields

$$\mathbf{V}(\widetilde{\eta}^R, \widetilde{\pi}^R) + \mathbf{B}(\widetilde{\eta}^R, \widetilde{\pi}^R) \equiv \frac{\delta}{1-\delta}\Big(v - (1-\tau)\widetilde{\pi}^R\Big)p^L \;\ge\; (1-\tau)\widetilde{\pi}^R p^L. \tag{C8}$$

[47] Intuitively, in a stationary relational contract, a deviation by either party triggers the same collapse of co-operation going forward. Hence, as long as the relationship as a whole generates enough discounted surplus to discipline the worst deviation, transfers within the relationship (here, the choice of $\widetilde{\eta}^R$) can redistribute that surplus so that each individual constraint is also satisfied.

**Step 2. The aggregate constraint is easier to satisfy than without the buyer.** Because $v > \eta^W$, it follows that the total continuation value on the left-hand side of (C8) strictly exceeds the continuation value available to the exporter alone (consider (C7) when the farm-gate premium is $\widetilde{\pi}^R$), while the right-hand side of (C8) reflects the same fundamental *current-period* costs of honoring the promised premia. At any given discount factor $\delta$, more surplus can now be credibly promised to farmers in the form of a higher farm-gate premium $\widetilde{\pi}^R$, because the relationship now has a larger pool of future rents at stake.

**Step 3. Implication for discount factors.** Proposition 1 established that, without the buyer, the maximum credible farm-gate premium $\pi^D(\delta)$ is weakly increasing in $\delta$, and that there exist thresholds $\delta^{\underline{E}} < \delta^{\overline{E}}$ such that: for $\delta \leq \delta^{\underline{E}}$ no premium above $\pi_{\min}$ can be credibly promised, while for $\delta \geq \delta^{\overline{E}}$ the exporter can implement the static benchmark premium. A similar logic applies to the case with the relational vertical restraint: the aggregate incentive constraint (C8) is (weakly) *easier* to satisfy at any given $\delta$ than the stand-alone constraint (C7) was. Therefore, for each $\delta$, the set of sustainable premia under $(\widetilde{\eta}^R, \widetilde{\pi}^R)$ is (weakly) larger than the set of sustainable premia under the exporter-only relationship. Conversely, the lowest discount factor at which the buyer–exporter vertical restraint can sustain a farm-gate premium at least as large as $\pi_{\min}$, denoted $\delta^R$, shifts to the left: $\delta^R < \delta^{\underline{E}}$.

For any $\delta \in (\delta^R, \delta^{\underline{E}})$, we then have that the exporter on his own cannot sustain any premium $\pi \geq \pi_{\min}$ (by Proposition 1, since $\delta < \delta^{\underline{E}}$), but the joint buyer–exporter relational contract can sustain a farm-gate premium $\widetilde{\pi}^R \geq \pi_{\min}$.

**Step 4. Side-selling and the level of $\widetilde{\eta}^R$.** Note that the aggregate IC constraint does not depend on $\widetilde{\eta}^R$. The buyer sets $\widetilde{\eta}^R$ to make the exporter's IC binding. This implies $(1+\widetilde{\eta}^R) = (1-\delta)(1+\eta^W) + (1-\tau)\widetilde{\pi}^R$. For $\delta$ sufficiently low, we thus have $\widetilde{\eta}^R > \eta^W$. □

### Proof of Proposition 3

Fix an export gate premium $\eta$ promised by the buyer to the exporter. In an interior solution, the exporter's incentive compatibility (IC) constraint binds, and neither $\pi$ nor $\eta$ is at a corner. We show that, in this interior region, the optimal $\pi$ can be written as the solution to a weighted welfare-maximization problem over the exporter and the farmers.

**Step 1. Binding ICs.** From (8), the exporter IC requires

$$\mathbf{V}(\eta,\pi) = \Big[(\eta^W - \eta) + (1-\tau)\pi\Big]p^L, \tag{C9}$$

Recall that we defined $\vec{\theta}$ as the vector of parameters that are either directly observed or can be estimated. These include the world price $p^L$, the exporter's cost, $\tau$, the parameters governing farmers' supply and upgrading decisions $(\vec{\sigma})$, and the discount factor $\delta$. Define the exporter's discounted payoff along the equilibrium path as

$$\mathbf{\Pi}^E(\pi,\eta;\vec{\theta}) \equiv \frac{1}{\delta}\,\mathbf{V}(\eta,\pi)\,\mathbf{Q}(\pi,\vec{\sigma}).$$

Similarly, define the discounted payoff accruing to farmers as

$$\mathbf{W}^F(\pi;\vec{\theta}),$$

i.e. the (discounted) rents to farmers from being paid $\pi$ at the farm gate and supplying high quality according to $\mathbf{Q}(\pi,\vec{\sigma})$. $\mathbf{W}^F$ depends on $\pi$ and on technology/behavioral parameters in $\vec{\theta}$, but it does not depend directly on $\eta$, since $\eta$ is a transfer between buyer and exporter at the export gate. $\mathbf{W}^F(\pi;\vec{\theta})$ monotonically increases with $\pi$.

**Step 2. First-order optimality and weighted surplus maximization.** Because the exporter's IC binds, any small change in $\pi$ that lowers the exporter's continuation value must be offset by an increase in $\eta$. Formally, at the interior optimum $(\eta,\pi) = (\widetilde{\eta}^R, \widetilde{\pi}^R)$, the buyer's choice of $\pi$ must satisfy a first-order condition of the form

$$\lambda(\eta;\vec{\theta},v)\,\frac{\partial \mathbf{\Pi}^E(\pi,\eta;\vec{\theta})}{\partial \pi} \;+\; \big(1-\lambda(\eta;\vec{\theta},v)\big)\,\frac{\partial \mathbf{W}^F(\pi;\vec{\theta})}{\partial \pi} \;=\; 0, \tag{C10}$$

for some $\lambda(\eta;\vec{\theta},v) \in [0,1]$. The weight $\lambda(\eta;\vec{\theta},v)$ captures the required change induced by the binding IC.

The condition (C10) is equivalent to saying that $\widetilde{\pi}^R$ solves

$$\widetilde{\pi}^R(\vec{\theta},v) \in \arg\max_{\pi}\left\{\lambda(\eta;\vec{\theta},v)\,\mathbf{\Pi}^E(\pi,\eta;\vec{\theta}) + \big(1-\lambda(\eta;\vec{\theta},v)\big)\,\mathbf{W}^F(\pi;\vec{\theta})\right\}, \tag{C11}$$

where $\eta$ is fixed at the level the buyer has chosen. That is, at an interior solution, the buyer's optimal farm-gate premium is exactly the maximizer of a weighted average of exporter surplus and farmer surplus, with weight $\lambda(\eta; \vec{\theta}, v) \in [0, 1]$.

**Step 3. Statement in the form of the proposition.** Relabel the optimal farm-gate premium from the relational vertical restraint as $\pi^R(\vec{\theta}, v)$, and define

$$\pi^*(\vec{\theta}, \lambda, \eta) \equiv \arg\max_{\pi} \Big\{ \lambda \, \mathbf{\Pi}^E(\pi, \eta; \vec{\theta}) + (1 - \lambda) \, \mathbf{W}^F(\pi; \vec{\theta}) \Big\}.$$

For each $\eta$ chosen in the interior region of (8), there exists a $\lambda \in [0, 1]$ such that

$$\pi^R(\vec{\theta}, v) = \pi^*(\vec{\theta}, \lambda, \eta),$$

and $\pi^R(\vec{\theta}, v)$ is strictly interior (i.e. $\pi^R > \pi_{\min}$ and below any upper corner). □

# D The Sustainable Quality Program

## Table D1. **Program vs. Non Program Municipalities**

| | Non-Program Mun. | | Program Mun. | | Difference |
|---|---|---|---|---|---|
| | N | Mean/SE | N | Mean/SE | T-test |
| | (1) | (2) | (3) | (4) | (5) |
| Official Area ($Km^2$) | 32 | 419.812 | 33 | 374.788 | 45.025 |
| | | (77.080) | | (63.005) | |
| Altitude | 32 | 1715.031 | 33 | 1683.727 | 31.304 |
| | | (129.935) | | (112.956) | |
| Distance to district capital | 32 | 52.266 | 33 | 53.062 | -0.796 |
| | | (4.562) | | (3.585) | |
| Rurality Index (Rural/Total Population) | 32 | 0.737 | 33 | 0.767 | -0.030 |
| | | (0.034) | | (0.029) | |
| Poverty Index (SISIBEN) | 32 | 93.068 | 32 | 97.587 | -4.520 |
| | | (3.062) | | (0.430) | |
| Land Gini Index | 32 | 0.764 | 32 | 0.739 | 0.024 |
| | | (0.016) | | (0.013) | |
| Land Gini Index (Ownership) | 32 | 0.751 | 32 | 0.716 | 0.034** |
| | | (0.013) | | (0.009) | |
| Literacy rate in 2005 | 32 | 84.713 | 32 | 85.435 | -0.723 |
| | | (1.910) | | (0.794) | |
| Index of soil agricultural suitability | 31 | 2.753 | 32 | 2.393 | 0.360 |
| | | (0.270) | | (0.176) | |
| Coffee cultivation 1997 (thsds. hectares) | 28 | 1.651 | 29 | 1.181 | 0.470 |
| | | (0.337) | | (0.155) | |
| Presence of coca cultivation | 32 | 0.292 | 33 | 0.313 | -0.021 |
| | | (0.076) | | (0.074) | |
| Presence of indigenous population (1535-1540) | 32 | 0.406 | 33 | 0.758 | -0.351*** |
| | | (0.088) | | (0.076) | |
| Spanish occupied land (1510-1561) | 32 | 0.406 | 33 | 0.273 | 0.134 |
| | | (0.088) | | (0.079) | |
| Presence of land conflicts (1901-1917) | 32 | 0.062 | 33 | 0.061 | 0.002 |
| | | (0.043) | | (0.042) | |
| Presence of land conflicts (1918-1931) | 32 | 0.094 | 33 | 0.121 | -0.027 |
| | | (0.052) | | (0.058) | |
| Presence of Violence (1948-1953) | 32 | 0.156 | 33 | 0.061 | 0.096 |
| | | (0.065) | | (0.042) | |
| Presence of ELN | 32 | 0.109 | 32 | 0.078 | 0.031 |
| | | (0.043) | | (0.033) | |
| Presence of FARC | 32 | 0.609 | 32 | 0.219 | 0.391*** |
| | | (0.077) | | (0.059) | |
| Guerrilla Massacres | 28 | 0.143 | 29 | 0.069 | 0.074 |
| | | (0.067) | | (0.048) | |
| Paramilitary Massacres | 28 | 1.000 | 29 | 0.172 | 0.828** |
| | | (0.356) | | (0.100) | |

Notes: The Table reports information on socio-economic characteristics at the municipality level. Corresponding information at the *vereda* level is not available. The variables on land distribution, poverty, coca presence and armed groups presence are the mean for the 2012-2014 period. The incidence of conflict (Masacres) is the average for the 2000-2005 period. Differences in numbers of municipalities across variables are due to missing information. Program status defined as municipalities where the Program had expanded by 2014. Source: CEDE Database, Universidad de Los Andes

Table D2. **The Program — Coffee Sample Characteristics**

| | Panel A: Sample Characteristics at Mill Entry (2009-2014) | | | | | |
|---|---|---|---|---|---|---|
| | OLS | | ITT | | ITT Spillovers | |
| | % Size 14+ | % Defects | % Size 14+ | % Defects | % Size 14+ | % Defects |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Program Batch | 0.015*** | -0.011*** | | | | |
| | (0.001) | (0.002) | | | | |
| Program Origin | | | 0.008** | -0.012*** | 0.006+ | -0.010** |
| | | | (0.004) | (0.004) | (0.004) | (0.004) |
| Sample | All | All | All | All | Non-program | Non-program |
| Origin-Month-Year FE | Yes | Yes | No | No | No | No |
| Year-month FE | No | No | Yes | Yes | Yes | Yes |
| Origin-month FE | No | No | Yes | Yes | Yes | Yes |
| R2 | 0.67 | 0.66 | 0.50 | 0.49 | 0.49 | 0.48 |
| Obs. | 118,975 | 118,975 | 122,532 | 122,532 | 107,561 | 107,561 |
| | **Panel B: Sample Characteristics at Farm Gate (2018-2019)** | | | | | |
| | OLS | | ITT | | ITT Spillovers | |
| | % Size 14+ | % Defects | % Size 14+ | % Defects | % Size 14+ | % Defects |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Program Sales | 0.025*** | -0.002 | | | | |
| | (0.004) | (0.002) | | | | |
| Program Origin | | | 0.024*** | -0.006 | 0.004* | -0.008 |
| | | | (0.002) | (0.008) | (0.002) | (0.011) |
| Sample | All | All | All | All | Non-program | Non-program |
| Origin-Month-Year FE | Yes | Yes | No | No | No | No |
| Farmer FE | Yes | Yes | No | No | No | No |
| Month-year and seasonality FE | No | No | Yes | Yes | Yes | Yes |
| R2 | 0.81 | 0.87 | 0.49 | 0.05 | 0.16 | 0.10 |
| Obs. | 198,268 | 198,268 | 210,809 | 210,809 | 80,176 | 80,176 |

Notes: Robust standard errors (clustered on origin and cooperative-year in Panel A, origin and farmer-year in Panel B) in parentheses. *** p<0.01, ** p<0.05, * p<0.1, + p<0.15. For mill entry, time period is 2009-2014, and the unit of observation is a coffee batch entering the mill. For farm gate, time period is 2018-2019, and the unit of observation is a farmer sale. Columns 1 and 2 (OLS) compare batches of coffee sourced for the Program against non-Program batches sourced from the same origin (buying point) and same farmer in the same season (i.e., *within* farmer-origin-season). Columns 3 and 4 (ITT) compare batches from Program origins with batches from non-Program origins, sourced at the same time and controlling for seasonality. Columns 5 and 6 (ITT spillover) compare non-Program batches sourced sourced from Program origins and non-Program origins. We define a buying point as a Program origin after at least one *vereda* (farmer) supplying the buying point becomes eligible for the Program. For the farm-gate analysis (Panel B), all Program origins are already in the Program at the start of the sample, hence origin fixed effects can not be included in columns 3-6.

Table D3. **Participation in FNC Programs**

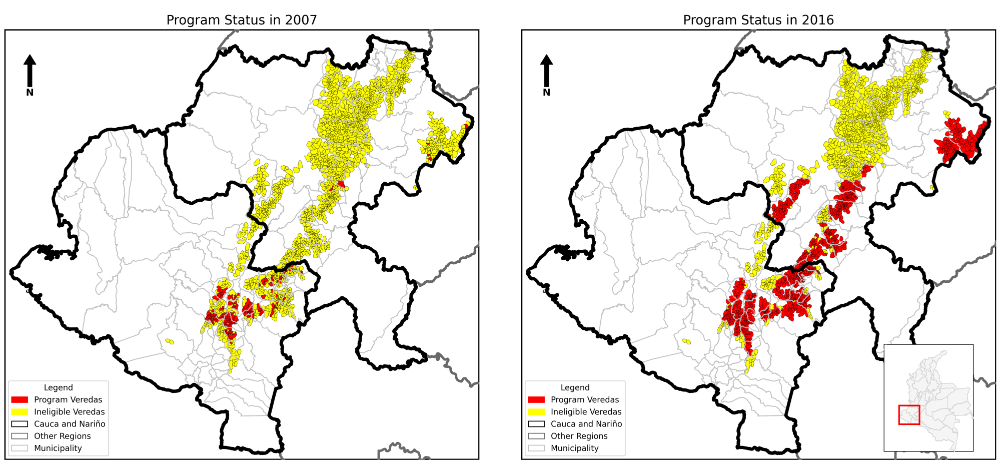
| | Individual Extension | | Extension Program | | Credit Program | | ID Program | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Program Farmer | 0.077*** | | -0.017** | | 0.006** | | -0.030*** | |
| | (0.008) | | (0.007) | | (0.003) | | (0.003) | |
| Program Vereda | | 0.013 | | 0.010 | | -0.015** | | -0.033 |
| | | (0.015) | | (0.017) | | (0.007) | | (0.025) |
| Farmer and Mun-year FE | Yes | Yes | Yes | Yes | Yes | Yes | No | No |
| Municipality FE | No | No | No | No | No | No | Yes | Yes |
| Mean dep. var. | 0.395 | 0.395 | 0.447 | 0.447 | 0.047 | 0.047 | 0.068 | 0.068 |
| R2 | 0.55 | 0.55 | 0.42 | 0.42 | 0.25 | 0.25 | 0.04 | 0.04 |
| Obs. | 99,482 | 99,482 | 291,081 | 291,081 | 291,081 | 291,081 | 50,257 | 50,257 |

Notes: Robust standard errors in parentheses (clustered by *vereda*) *** p<0.01, ** p<0.05, * p<0.1. The specifications are as in Equation (16) but at the farmer, rather than plot, level and, due to data availability, cover varying sample periods from 2007-2013. For the Columns 1 and 2, available years are 2007, 2008 and 2013; for Columns 3-6 full sample years are available; and for Columns 7 and 8, only 2013 is available. The sample includes all plots in the municipalities where the Program eventually expanded. At the end of the panel 97% of the plots in these municipalities were eligible. The dependent variable is a dummy that takes value 1 if the farmer participated in the indicated program in a given year. The "Individual extension" dummy takes value 1 if the farmer had a one-on-one activity with the extension services. The "Extension program" dummy takes value one if farmer participated in any group or individual extension program. The "Credit program" dummy take value 1 if farmer participated in any of the various FNC credit programs, of different values and conditions. The "ID program" dummy takes value 1 if farmer participated in the FNC program to ensure all farmers had an ID that allowed them to do monetary transactions with the cooperative and keep track of the programs they are involved and their benefits.

## Figure D1. **Prices at Buying Points: An Illustration**

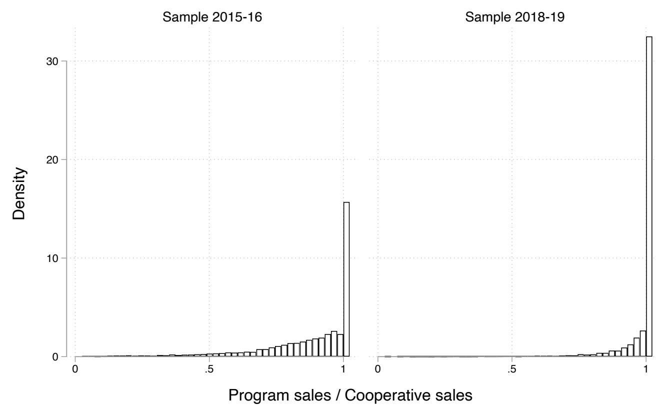

Notes: The image illustrates how the base price and the Program's price premium was announced to farmers. All cooperatives buying points around the country post the weekly base price. The base price is established for humidity <12% and conversion factor from parchment to excelso ≤ 94. These characteristics are well known to farmers and provide a very minimal quality standard met by essentially all coffee produced. The base price is adjusted to take account of regional differences in transport costs. In the image, the base price (determined by the FNC price-guarantee scheme) was 4,920 COP per kg (or 615,000 COP per *carga* of 125 kg). The Program's price per kilo was 5,320 COP/kg. This fixed price premium of 400 COP/kg remained stable for most of the sample period.

## Figure D2. **Program Expansion**



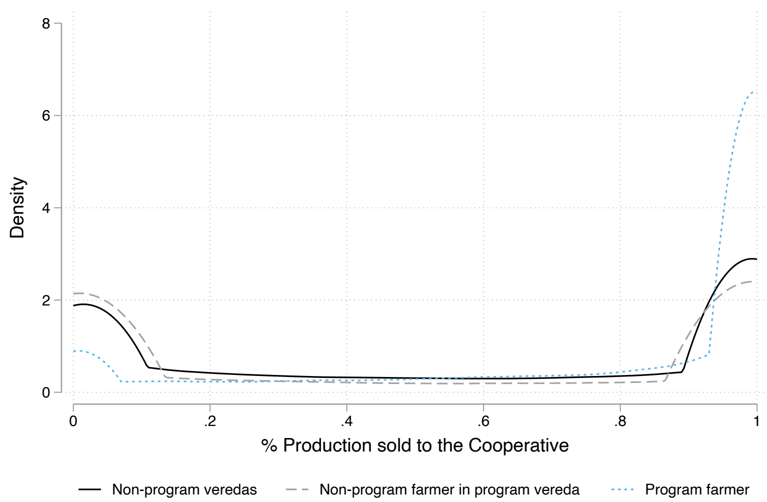

Notes: These maps, of the Cauca and Nariño regions (see inset for location relative to Colombia as a whole), show the Program and non-Program coffee-producing *veredas* in 2007 (left) and 2016 (right). Municipalities within Cauca and Nariño are plotted with light grey boundaries, while regions (*departamentos*, "departments") other than Cauca and Nariño have dark grey boundaries.

Figure D3. **Program Sourcing: Share of Parchment Delivered Under Program**



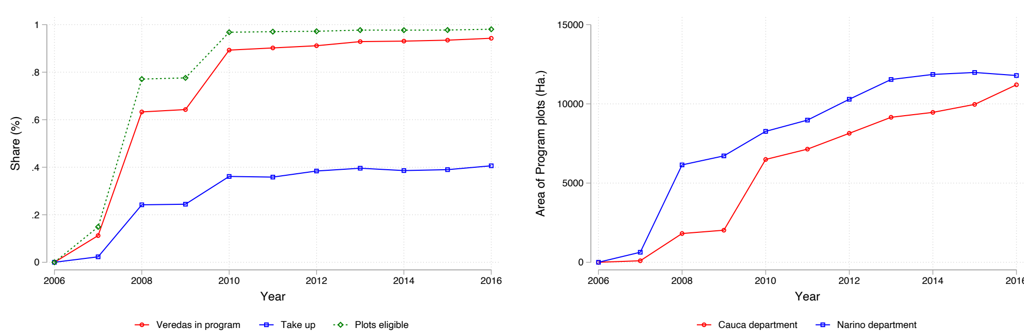

Notes: The Figure shows the distribution of the share of Program farmer's deliveries that actually occur under the Program. The data cover Program farmers from one of the implementing cooperatives. On average, over 86% of Program's farmers deliveries to the cooperative are bought by the Program (mean 86.4% for earlier sample, 97% for latter one).

## Figure D4. **Program Sourcing: No Side-Selling**



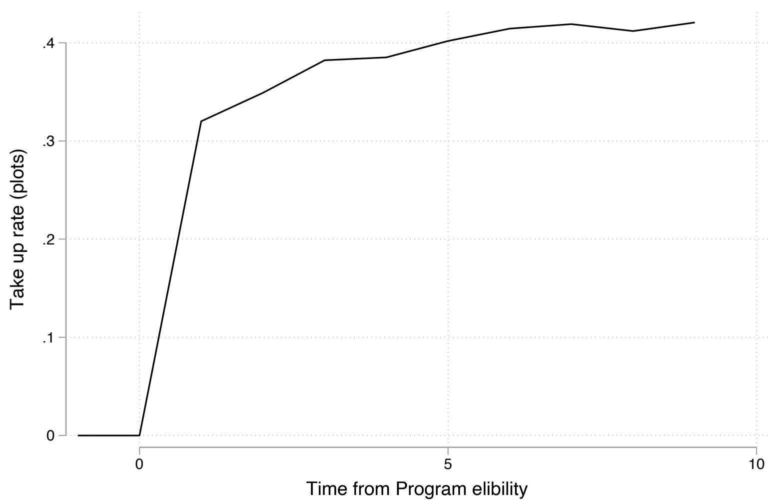

Notes: The Figure provides descriptive evidence on farmers' sales patterns across eligible and non-eligible *veredas*. The Figure relies on data from the Protección del Ingreso Cafetero (PIC) program. The PIC data covers the universe of coffee transactions between *any* farmer and *any* buyer — including cooperatives, traders and other private buyers — in the Colombian countryside for the 2012-2013 season. The sample includes all farmers in the municipalities where the Program eventually expanded. The Figure shows the share of farmer's sales delivered to the cooperative implementing the Program (with any other buyers being the alternative). Farmers in Program *veredas* deliver significantly more coffee to the Program implementer than farmers in non-eligible ones. The difference, however, is entirely driven by Program farmers. In fact, the Figure shows that a significantly higher share of Program farmers (79% vs. 64 %) sell almost all their coffee to the cooperative implementing the Program.

## Figure D5. **Program Rollout in Cauca and Nariño Departments**




Notes: The Figure illustrates the expansion of the Program in the Cauca and Nariño departments between 2006 and 2016. The left figure plots the evolution of the land under the Program in each department. The variation in the Figure corresponds to the OLS specifications in the plot-panel analysis. The right Figure presents the expansion of the Program in terms of eligibility and take-up. The Figure thus captures the variation used in the ITT specifications on the plot-level panel. At the end of the panel, 88% of the *veredas* in municipalities where the Program expanded are eligible, what represents 97.67% of the plots in these municipalities.

Figure D6. **Program Take-Up Over Time**




Notes: The Figure illustrates the Program take-up rate over time. The year zero is defined as the last year before the plot's *vereda* becomes eligible for the Program. The Figure shows that in the first year after becoming eligible approximately 30% of eligible plots take up the Program. The take-up rate keeps increasing and it stabilizes around 40% five years after eligibility. The dynamic patterns reflects *i)* the fact it might take some time for farmers to upgrade the plot to the required standards, and *ii*) some farmers might "wait and see" and learn from the experience of others how the Program works before incurring the costs of joining.

# E Structural Model

This section provides more details on the structural model, our estimation procedure, and additional results.

## E.1 Model Setup

The model's unit of observation is a plot. Each plot is managed by a profit-maximizing, infinitely lived farmer.

### State Space

Each plot of land is characterized by the age of its trees, its area, and its Program status. We discretize the state variables for age and area, expressing the age of the trees in years, $x \in \{1, 2, 3, \dots\}$, and the area of the plot in 1,000 square meter (0.1 hectare) increments, $a \in \{1, 2, 3, \dots\}$. An indicator of participation in the Program, $q \in \{1, 2\}$, takes the value 1 when the plot is not part of the Program and produces standard coffee and 2 when the plot is part of the Program and produces high-quality coffee. We assume that entering the Program is an absorbing state.

### Choices

In each period, the farmer chooses an action $j \in \mathcal{J}(q)$ to maximize her objective function. The farmer has four available actions: renew the plot and do not join the Program ($j = 1$); do not renew the plot and do not join the Program ($j = 2$); renew the plot and join (or stay in) the Program ($j = 3$); do not renew the plot and join (or stay in) the Program ($j = 4$). Because joining is an absorbing state, the choice set is a function of $q$ such that $\mathcal{J}(q = 1) = \{1, 2, 3, 4\}$ and $\mathcal{J}(q = 2) = \{3, 4\}$.

### Transition Dynamics

We set up a dynamic model in which today's choices affect tomorrow's state. Renewing the plot resets its age such that $x_{t+1} = 1$ if $j_t \in \{1, 3\}$ but $x_{t+1} = x_t + 1$ if $j_t \in \{2, 4\}$. Joining the Program is an absorbing state such that $q_{t+1} = 1$ if $j_t \in \{1, 2\}$ and $q_{t+n} = 2$ for all $n \geq 1$ if $j_t \in \{3, 4\}$. The area of the plot, $a$, does not change over time.

### Profit Parametrization

Let $\theta = \{\theta_1^R, \theta_2^R, \theta_1^J, \theta_2^J, \theta_3^J, \sigma\}$ be a vector of structural parameters. The profits of a plot in each period are given by

$$\begin{aligned} u_j(x,a,q,\theta) &= [Price(q) - MgCost(q)] \times Quantity_j(x,a,q) - FxdCost_j(x,a,q,\theta) + \varepsilon_j \\ &= \bar{u}_j(x,a,q,\theta) + \varepsilon_j \end{aligned}$$

where

$$\begin{aligned} Price(q) &= p + p \times \widetilde{\pi}^R \times \mathbb{I}\{q = 2\} \\ MgCost(q) &= c + c \times \gamma \times \mathbb{I}\{q = 2\} \\ Quantity_j(x,a,q) &= 0 + \{Q(x) + Q(x) \times \omega \times \mathbb{I}\{q = 2\}\} \times a \times \mathbb{I}\{j = 2,4\} \\ FxdCost_j(x,a,q,\theta) &= 0 + \{\theta_1^R + \theta_2^R \times a\} \times \mathbb{I}\{j = 1,3\} + \{\theta_1^J + \theta_2^J \times a + \theta_3^J \times x\} \times \mathbb{I}\{j = 3,4\} \times \mathbb{I}\{q = 1\}. \end{aligned}$$

Mill-gate price $p$ and production cost $c$ increase when participating in the Program (and producing high quality coffee) by $\widetilde{\pi}^R$ percent and $\gamma$ percent respectively (see Table E1 for their values). Production depends on the age of the plot's trees $x$ and the plot's size $a$. Production increases with Program participation by $\omega$ percent, but is zero in the period in which the plot is renewed (when $j = 1$ or 3). Renewal costs vary linearly with plot size, and joining costs vary linearly with plot size, age, and depend on Program status $q$. Joining costs are only paid once upon entry into the Program. The results are robust to assuming different specifications for the fixed costs, such as allowing them to vary by farmer size, estimating different costs by quartiles of the land distribution, or adding a quadratic term in plot size. $\varepsilon_j$ is a choice-specific Type 1 Extreme Value (T1EV) shock with mean zero and scale $\sigma$, which is assumed to be independent across choices, plots, and time.

### Value Function

The conditional value function for each choice $j$ is

$$v_j(x,a,q,\theta) = \bar{u}_j(x,a,q,\theta) + \delta V(x', a, q', \theta)$$

where $x', q'$ denote future states (given current states and action $j$ and the dynamics outlined above), $\delta$ represents time preferences, and the value function can be expressed as

$$V(x,a,q,\theta) = \mathbb{E}\left[\max_{j\in\mathcal{J}(q)}\{v_j(x,a,q,\theta)+\varepsilon_j\}\right] = \sigma\log\left(\sum_{j\in\mathcal{J}(q)}\exp\left(v_j(x,a,q,\theta)/\sigma\right)\right)$$

where we omit time subscripts as the problem is stationary. The conditional choice probabilities follow the logit form:

$$P_j(x,a,q,\theta) = \frac{\exp(v_j(x,a,q,\theta)/\sigma)}{\sum_{k\in\mathcal{J}(q)}\exp\left(v_k(x,a,q,\theta)/\sigma\right)}$$

## E.2 Model Estimation

We set the value of the parameters as in Table E1. We set time preferences $\delta = 1/(1+r)$ based on Colombian interest rates reported by the IMF. The average real interest rate in Colombia from 2006-2016 was 8%, and the average lending interest rate was 13%. We use the average value and set $r = 10.5\%$. Program agronomists estimate a value of 20% for the productivity increase parameter $\omega$. Because this value seems quite generous, we also present results for $\omega = 0\%$ and 10%. The mill-gate and export prices are set as the average of the values reported in Table 1 for E1 and E2 expressed in terms of kg of green coffee. Table 1 reports an average mill-gate price of 6,943 COP/kg of parchment coffee. As it takes on average 1 kg of parchment coffee to produce 0.8 kg of green coffee, we set $p = 6,943/0.8$. We use the same conversion to set the marginal cost $c = 2,823/0.8$ based on the agronomist estimates for variable costs in Section 2.3.

Given data constraints, we estimate the production function of coffee by age in several steps. Data on production is only available at the *farmer* level, and farmers may own many plots consisting of trees with different ages. We first estimate the following equation:

$$Y_{fm} = \sum_{k=0}^{16}\beta_k\,\text{Share}_{fm}^{k} + \gamma X_{fm} + \mu_m + \varepsilon_{fm}, \tag{E1}$$

where $Y_{fm} = \ln(Q_{fm}) - \ln(Area_{fm})$ is the log production per hectare for farmer $f$ in municipality $m$. $\text{Share}_{fm}^{k}$ is the fraction of land cultivated at age $k$. $X_{fm}$ is a vector of covariates including the average planting density, the share planted with resistant varieties, the share of land in full sun, and the log average plot size. $\mu_m$ is a municipality fixed ef-

Table E1. **Externally Set Parameters**

| Parameter | Value | Source |
|---|---|---|
| $\delta$ - time preference | 0.90 | $\delta = 1/(1+r)$ with $r$ from the IMF |
| $\widetilde{\pi}^R$ - mill-gate premium | 10% | Table 3 |
| $\omega$ - production increase | 0, 10 or 20% | |
| $\eta^W$ - export world premium | 4% | Table 2 |
| $\widetilde{\eta}^R$ - Program premium | 17% | Table 2 |
| $p$ - mill-gate price | 8,680 COP/kg green coffee | Table 1 |
| $p^W$ - export price | 9,907 COP/kg green coffee | Table 1 |
| $\tau$ - transaction costs | 12% | $\tau = 1 - p/p^W$ |
| $c$ - marginal cost | 3,529 COP/kg green coffee | Section 2.3 |
| $\gamma$ - cost increase | 11% | Section 2.3 |

Notes: The Table reports the value of parameters that we take as given when estimating the structural model of farmers' decisions or to compute the profits of the exporter.

fect, and $\varepsilon_{fm}$ is the error term. We estimate equation (E1) using data from non-eligible farmers to avoid any contamination due to an increase in productivity when joining the Program. Table E2 presents summary statistics about the variables used to estimate the regression. Using these estimates (reported in Table E3), we predict production at the *plot* level (using equation (E1), with $\text{Share}^k_{fm} = 1$ if the plot is $k$ years old). Finally, we average predicted production over all plots by age to obtain our estimate of the production function. Figure E1 presents the results in kilograms of parchment coffee. Since prices and costs are expressed in terms of green coffee (see Table E1), we also convert these at the same rate of 1 kg of parchment to 0.8 kg of green coffee.

Table E2. **Summary Statistics of the Data Used to Estimate the Production Function**

| | Obs. | Mean | SD | P10 | Median | P90 |
|---|---|---|---|---|---|---|
| Production (kg) | 31,958 | 936.31 | 1101.06 | 83.56 | 551.47 | 2283.16 |
| Area (1,000m2) | 31,958 | 24.01 | 30.47 | 3.90 | 13.00 | 57.80 |
| Age | 31,958 | 5.41 | 4.36 | 2.00 | 4.00 | 11.00 |
| Density (trees/1,000m2) | 31,958 | 524.82 | 93.35 | 435.23 | 512.80 | 639.77 |
| Share resistant | 31,958 | 0.62 | 0.43 | 0.00 | 0.85 | 1.00 |
| Share in full sun | 31,958 | 0.94 | 0.21 | 0.91 | 1.00 | 1.00 |

Notes: The Table presents summary statistics about the data used to estimate the production function. The unit of observation is a farmer, and we only use non-eligible farmers.

We then estimate the parameters $\theta$ via Maximum Likelihood (ML) using observed choices and states. Let the observed data be indexed by $i = 1, \ldots, N$ (plots) and $t = 1, \ldots, T$

Table E3. **Production Function Estimates**

| | Yield (log), Parchment (Kg per 1,000 Sq. Meters) |
|---|---|
| Share of Trees Age 0 | -0.9340*** |
| | (0.0782) |
| Share of Trees Age 1 | -0.1503** |
| | (0.0589) |
| Share of Trees Age 2 | 0.5689*** |
| | (0.0572) |
| Share of Trees Age 3 | 0.6640*** |
| | (0.0569) |
| Share of Trees Age 4 | 0.6772*** |
| | (0.0586) |
| Share of Trees Age 5 | 0.6096*** |
| | (0.0610) |
| Share of Trees Age 6 | 0.4175*** |
| | (0.0625) |
| Share of Trees Age 7 | 0.3169*** |
| | (0.0572) |
| Share of Trees Age 8 | 0.2306*** |
| | (0.0679) |
| Share of Trees Age 9 | 0.3057*** |
| | (0.0700) |
| Share of Trees Age 10 | 0.0758 |
| | (0.0757) |
| Share of Trees Age 11 | 0.1088 |
| | (0.0829) |
| Share of Trees Age 12 | -0.0832 |
| | (0.0948) |
| Share of Trees Age 13 | 0.1046 |
| | (0.0865) |
| Share of Trees Age 14 | -0.0264 |
| | (0.1027) |
| Share of Trees Age 15 | -0.0051 |
| | (0.1222) |
| Share of Trees Age 16 | -0.2675 |
| | (0.1901) |
| Density (Trees per 1000 Sq. Meters) | 0.0007*** |
| | (0.0001) |
| Share Resistant | 0.2359*** |
| | (0.0265) |
| Share in Full Sun | 0.0687 |
| | (0.0459) |
| Average plot size (log) | 0.0051 |
| | (0.0194) |
| Municipality FE | Yes |
| R2 | 0.122 |
| Obs. | 31,958 |

Notes: Robust standard errors in parentheses (clustered by *vereda*) *** p<0.01, ** p<0.05, * p<0.1. The Table reports the coefficients from estimating equation (E1). To estimate the plot-level production function by tree age, we use farmer-level data that contain information on the shares of each farmer's trees of a given age. The excluded category is the share of trees over 16 years old. We regress the realized yields for parchment on the shares, controlling for density, share the share of *roya* resistant trees, share of trees in full sun, the (log) average plot size of the farmer, and municipality FEs.

Figure E1. **Estimated Production as a Function of Age**


Notes: The Figure illustrates how the estimated production of parchment coffee, expressed in kg per 1,000 square meters, first increases and then decreases with the age of the plot.

(years). Each observation corresponds to a realized state $(x_{it}, a_i, q_{it})$ and a choice $d_{it} \in \{1, 2, 3, 4\}$. Given the log-likelihood function

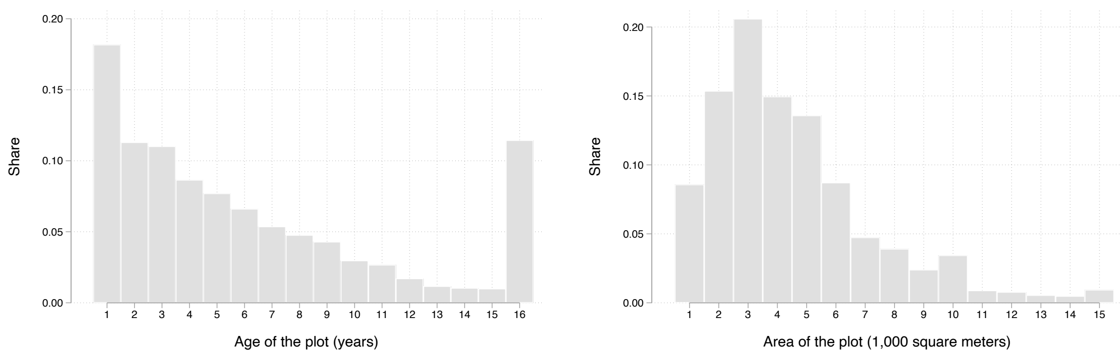
$$\mathcal{L}(\theta) = \sum_{i=1}^{N} \sum_{t=1}^{T} \sum_{j=1}^{4} \mathbb{I}(d_{it} = j) \cdot \log P_j(x_{it}, a_i, p_{it}, \theta),$$

the ML estimator is $\hat{\theta} = \arg\max_{\theta} \mathcal{L}(\theta)$. We cluster standard errors at the plot level.

In order to solve the model and compute the conditional choice probabilities, we use a linear grid for age from 1 to 16. 90% of the observations in the data have age of at most 16. For simplicity, we assume that production beyond age 16 equals production at age 16 (the coefficients for ages over 10 are not significant in Table E3, and Figure E1 is largely flat after this age), and therefore the value function is also constant from age 16. We thus pool ages from 16 onward in the data. Similarly, we use a linear grid for the area of the plot from 1 to 15 with steps of 1 (thousands of square meters). 15,000 square meters is the maximum plot area observed in the data.

We estimate $\theta$ using observations from plots that are eligible for the Program. We use a balanced panel of 47,010 plots that are observed for five consecutive years following from the year of initial eligibility, for a total of 235,050 observations. (The sample size decreases if we require more consecutive years.) Figure E2 shows the distribution of the state variables, the age and area of the plots, in the first period of the data when no plot has joined the Program.

Figure E2. **Distribution of the State Variables**




Notes: The Figure presents the distribution of the state variables, i.e. the age and area of the plot, in the first period of the data used to estimate the structural model. We pool ages from 16 onward in the data. Because the data correspond to the time when plots first become eligible for the Program, there is no variation in Program status. N=47,010.

Table E4 presents the estimates of $\theta$. The estimates for the renewal costs are similar across different values of $\omega$, and they suggest that larger plots pay a smaller cost. We estimate that renewing a one-hectare plot costs between 6.9 and 7.5 million 2015 COP across values of $\omega$, within agronomists' estimated range of 6.9-10.4 million 2015 COP (USDA, 2018). Our estimates for the joining costs are more sensitive to the choice of $\omega$ because, as the Program becomes more attractive, the model needs a higher joining cost to rationalize observed take-up. Joining costs increase both with the size of the plot and its age.

Table E4. **Structural Parameter Estimates for Eligible Plots**

| | $\omega$ = 0% | | $\omega$ = 10% | | $\omega$ = 20% | |
|---|---|---|---|---|---|---|
| Parameter | Estimate | Std. Err. | Estimate | Std. Err. | Estimate | Std. Err. |
| $\theta_1^R$ | 10945.16 | 222.46 | 11202.09 | 225.31 | 11549.11 | 234.70 |
| $\theta_2^R$ | −403.16 | 17.96 | −403.15 | 18.76 | −404.23 | 19.40 |
| $\theta_1^J$ | 4741.07 | 175.53 | 4882.11 | 177.30 | 5056.82 | 186.31 |
| $\theta_2^J$ | 117.71 | 27.89 | 521.74 | 27.71 | 925.02 | 29.37 |
| $\theta_3^J$ | 181.25 | 11.46 | 163.27 | 11.30 | 148.09 | 12.09 |
| $\sigma$ | 4346.34 | 87.89 | 4454.66 | 88.56 | 4602.29 | 92.14 |

Notes: The Table reports the estimate of the parameters from the structural model for eligible plots. The estimates are expressed in 1,000 COP. We cluster standard errors at the plot level. Renewal costs equal $\theta_1^R + \theta_2^R \times area$ (in 1,000 sq. meters) and joining costs equal $\theta_1^J + \theta_2^J \times area + \theta_3^J \times age$. $\sigma$ is the scale of the T1EV structural shock.

We further estimate a simpler version of the model using data from non-eligible plots. In this simplified model each plot is characterized by state variables $\{x, a\}$ and only choices $j = 1, 2$ are available. For non-eligible plots, we fix the scale of the T1EV shock $\sigma$ to that estimated from eligible plots (which varies with $\omega$), and only estimate renewal costs . The estimates in Table E5 suggest that non-eligible plots pay around 5% more than eligible ones to renew, consistent with the Program having subsidized access to seedlings and agricultural inputs (which account for 15-20% of the total renovation costs).

Table E5. **Structural Parameter Estimates for Non-Eligible Plots**

| | $\omega = 0\%$ | | $\omega = 10\%$ | | $\omega = 20\%$ | |
|---|---|---|---|---|---|---|
| Parameter | Estimate | Std. Err. | Estimate | Std. Err. | Estimate | Std. Err. |
| $\theta_1^R$ | 11709.97 | 85.21 | 11970.30 | 86.10 | 12325.07 | 87.76 |
| $\theta_2^R$ | −445.84 | 19.54 | −451.25 | 19.63 | −458.61 | 19.87 |

Notes: The Table reports the estimate of the parameters from the structural model for non-eligible plots, assuming they face shocks with the same distribution of those estimated for eligible plots (hence we do not separately estimate $\sigma$). The estimates are expressed in thousands of 2015 COP. We cluster standard errors at the plot level. Renewal costs equal $\theta_1^R + \theta_2^R \times area$.

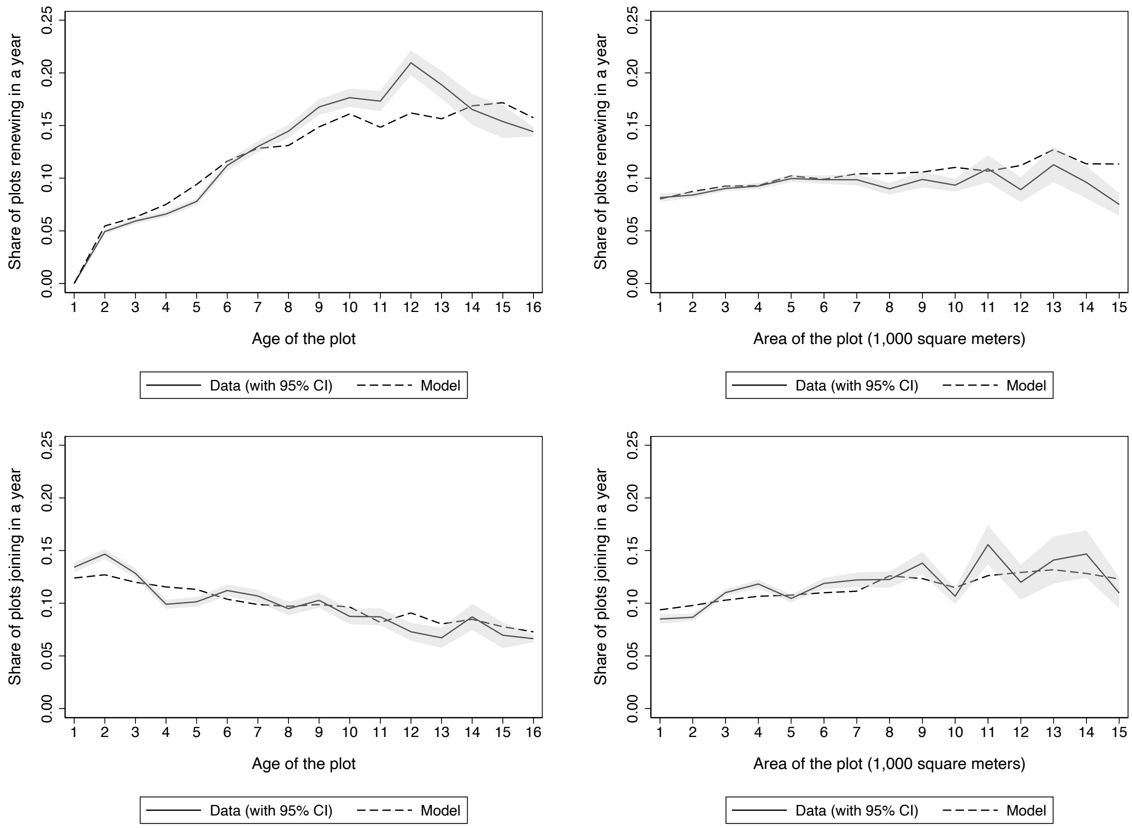
## E.3 Model Fit

Given the estimates in Table E4, we simulate farmers' decisions for five periods using the same initial conditions of the data used for estimation (see Figure E2). Figure E3 shows the model fit for the renewal (top figures) and joining decisions (bottom figures) with respect to the age (left figures) and the size of the plots (right figures) assuming $\omega = 10\%$. The results are virtually identical using estimates corresponding to $\omega = 0\%$ or 20% and not reported here. The model successfully replicates observed behavior in the data and its heterogeneity by age and size. Figure E4 shows the fit for the simpler model of non-eligible plots.

## E.4 Welfare

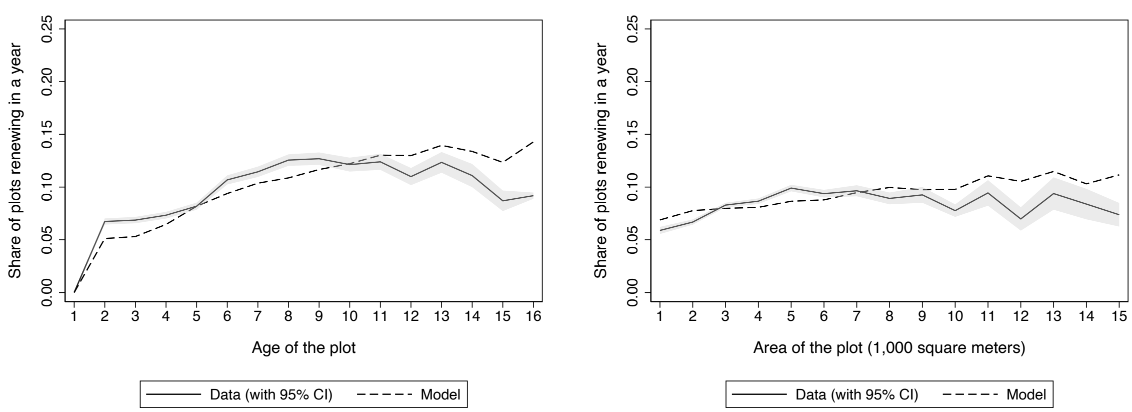
Given the estimates of the structural parameters, we compute the net present value of profits from plot $i$ as $V(x_{i1}, a_i, q_{i1}, \hat{\theta})$ using the value of the state variables observed when the plot becomes eligible to join the Program. We then compute farmers' welfare by aggregating over plots, $\sum_i V(x_{i1}, a_i, q_{i1}, \hat{\theta})$. We refer to this quantity as $\mathbf{W}^F(\widetilde{\pi}^R, \vec{\sigma})$ in the

## Figure E3. **Model Fit for Eligible Plots**




Notes: The Figure presents the model fit for the renewal (top figures) and joining decisions (bottom figures) of eligible plots with respect to the age (left figures) and the size of the plots (right figures) assuming $\omega = 10\%$. The results are virtually identical using estimates corresponding to $\omega = 0\%$ or 20% and not reported here.

## Figure E4. **Model Fit for Non-Eligible Plots**




Notes: The Figure presents the model fit for the renewal decisions of non-eligible plots with respect to the age (left figures) and the size of the plots (right figures) assuming $\omega = 10\%$. The results are virtually identical using estimates corresponding to $\omega = 0\%$ or 20% and not reported here.

text, and study how it varies with Program features. (See Table 7 and the accompanying discussion in the main text.)

On the demand side, by assumption, the exporter makes zero profits on standard coffee, $p^W - \tau p^W - p = p^W - \tau p^W - (1-\tau)p^W = 0$, and earns $(1+\widetilde{\eta}^R)p^W - \tau p^W - (1+\pi)p = p^W[\widetilde{\eta}^R - (1-\tau)\widetilde{\pi}^R]$ on each kg of quality coffee. Given the estimates of the structural parameters, we simulate farmers' decisions forward (starting from initial conditions $\{x_{i1}, a_i, q_{i1}\}$) to compute the aggregate quality supply function and then the exporter profits $\mathbf{\Pi}^E(\widetilde{\pi}^R, \widetilde{\eta}^R, \vec{\sigma})$, assuming they have the same time preferences as farmers ($\delta$).

Because both $\mathbf{W}^F(\widetilde{\pi}^R, \vec{\sigma})$ and $\mathbf{\Pi}^E(\widetilde{\pi}^R, \widetilde{\eta}^R, \vec{\sigma})$ are measured in COP, we can sum them to compute the welfare along the supply chain (see Table 7). We also use a weighted sum of the two to test Prediction 2f, as shown in Figure 4.

We also calculate farmer upgrading decisions under alternative values of $\pi$ in the absence of the Program but with a perfectly competitive export market. In particular, in this case we assume that $\pi^M = \eta^W/(1-\tau)$, reflecting the full pass through of the observed $\eta^W = 4\%$ in the data.