# Got (Clean) Milk? Organization, Incentives, and Management in Indian Dairy Cooperatives

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**Abstract**

Much smallholder production in developing countries takes place in groups that enforce production norms and mediate internal allocation of surplus. We evaluate incentive contracts for quality upgrading among such production teams. In a randomized experiment with rural Indian dairy cooperatives, we find group incentives improve aggregate quality even when individual quality cannot be traced, with evidence of increased effort from both producers and managers. However, several cooperative managers decline incentive payments when local elites cannot control payment-related information disclosure. Survey evidence suggests disclosure introduces frictions, implying that some efforts to limit elite capture may undermine broader development goals.

Keywords: quality upgrading, cooperatives, dairy, elite capture, India

JEL Codes: O13, L23, Q13, P13, D23

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# 1 Introduction

Much of the world's population engages in small-scale production. An estimated 400 million farms operate below one hectare (Lowder et al., 2016) and over 90% of firms worldwide employ fewer than ten workers (Hsieh and Olken, 2014). Linking these producers to broader input and output markets can raise profits, thereby increasing productivity and improving livelihoods. To this end, development policy has promoted cooperatives or collective organizations that take advantage of economies of scale, with an estimated half of the world's population involved in some form of cooperative enterprise (Organization, 2014). More recently, policymakers have emphasized quality upgrading as a further means to link small-scale producers in developing countries to global value chains with greater economic returns (World Bank, 2020).

This paper evaluates the effectiveness of incentive contracts for quality upgrading in cooperative agriculture through an experiment among rural Indian dairy farmers. Incentive contracts in cooperative systems generate a tension because production is carried out by individual members but returns are realized at the group level, leading to potential free-riding problems and coordination frictions. Nevertheless, cooperatives frequently organize around local community and social structures that have the potential to mitigate this misalignment of incentives (e.g. Ostrom, 1990). On the other hand, hierarchy in social status and power among producers governs the allocation of group surplus and generates the potential for elite capture. In this study we directly test the capacity for dairy cooperatives to upgrade quality in response to group-level incentive contracts, provide indirect evidence on how the resulting revenue is allocated within the cooperative, and reveal how these two outcomes are fundamentally linked by the behavior of powerful cooperative members.

We study these questions in the context of village dairy cooperatives in Karnataka, India. The state's dairy sector encompasses more than 2.4 million producers in over 22,000 villages. Production is organized through village-level cooperative societies composed of smallholder farmers who pool their milk for sale and delivery to bulk processing facilities. Dairy is an important source of income for smallholder farmers throughout the developing world, and similar cooperative structures exist at the local level in the agricultural sector worldwide.

Quality upgrading in this setting means lowering microbial contamination at the point of production. Lowering contamination of raw milk raises profitability along the supply chain by enabling production of higher value-added products such as cheese, yogurt, and milk sweets. Despite this potential, microbial load currently has little bearing on direct compensation for cooperatives at the production stage. Instead, the Indian dairy sector has invested heavily in technology and infrastructure to minimize the damage from contamination farther downstream.

At the point of production, contamination is mitigated by individual sanitary practices such as washing hands and sterilizing equipment. However, incentives for milk cleanliness must be delivered at the cooperative level because technological constraints render it prohibitively expensive to decentralize measurement down to the individual producer. Since contamination cannot be traced back to any single individual, each member has a financial incentive to minimize private effort and rely on the cleanliness of their peers. The cooperative effectively constitutes a production team that relies on internal governance to minimize free-riding.

We evaluate the potential for quality upgrading with two levels of experimental variation. First, we randomly introduce cooperative-level incentive contracts. In all study cooperatives, we measure and report microbial contamination in pooled milk. Among a subset, we offer an incentive payment tied to this aggregate measure of cleanliness. This intervention tests whether cooperatives can effectively improve production quality to take advantage of an opportunity for collective payment at the margin.

Second, among those offered incentives, we further randomize transparency around the incentive contract. All incentive payments are transferred to the cooperative bank account operated by cooperative managers. We randomly vary whether the contract and transfer are disclosed privately to managers alone or announced publicly to managers as well as a subset of cooperative members. Prior work has found trust in leadership to be a determinative factor in sustaining collective action among smallholder farmers (Casaburi and Macchiavello, 2015; Bernard et al., 2021; Aflagah et al., 2022). This second manipulation gives insight into whether transparency can alleviate trust-based inefficiencies, and investigates how such transparency affects bargaining, distribution of surplus, and production outcomes.

We present two key findings. First, microbial contamination decreases among cooperatives offered financial incentives. We report indirect evidence that both dairy farmers and managers adjust their practices to improve sanitation. This result indicates that cooperatives can internally enforce a norm of cleanliness even without explicit individual-level quality measurements.

We find little evidence that this norm is enforced through direct financial remuneration to farmers from the cooperative. Instead it appears that managers promote cleanliness through informal pressure along financial or social channels not directly related to this experiment. It remains unclear whether this pressure comes in the form of greater rewards for cleanliness or harsher punishment for lack of effort.

The increase in cleanliness is quantitatively large relative to the magnitude of the incentive. The incentive schedule offers the potential to raise cooperative revenue by up to 2.5 percent over a two-week period[1]. This modest opportunity generates an improvement in milk quality of up to 0.64

[1] Of course, most cooperatives do not achieve the maximum payment. Actual payouts amount to a realized increase in cooperative revenue of one percent on average.

standard deviations, which corresponds to an 81% increase in the fraction of raw milk suitable for high-value processing. The size of response indicates a high capacity for organizational innovations to complement technological adoption in quality upgrading.

Second, almost a third of cooperative managers opt out of receiving incentive payments entirely rather than receive the payment with public knowledge. Opting out indicates that public information lowers managers' surplus relative to their cost of effort. This loss of surplus must be related to the publicity itself, as managers who opt out first request to keep the payment private. On being declined that option, they ultimately consent to continue milk testing without payment. The decision to forego payment is especially perplexing because all cooperatives would have received positive payment had they merely maintained the status quo with no change to production practices. Commensurate with the high rate of opt-out, we measure a diminished treatment effect of incentives in the public information arm, though we lack power to statistically distinguish this difference from zero.

Refusing payment is most common among managers with weaker oversight and lower social status. Managerial oversight and status may modulate the effect of public information in two ways. First, publicly announcing payments may create extra work for the manager if the announcement is confusing and managers play a role in coordinating information and expectations within the cooperative. Second, publicity may lower managers' share of surplus from the experiment if managers enjoy information rents from private knowledge about payouts. It remains an open question exactly how publicity affects the surplus allocated to the cooperative manager, but in either case public announcement of revenue is less damaging to administrators with higher status.

The latter explanation is consistent with economic models of income hiding. Lab experiments have previously demonstrated participants' willingness to sacrifice returns in order to keep income hidden from their social network (Jakiela and Ozier, 2015). This type of behavior has been shown to constrain efficiency in risk-sharing arrangements (Kocherlakota, 1996; Ligon, 1998; Kinnan, 2021). Managers opting out of payment in our experiment can be considered an extreme version of income hiding where income is sacrificed in its entirety.

Together, these two findings paint a nuanced picture of the collective response to group-level incentives among agricultural cooperatives. Improvements in milk cleanliness indicate that at the margin, potential misalignment between the private and aggregate returns to cleanliness does not undermine the role of incentives. However, the collective response to incentives may be diminished by barriers to the cooperative's ability to coordinate or to allocate surplus. In our study, these limitations lead to a trade-off in which the payment structure that maximizes productive surplus is that which also enables elite capture by cooperative managers.

This paper relates to several stands of literature. First, we expand the large body of work on quality upgrading in agriculture. Incentives in our study resemble contract farming (see Bellemare and Bloem, 2018, for a review), which we extend to cooperative agriculture. Our research most closely relates to prior studies of quality incentives in dairy using observational variation (Treurniet, 2021) or hypothetical elicitations (Saenger et al., 2013), and to experimental evaluation of quality incentives among Colombian coffee cooperatives (Macchiavello and Miquel-Florensa, 2019).

Incentive contracts represent a demand-driven approach to quality upgrading. Related demand-side factors affecting agricultural output quality include contract design (Goodhue et al., 2010; Saenger et al., 2013), market competition (Bernard et al., 2017; Macchiavello and Morjaria, 2021b; Bold et al., 2022), and quality verification (Saenger et al., 2014; Bai, 2021; Hasanain et al., 2022). This work complements research on supply-side determinants of quality such as producer skill and technology adoption (see de Janvry et al., 2017, for a review).

The recent policy emphasis on quality upgrading as a means of economic development relies crucially on value-added in the supply chain passing through to upstream producers. Existing work demonstrates how transportation costs and market power can limit price passthrough from central markets to rural communities (Atkin and Donaldson, 2015; Mitra et al., 2018; Bergquist and Dinerstein, 2020). We reveal how elite power at the community level can further curtail the share of value-added that reaches smallholder producers.

Second, our research sheds light on cooperatives in agricultural production. Cooperative agriculture has been promoted as a potential pathway out of rural poverty by connecting producers to markets with higher prices (e.g. Bernard et al., 2008; Markelova et al., 2009; Wanyama, 2014; Hill et al., 2021) and facilitating a more equitable distribution of agricultural revenue (Montero, 2022). Cooperative function is sustained by social capital (see Ostrom and Ahn, eds, 2003; Durlauf and Fafchamps, 2005). This paper presents an empirical investigation of the role of social capital within Indian dairy cooperatives. The heterogeneous response to public information in our field experiment is consistent with results in prior lab experiments (e.g. Kosfeld and Rustagi, 2015) and observational studies (e.g. Macchiavello and Morjaria, 2021a) demonstrating the importance of manager identity in addition to general social capital.

Third, we contribute to the empirical literature on the optimal design of incentives for team production.[2] There is a large body of empirical work evaluating incentive structures for individuals within teams (see Bandiera et al., 2011; Bloom and van Reenen, 2011). When individualized incentives are infeasible, team-level incentives can increase aggregate productivity (e.g. Bandiera et al., 2013; Friebel et al., 2017). We extend the study of team incentives to a setting where the hierarchy of formal authority within the production unit corresponds to informal status in the social network outside the production unit. Our field results are consistent with lab experiments on the

[2] See Marschak and Radner (1972) for a theoretical discussion.

role of management in achieving production goals and allocating surplus (Drouvelis et al., 2017).

Finally, we provide evidence on the role of local leaders in policy implementation. Local leaders act as implementing agents for centralized policy in many development settings (Bardhan, 2002; Besley and Coate, 2003; Platteau, 2009). Such arrangements have been shown to leverage local information to improve outcomes in tax collection (Balán et al., 2022), public procurement (Bandiera et al., 2021), and resource targeting (Alatas et al., 2012; Hussam et al., 2020). However, local autonomy can also enable elite capture of public surplus (e.g. Reinikka and Svensson, 2004; Olken, 2007; Niehaus and Sukhtankar, 2013; Alatas et al., 2019). In the context of cooperative agriculture, Banerjee et al. (2001) and Casaburi and Macchiavello (2015) provide evidence on how cooperative leaders skew their behavior to generate private returns. Our findings highlight the tension between these two competing pressures.

In many cases, transparency has been employed as a tool to constrain elite capture. Information disclosure or technological barriers to leakage may discipline elites and reduce their ability to extract surplus (Ferraz and Finan, 2008; Muralidharan et al., 2016; Banerjee et al., 2018, 2020). However, transparency can also generate perverse incentives in principal-agent relationships (e.g. Anagol et al., 2017; Mejia and Parker, 2021; Desarronno et al., 2021). The results of this study reinforce the concern that policies to constrain elite power may backfire if they lead elites to shift towards more distortionary practices or seek out ways to circumvent these efforts entirely.

The rest of the paper proceeds as follows. In Section 2, we describe the setting and production process in more detail. Section 3 outlines our experimental design, and Section 4 presents results. We discuss the findings in Section 5, and Section 6 concludes.

# 2 Setting

We study quality upgrading in the context of dairy cooperatives in Karnataka, India. Milk production in the state is organized through village-level cooperatives that aggregate output from smallholder farmers for delivery to processing plants. Cooperatives consist of farmer producers that act as shareholders and managers that oversee production and finances. The typical farmer producer owns 1–2 milking cows and earns 20–30% of their total income from dairy activities. Karnataka state alone processes 2 million gallons of milk per day from over 2.4 million producers in over 22,000 villages across the state. Moreover, similar cooperative organizations are present for milk and agricultural production in many Indian states and other developing nations.

Revenue in the dairy sector is a function of both milk quantity and quality. However, due to bureaucratic and logistical constraints, payments to farmer producers are based almost exclusively on quantity alone. The state dairy agency has invested heavily in technological upgrades along the supply chain to bolster quality, but there remains disconnect between downstream profitability and individual incentives at the point of milking.

In this paper, we explore the marginal return to an incentive payment explicitly tied to the aggregate quality of raw milk at the cooperative level before integration into the larger dairy supply-chain. We deliver the incentives through the existing financial structure under cooperative management.

## 2.1 Supply Chain and Cleanliness

Dairy production originates in rural villages with smallholder producers. Each village-level cooperative, typically consisting of 50–100 producers, collects milk from pouring members into common cans at the cooperative premises during a brief daily window. A single can holds milk from 5–10 different producers, and once full, cans are sealed for immediate pickup and delivery to a processing plant. Appendix A walks through the village milk collection process with photographs.

At the processing plant, milk samples from each can are tested for quality to determine suitability for various dairy products. Low-quality milk is packaged directly as liquid milk, while higher-quality milk is creamed into butter or ghee, or cultured for higher value-added products such as cheese, yogurt, and milk sweets.

In this study, we aim to promote quality upgrading along the dimension of microbial load. This is an important margin of adjustment because different retail products require different levels of cleanliness in their raw milk input due to pasteurization methods. Milk used in high-value production must be pasteurized at temperatures of 70–80°C. At this temperature, the USDA (2011) requires[3] that raw milk have no more than 500,000 colony-forming microbial units per milliliter (cfu/ml) to be used as an input for value-added milk products. Even below this threshold, variation in the bacterial content of raw milk produces noticeable differences in flavor down to 10,000 cfu/ml (Murphy et al., 2016).

There is substantial room for improvement in the cleanliness of milk in or study setting. Figure 1 presents a histogram of the microbial load by delivery can prior to any intervention. Of 225 cans tested at baseline, only 37 met the USDA standard for value-added processing. The remaining milk, with bacterial loads exceeding 500,000 cfm/ml, requires ultra-high temperature (UHT) pasteurization at 135°C. This process denatures enzymes and proteins, meaning the product is only suitable for sale as liquid milk.[4]

[Figure 1 about here.]

[3]To the best of our knowledge, the Food Safety and Standards Authority of India (FSSAI) sets standards for microbial load in final production but does not regulate raw milk inputs.

[4]UHT can accommodate bacterial contamination up to 5 million cfu/ml for shelf-stable packaging (Tetra Pak, 2014) and even greater levels if sold for immediate consumption. Milk that is unsuitable even for UHT is usually detectable by sight or smell, and is therefore rejected before it reaches the processing plant.

In this paper we evaluate incentive contracts for cleanliness at the point of collection. This outcome is affected by both farmers' milking practices as well as the cleanliness of shared equipment and cooperative premises. Farmers can lower the microbial count in their own product with basic sanitation procedures such as regularly cleaning their cows' udders, maintaining a sanitary milking space, and washing hands and equipment prior to milking. Because milk from each farmer is poured into common delivery cans, regular washing of village equipment also contributes to milk cleanliness. These activities complement recent technological investment by the dairy sector to limit contamination further along the supply chain.[5]

We break down the potential for improvement in each of these areas by comparing baseline samples taken from farmers immediately before pouring into village cans to samples taken from village cans immediately after pouring in Figure 2.[6] Panel A plots the distribution of cleanliness among individual producers. There is substantial variance, with only 14% of producers delivering milk that achieves the highest sanitation rating. Compressing this distribution by one standard deviation around the $95^{\text{th}}$ percentile would raise this fraction by 16% (2 percentage points). Panel B plots the distribution of sanitation at the cooperative level measured before and after pouring into shared cans. There is a large and statistically significant decline in the cleanliness of pooled milk samples from village cans from 4.26 to 3.52; a t-test rejects the equality of these two values with a t-statistic above 5 ($p < 0.01$). This contamination introduced by cooperative equipment is equivalent to a 0.5 standard deviation decrease in individual producer quality. Improvements in both individual milking practices as well as sanitation of collective equipment could increase the cleanliness of raw milk delivered for processing.

[5]In the recent past, the dairy sector has invested significantly in reducing the time to refrigeration through initiatives such as optimizing the transportation routes of collection trucks and installing rural bulk refrigeration facilities.

[6]It was prohibitively expensive to conduct a plate count of microbial load on individual milk samples. Instead, we plot results from a dye reduction test designed to measure microbial contamination, which unfortunately does not directly translate to USDA safety measures. The relationship between these two measures is discussed in Section 3.

[Figure 2 about here.]

Measuring microbial load requires lab equipment, training, and time. It is therefore logistically infeasible to regularly measure individual producers' milk at the point of collection beyond a basic sight and smell check for spoilage. In the supply chain, the most decentralized unit that could reasonably be tested is the delivery can, which contains milk from 5–10 producers. In practice, cooperatives do not track which producers pour into which cans so the effective unit of aggregation is the entire cooperative.

## 2.2 Production Incentives

Production incentives for farmers are misaligned with the value of sanitation in the supply chain in two ways. First, there is little return to cleanliness at the production stage. Cooperatives are paid based on the quantity of raw milk delivered, with little to no variation based on cleanliness. In this study we evaluate incentive contracts designed to address this source of misalignment. We introduce a high-quality testing procedure coupled with incentive payments linked to the measured microbial load at the aggregate cooperative level.

We leverage the existing financial infrastructure for incentive payments. Each cooperative has a bank account to receive payment from the processor. Management is then responsible for disbursing payments to individual farmers.[7] We supplement the regular cooperative revenue from processors with a bonus contract based on the measured microbial load in milk. Beyond making a deposit into the cooperative bank account, we offer no instruction on how this surplus revenue should be allocated.

The second source of misalignment arises because quality-based incentives at the aggregate level

[7] During the period of our study, these disbursements from the cooperative to the farmer were predominantly made in cash.

generate the potential for free-riding within the cooperative. Payments must be conditioned on the aggregate quality of pooled milk because it is prohibitively expensive to test quality at the individual level, so the return to any individual's effort is shared with the entire cooperative and the effect of shirking is literally diluted. However, shirking may be mitigated because cooperative members and management are part of a local village community and interact outside the cooperative. Even though the cooperative cannot directly measure the microbial load in any individual's milk, they may have local information about members' level of effort that enables them to internally enforce a norm of cleanliness.

### 2.3 Cooperative Governance

Each cooperative is managed by an elected president and secretary who make administrative decisions and serve as local points of contact for our study. Together they manage the cooperative financial account, which is held jointly in their names. In addition, the secretary is in charge of day-to-day operations, most notably managing daily milk collection. The two officers serve staggered ten-year terms, and are overseen by a board of directors typically consisting of 9–10 cooperative members. The board is composed of local member producers and is intended to provide representation for the various communities within the village, though the election process varies idiosyncratically by village.

In Table 1, we present demographic characteristics of producers, secretaries, members of the board of directors, and presidents in our area of study. It is clear from this table that presidents occupy traditional positions of high social status. They are wealthier and more educated on average than producers and directors, they are less likely to belong to a scheduled (i.e. low-status) caste or tribe, and they are more likely to have previously been elected to serve in the local legislative assembly (Gram Panchayat).

Secretaries embody a second type of local elite. While their demographic characteristics are more in line with typical producers, the one notable exception is in education. Secretaries have on average twice as much education as the typical producer. The position of cooperative secretary underscores an often overlooked channel through which people of historically lower socioeconomic status can participate in local administration.

Social perceptions of presidents and secretaries relative to directors correspond to their position as elites. The second part of Table 1 presents cooperative members' and directors' subjective perceptions of each group. The columns correspond to beliefs about a group, and the rows correspond to the group giving the evaluation. The table includes data on perceptions of social power/status, management capacity, and knowledge of dairy practices.

[Table 1 about here.]

Table 1 reveals that all groups evaluate secretaries and presidents higher than they evaluate members of the board of directors. In fact, secretaries are consistently rated slightly above presidents, even in questions of social standing. These differences in the characteristics of cooperative managers underscore the potential for elite capture in this setting. In particular, the managers in charge of the cooperative bank account—the president and the secretary—are also those that have the greatest education and social standing, and are seen to be the most capable and knowledgeable. Their dominant position in the village social network limits other stakeholders' ability to constrain their actions despite the formal oversight authority of the board of directors.

Rent extraction by elites is also hinted at in cooperatives' finances. Each cooperative runs an operating surplus to pay for facilities and maintenance as well as salaries for staff. At the end of the year, any remaining surplus is mandated by state law to be distributed among members. However, in practice the use of funds is murky. In the three years leading up to our study, all cooperatives participating in our study officially reported net accounting surpluses in every year, indicating that they should have paid bonuses to farmers. Despite this, at baseline only 20% of farmers surveyed could remember ever receiving a bonus from the cooperative, revealing a disconnect between official accounting and the actual use of funds.

# 3 Experimental Design

We implement a randomized evaluation of incentive contracts for quality upgrading by lowering the microbial load in milk. The incentive is offered at the cooperative (effectively village) level based on samples of pooled milk from delivery cans, and payments are made into the cooperative bank account. Each cooperative in the study is randomly assigned to either receive incentive payments or not, and the payment schedule is shared with the president and secretary of those chosen to receive incentives. Furthermore, in a randomly selected subset of incentivized cooperatives, we also announce the payment schedule publicly to a random subset of member producers. We evaluate the change in milk cleanliness from two rounds of baseline testing through two rounds of intervention.

## 3.1 Intervention

To promote clean production practices, we couple a high-quality testing procedure with incentive payments for cleaner milk. In every study village, treatment and control, we collect milk samples, measure the microbial load in a lab, and share the results with cooperative management. Cooperatives normally do not measure or receive feedback on cleanliness, so testing alone may provide new information. We keep monitoring and feedback uniform across study villages in order to experimentally isolate the effect of group incentives on production outcomes.

Experimental randomization takes place across cooperatives in two stages. First, each participating cooperative is randomly assigned to either receive incentive payments for clean milk or not. Second, in treated cooperatives, we further randomly vary whether incentive payments are announced privately or publicly. In the private treatment arm the existence of incentives is disclosed only to the secretary and president, though they may choose to share this information with others at their discretion. In the public treatment arm, we also inform a random subset of cooperative members about the incentive payments. Cooperatives in which we only conduct testing without associated incentives serve as the control group for our experimental manipulation.

The first stage of randomization introduces incentives in the form of a supplemental payment from our experiment based on measured milk quality. In each treated cooperative, we test a sample from each delivery can on a given collection day and then make the incentive payment to the cooperative financial account as a function of the average quality across all cans. This treatment generates returns to cleanliness for the cooperative as a whole, but introduces the possibility for internal free-riding because each individual's effort is diluted across the average quality of the entire village. We test whether the cooperative can raise its total quality in the aggregate even though it cannot directly measure the quality of any individual's output.

Incentive payments range from Rs. 0 for the lowest quality to Rs. 2,000 for the highest quality, equivalent to roughly \$40.[8] With average daily revenues of Rs. 5,600, producing the highest quality milk would generate a 36% increase in revenue for the day.[9] The payment schedule is scaled so that the average payment at baseline (i.e. with no quality improvement) would be ∼Rs. 500, or roughly \$10, representing a 9% increase in typical daily revenue. Because we test once in a two-week period, these values should be divided by 14 to interpret the expected size of the incentive on any given

[8]Full details of the payment schedule are provided in Appendix B.

[9]The high end of the payment scale is equivalent to just under one month's average salary for a secretary, and nearly 80% of a month's self-reported total earnings for the average dairy producer.

day.

The second stage of randomization varies the level of information disclosure about the incentive payment across cooperatives in the treated group. In all treated villages, we share the payment schedule and subsequently realized payment with the president and secretary. In a subset of these, designated the public payment arm, we further reveal this information to a random subset of pouring members at the time of milk collection. In the rest, designated the private payment arm, we do not disclose any information publicly. Information revelation plays two roles in this setting. First, it helps alleviate information asymmetry about the collective returns to cleanliness by increasing the set of participants that know about the group incentive. Second, it lowers the potential for managers to extract information rents by constraining their ability to hide the size of these payments. We investigate whether the public provision of information affects aggregate productivity, and whether it changes distributional outcomes by influencing the extent to which realized returns to cleanliness are shared with cooperative members.

The intervention is implemented over two rounds of incentivized production with three points of contact in each round. First, we announce a two-week window during which we may conduct testing, corresponding to the frequency with which processors pay cooperatives. In this visit we also describe the incentive structure to cooperative management in treated villages, and further share these details with 20 randomly selected producers in the public payment arm. Second, we pick a random day in the two-week window to return for milk testing. Following the regular milk collection, we collect samples from each can that we then chill and send to a laboratory. Finally, we return to reveal the test results to the secretary two days later. During this third visit we make payment into the cooperative account in treated villages, and disclose this payment to another 20 randomly selected pouring members in the public payment arm. We repeat this process twice across all study units.

### 3.2 Sample Selection and Randomization

We recruited village-level cooperatives affiliated to the milk processing facility in the Dharwad district of Karnataka in India. Participating cooperatives were recruited from the two sub-districts closest to the processor. We contacted all 56 cooperatives in the Hubballi and Dharwad sub-districts, out of which 55 agreed to participate. Four dropped out before the experiment began, leaving a final sample of 51 cooperative societies with a total of 2,859 pouring members.

Figure 3 shows the treatment assignment across the two rounds of intervention. In Round 1, there are 19 village assigned to control, 19 villages assigned to private payment, and 13 villages assigned to public payment. Between Rounds 1 and 2, we randomly reassign 6 villages from control to public payment and 3 from private to public payment.[10] There are no villages reassigned in the other direction because public announcement of payments is an absorbing state as we cannot credibly revoke the expectation that incentives will be paid.

[Figure 3 about here.]

Table 2 provides descriptive statistics for the treated and control groups. Covariates appear balanced; only the fraction of income earned from dairy differs significantly between the two. A joint test of significance for all survey outcomes fails to reject equality at the 10% level. Importantly, there are no statistically significant differences between treatment and control in average quantity poured, cleanliness, or number of livestock.

[Table 2 about here.]

[10]Motivation for changing treatment assignment mid-intervention is discussed in Appendix C.

### 3.3 Data Collection and Analysis

We conduct baseline surveys with cooperative management and a random sample of pouring members in each village, collect four rounds of data on milk cleanliness—two during baseline and two during the intervention—and then conduct endline surveys with another random sample of pouring members. We submitted a pre-analysis plan for this trial to the AEA RCT Registry before the start of the study, and discuss deviations from the pre-specified design that arose during project implementation in Appendix C.

#### 3.3.1 Milk Testing

The primary outcome of interest is the microbial load in raw milk produced by the cooperative. We measure the average microbial load by taking samples from the morning dairy collection to a lab for testing. To limit the extent to which test results are influenced by transportation time, each collection team visited only one village per day and carried an insulated container of ice for immediate chilling. Each village was visited twice in the baseline period and twice during the intervention period. In each visit, we collected samples from every can filled by the cooperative, and in the first baseline visit we collected individual-level samples from a subset of producers prior to pouring.[11]

We employ two lab tests of bacterial load: the methylene blue reduction test (MBRT) and the standard plate count (SPC). MBRT is a cheap, fast measure commonly used at processing centers to quickly determine the suitability of raw milk for various products. SPC requires more equipment and training, and does not produce results for 24 hours. This test is typically used by food safety regulators, and is similarly used internally by processors to spot-check sanitary standards. Details

[11] Individual-level sampling proved to be too disruptive to milk collection and was therefore discontinued after the first round.

of each measure are discussed in Appendix B.

MBRT and SPC can be considered two noisy measures of underlying milk cleanliness. To maximize power, our primary outcome for analysis is a composite measure of milk quality that is the first principal component of these two variables.[12] We construct this index at the village level by averaging over can-level measurements. Details of the relationship between the two measures and the principal components analysis are provided in Appendix B.

To evaluate testing-related outcomes, we implement a difference-in-differences (DD) estimation strategy at the village level. The estimating equation is

$$Y_{jt} = \beta^{Pr} T_{jt}^{Pr} + \beta^{Pu} T_{jt}^{Pu} + \gamma_j + \delta_t + \epsilon_{jt} \tag{1}$$

where $j$ indexes cooperatives and $t$ indexes testing rounds. The variables $T^{Pr}$ and $T^{Pu}$ are dummies representing assignment to either private or public payment arms in round $t$, and both dummies are 0 for all cooperatives in the two baseline rounds of observation. $\gamma$ and $\delta$ represent village and time fixed effects, respectively.

#### 3.3.2 Survey Data

We supplement the milk quality tests with two rounds of survey data. At baseline, prior to any milk testing, we surveyed twenty producers in each village randomly selected from the population of farmers contributing milk on the day of the visit. Baseline questions included information on demographics, income, and dairy production practices. We also administered a baseline questionnaire to cooperative secretaries, directors, and presidents covering their demographics, dairy

[12] Incentive payments were based only on MBRT for transparency. MBRT is the primary measure used for day-to-day production decisions by processors, and in focus groups we found that most cooperative members and secretaries were familiar with MBRT but not with SPC. It is highly unlikely that study participants could take actions specifically aimed to improve MBRT readings without increasing overall milk cleanliness.

involvement, and managerial practices. After the final round of testing during the intervention, we administered an endline questionnaire to another randomly sampled twenty pouring members per village covering demographics, dairy involvement, and knowledge about incentive payments.

During baseline, we additionally elicited subjective beliefs about the knowledge, performance, and social status of members and managers. Each respondent was asked about their perceptions of the president, secretary, each member of the board of directors independently, and about their own village member producers collectively. Beliefs were scored on a scale of one to five. At endline we reevaluate cooperative members' subjective beliefs about producer and secretary performance.

Survey data are a repeated cross-section at the individual level because the sample of respondents is drawn anew between baseline and endline. Therefore, analysis using outcomes from survey data employs a DD strategy with individual-level observations and cooperative-level fixed effects. The estimating equation is

$$Y_{ijt} = \beta^{Pr} T_{jt}^{Pr} + \beta^{Pu} T_{jt}^{Pu} + \gamma_j + \delta_t + \epsilon_{ijt} \tag{2}$$

where $i$ indexes individual producers in village cooperative $j$.[13] For the subset of endline survey outcomes that were not asked at baseline, we drop the fixed effect terms and estimate the simple difference between study arms, which should be balanced under the null due to randomization.

### 3.4 Timeline

The timeline of activities was arranged around seasonality in dairy production. The two-year production cycle of a dairy cow starts with gestation, which lasts roughly nine months. Viable milk production begins in the week after calving, peaks around 2 months later, and remains high for

[13] Because some cooperatives change treatment status but there is only a single endline observation per individual, we assign treatment status to be the treatment status in the final round of intervention.

another 6–7 months before tapering off, ending around one year after a calf is born. The cow then goes into a 2–3 month dry rehabilitation period before it is once again ready for insemination. In Karnataka during the time of study, the lean dairy season fell around January–April, with peak production in the months of May–December.

The baseline survey for this study took place in July–August 2014 followed by two rounds of baseline milk testing in September–October. Program activities then paused through the subsequent dry season to minimize any influence of baseline data collection on endline activities. Following the dry season, state-wide elections were held in June, 2015. Milk testing resumed in 2015 with the two rounds of intervention milk testing and payment in July–August 2015, followed by endline surveying at the end of August 2015. A full timeline of project activities is given in Figure 3.

## 4 Results

Milk cleanliness improves substantially among cooperatives that receive incentive payments. We observe an increase in cleanliness of up to 0.64 standard deviations in response to incentives, which would raise the fraction of raw milk suitable for higher-value processing by 81%. This gain was induced by an incentive payment amounting to only 1% of revenue over the two-week measurement window. The relative magnitudes of these effects reveal large potential returns to broader uptake of sanitation practices at the point of collection.

The estimated effect of incentives is weaker in the public payment arm compared to private payment, though this difference is not statistically significant. Attenuation of the point estimate is driven in large part by an unexpected request among several secretaries to opt out of receiving publicly announced payments. In the final intervention round, seven of twenty-two cooperative managers chose to forego payment altogether rather than allow the payment to be revealed publicly.

This decision is puzzling because all cooperatives would have received positive payments had they accepted incentives without altering their behavior in any way. Opting out is negatively correlated with the social status of management at baseline, especially as perceived by member producers. We explore the relationship between information, managerial authority, and the choice to forego potential revenue further in the next section.

### 4.1 Cleanliness

Group incentives induce improvements in milk cleanliness. This main result is presented in Table 3, which reports the effect of treatment assignment on milk quality.[14] Col. 1 reports estimates from the DD specification in equation (1) on the index of cleanliness, and Col. 2. repeats the same exercise with control variables selected using the double-lasso method proposed by Belloni et al. (2013) to increase precision.[15] Assignment to the private payment arm improves average cleanliness by 0.64 standard deviations, significant at the 10% level without controlling for covariates and at the 5% level with controls. The effect of treatment in the public payment arm is also positive, but smaller in magnitude at 0.32 standard deviations. Given the limited size of the experiment, we can neither statistically distinguish this effect from zero nor can we rule out that it is equal to the effect of private payment.

[Table 3 about here.]

We next decompose the treatment effect into its constituent components. Cols. 3 and 4 show the independent effect of treatment assignment on SPC and MBRT test measures. The SPC microbial

[14] Table 3 and all subsequent regression tables report both standard errors clustered at the village level in parentheses and p-values generated by randomization inference in square brackets. Randomization inference uses 10,000 iterations of a clustered bootstrap procedure following Bloom et al. (2012) and MacKinnon and Webb (2020). To estimate the significance of the coefficient on assignment to private payment, we randomly re-draw 19 cooperatives from 19+13 = 32 total private payment treatment and control cooperatives in each iteration. For the public payment treatment, we redraw 22 cooperatives from the 22+13 = 35 total public and control cooperatives in each iteration.

[15] Details are discussed in Appendix B.

load decreases by 0.42 log(cfu/ml) and the time to MBRT reduction increases by 0.4 hours on average among cooperatives in the private treatment arm. These values represent improvements of .37 and 0.7 standard deviations, respectively, which are both consistent with the magnitude of change in the quality index. In Appendix B, we further break the treatment effect down by quantiles. Among treated cooperatives, we find the treatment effect to be consistently strong across the distribution of quality in the private payment arm.

We quantify the economic importance of these effects relative to the benchmark SPC threshold of 500,000 cfu/ml recommended by the USDA for raw milk inputs into value-added processing. Recall from Figure 1 that only 16 percent of cans tested at baseline satisfied this threshold. A 0.64 standard deviation improvement in the baseline distribution of SPC would correspond to an 81% increase in this number, to nearly 30 percent of cans acceptable for high-value production.[16]

## 4.2 Payment

The gains in cleanliness were achieved with fairly low-powered incentives. The first two columns of Table 4 show the size of aggregate cleanliness payments to treated cooperatives relative to the counterfactual payment the average control cooperative would have earned in each intervention round. Greater sanitation among treated cooperatives brings in roughly an additional Rs. 100 per collection day per cooperative in the private payment arm. In total, treated cooperatives earn around Rs. 800 per round per cooperative in payments for cleanliness, equivalent to $16 at the time of study. Compared to the average daily revenue of Rs. 5,600, this value amounts to only a 1% increase in revenue over the two-week testing window. The magnitude of the aggregate response to such a small incentive testifies to the low cost of improving cleanliness at the margin.

[16] Regression analysis using a dummy for passing 500,000 cfu/ml on the left hand side estimates a comparable treatment effect magnitude of nine percentage points in the private information arm. However, such a coarsening of the outcome variable in an already small sample leads to large standard errors for this exercise.

[Table 4 about here.]

Producers in the public payment arm appear to behave strategically during the intervention period to secure a portion of this additional revenue. Almost all dairy-related payments in this setting are apportioned as a function of quantity poured: Producers and cooperatives are paid directly by volume, and any year-end bonuses or producer support schemes are awarded per liter. This fact gives context to the producer-level increase in quantity[17] in the public payment arm, reported in Col. 3 of Table 4. A quantity increase of nearly 16% per producer is observed in the intervention arm where producers knew the cooperative would receive additional revenue, and potentially reflects their attempts to secure a share of that revenue.

Despite producers' efforts, we find no direct evidence that incentive payments were shared with cooperative members in either treatment arm. There is no difference between treatment and control in the share of farmers that recall receiving bonus payments from the cooperative post-intervention, reported in Col. 4 of Table 4.[18] This null result implies that any gains from producer effort were likely achieved through informal social pressure rather than explicit remuneration.

### 4.3 Declined Payment

Some of the gap in measured treatment effect between the public and private payment arms can be attributed to the unexpected fact that a substantial fraction of managers in cooperatives assigned to public treatment declined to be paid. In the second round of intervention, seven out of twenty-two secretaries opted to forego payment entirely rather than accept a publicly announced incentive payment (Table 4, Col.5). In all cases, the managers first requested that payment be made to the

[17] It is difficult to change quantity through number or quality of livestock over the short horizon of our study, so the most likely margin of adjustment is additional days of milking.

[18] This result is presented with the caveat that the share in control rose from 20% at baseline to 80% at endline due to a statewide support scheme delivered in early 2015, which might drown out any differential impacts between treatment and control arising from our intervention.

cooperative account without public knowledge. Upon being denied, all seven opted out of payment, but consented to continue milk testing and subsequent endline surveying.

We explore the relationship between opting out and cleanliness in Figure 4. Panel A plots the treatment effect in the two payment arms as the event study counterpart to Table 3, Col. 1. Panel B splits the public payment event study into cooperatives that participate and those that opt out in the second round. The figure reveals two facts: First, cooperatives that opted out start with ex ante lower milk quality than those that remain in the experiment. Therefore, there may be selection into opting out based on the anticipated size of payment or other cooperative characteristics. Second, the trend line for villages that stay in the experiment with public payments closely tracks that of private payments, while the trend line for those foregoing payment remains nearly flat. Quantile treatment effects presented in Appendix B verify this effect heterogeneity, with larger effects observed at higher cleanliness quantiles in the public payment arm.

[Figure 4 about here.]

Regression analysis reveals that opting out explains at least some of the gap between treatment arms. In a two-stage least squares version of equation (1) using treatment assignment as an instrument for actual incentive status,[19] the estimated effect of public payment increases from 0.32 (Table 3, Col. 1) to 0.39. Note that this latter value is not directly comparable to the estimated 0.64 effect size in the private treatment arm because it is a local average treatment effect among a selected subset of cooperatives. Those remaining in the public payment arm (i.e. treatment compliers) have higher quality at baseline, and hence may have lower potential for improvement than those that opt out.

[19]The DD estimate can be thought of as an Intention to Treat (ITT), and the 2SLS as a Treatment on Treated (TOT).

Cooperatives that opt out of public payment appear to be negatively selected by managerial capacity. In Table 5 we report ex ante correlates of opting out in baseline data. Across all indicators of management quality, cooperatives where the secretary declines payment perform consistently worse than those that remain in the public payment arm. The board of directors meets less frequently, producers can identify fewer board members, and producers are less likely to recall having received bonuses. Moreover, producers rate all managers lower in both management quality as well as social status. An F-test confirms the joint significance of producers' negative beliefs about management quality at the 1% level, revealing that managers with lower social standing are more likely to forego public payment.

[Table 5 about here.]

## 5 Discussion

Experimental results indicate that dairy cooperatives have the capacity to improve aggregate cleanliness in response to a marginal group-level incentive. This capacity for quality upgrading is realized universally when knowledge of the incentive payment is restricted to cooperative management, but weaker managers prefer to forego payment rather than face the prospect of public disclosure about earnings. In this section, we further examine how quality improvements relate to elite power and the role of information.

We first explore the mechanisms through which cooperatives achieve gains in cleanliness. While we cannot directly measure microbial load at the individual level, we present indirect evidence of increased effort on the part of both cooperative members and managers. However, behavior change on the part of producers seems to be initiated by social pressure form managers rather than direct financial compensation.

The decision to opt out indicates that some managers believe their efforts to lower contamination would not be sufficiently compensated in the presence of public information. We present qualitative evidence on manager's stated motivation for opting out and discuss how these motivations may translate into constraints on managerial compensation.

### 5.1 Margins of Adjustment

To generate the ideal data to quantify margins of adjustment for cleanliness, we would need to test individual-level milk samples before pouring into common cans. We could then decompose aggregate improvements into the portion attributable to individual producers and the portion attributable to village equipment. While we collected individual milk samples in the first round of baseline data collection, this process turned out to be excessively disruptive to cooperative operations and had to be dropped in order for the experiment to continue. As a result, we cannot provide direct data on the microbial load contributed by individual producers during the experimental rounds of evaluation.

Though we cannot directly measure sources of change within a cooperative, we report suggestive evidence that improvements in cleanliness come from both better sanitation of village equipment and from individual producers pouring cleaner milk. On the part of management, enumerators and producers frequently observed cooperative staff washing collection equipment in incentivized villages during the intervention period; such sights were rare both prior to our involvement and in control villages during the experiment. As reported in Figure 2, average time to MBRT reduction was 0.74 hours lower in pooled milk than in individual samples at baseline. Therefore, effective sanitation of village equipment alone has the potential to generate the full 0.4 hour treatment effect.

There is also indirect evidence of cleaner milking practices among producers in incentivized cooperatives. Table 6 reports results from endline surveying following the intervention period. In Col. 3, we show that producers' beliefs about others' cleanliness improve in both incentive arms. This change is not caused by the salience of testing because the table reports increases relative to control, where quality testing also takes place. It similarly cannot be attributed to the salience of payments because we observe the effect even in the private payment arm where there is little knowledge about incentive payments among member producers (Col. 1). Instead, the difference in perception likely reflects a real change in the observed behavior of other producers.

[Table 6 about here.]

To the extent that sanitation improves among individual producers, it seems lack of knowledge was not a constraining factor. There are insignificant and quantitatively small differences between treatment and control in the frequency with which cooperatives taught members about clean practices (Col. 2). Qualitative surveying confirms widespread recognition that washing hands and sanitizing equipment are crucial to mitigating contamination. For the most part, producers in our experiment already understood how to improve, and gains were achieved through increased effort.

While perceptions are consistent with cleaner practices among cooperative members, the mechanism driving this behavior change remains unclear. We observe no evidence of increased pay directed to individual producers (Table 4, Col. 4). Moreover, in the private information arm, management does not even notify producers about the existence of incentive contracts for cleanliness (Table 6, Col. 1). These facts imply that producers are not responding to explicit financial rewards for observed effort, but managers instead exert influence through informal channels that are more difficult to quantify. Informal pressure is successful despite the fact that individual quality measurement is prohibitively expensive, suggesting that there is substantially greater local knowledge about private effort than what is observable to the outside market.

The survey results together highlight two channels through which managerial effort affects milk contamination. Most directly, managers spend time sanitizing shared village equipment. They also indirectly lower contamination by expending social capital to promote clean practices or establish norms among producing members. At the margin, we measure high cleanliness returns to the managerial effort induced by a relatively small group incentive.

Counterintuitively, perceptions of secretary cleanliness decrease in the private payment arm despite measured improvements in aggregate quality. This decrease in perception, reported in Col. 4, may stem from the visibility of cleaning activities. Without corresponding knowledge of an increase in returns, from the farmers' perspective it would appear that the cooperative is suddenly promoting clean practices with no additional benefit. It is possible that this leads farmers to conclude that secretaries must have been inefficiently dirty in the past. It is notable that producers only update beliefs about cleanliness specifically and not about managerial capacity in general (Col. 5). In contrast, producers in the public payment arm know that additional effort is a response to new financial incentives and therefore do not update beliefs about the past. Other explanations are possible, but this dynamic hints at a potential channel of path dependence in governance or management that warrants further study. Leaders may maintain bad behavior to avoid revealing information about the low quality of their prior actions.

### 5.2 Information and Managerial Returns

Although incentive payments are offered to the cooperative as a whole, managers maintain unilateral authority to block participation. Therefore, a necessary condition for success is that managers' private compensation from our experiment exceeds their private cost of effort. This level of compensation is realized across all cooperatives in the private payment arm, where the secretary and president retain near complete discretion over how incentives payments are allocated. In contrast, the frequency of opting out in the public payment arm indicates that public information constrains managerial returns.

The constraint on managers' share of surplus must be substantial given the structure of incentives. Cooperatives in the public payment arm would have received net positive payment at their baseline level of cleanliness with no change in milking practices. Therefore, simply accepting this revenue and distributing it among members would constitute a Pareto improvement relative to opting out.[20] Coase (1960) argues that in the absence of internal frictions, groups should be able to reach Pareto improving outcomes regardless of how the surplus is initially delivered. The fact that nearly a third of managers decline this option indicates that public information must introduce frictions. Furthermore, these frictions are substantial enough that many cooperatives cannot compensate management for bringing in a new source of free revenue.

Qualitative evidence around the decision to forego payment points to two candidate explanations for the limitations to managerial compensation. Managers who opted out made statements such as, "farmers [will be] angry about why the monetary reward is going to the cooperative when they were the ones who produced the milk" and "farmers will regularly start expecting payments." These statements are consistent with information either imposing coordination costs on secretaries or constraining the share of cooperative surplus claimed by managers.

The first possible explanation for managerial opt-out is that public information raises the cost

[20] The aggregate welfare impacts net of the cooperative's production response are ambiguous because managers can induce effort on the part of producers using both social rewards and punishment. If managers face a binding limited liability or participation constraint when setting incentives for producers, then producer welfare cannot decrease and improved cleanliness must reflect greater aggregate welfare. However, if neither constraint binds, then producer-level behavior change may be motivated by the threat of punishment. This threat can be sufficiently immiserating to offset any welfare gains that accrue to managers, so it is possible that cleanliness improvements accompany a net decrease in aggregate welfare relative to the prior status quo.

of coordination within the cooperative. This situation would occur if producers inferred different information from our public announcement than they received from cooperative management.[21] In this case, managers would have to exert additional effort to coordinate beliefs about aggregate returns within the cooperative, meaning the net surplus from the public payment arm would be lower than that of the private payment arm *for the same level of payment.* The cost of coordination is likely higher for those with lower social status, and may be high enough that the cost of effort exceeds the revenue from the experiment. Coordination costs would be lower in the private payment arm where managers fully control messaging about revenue.

A second possibility is that announcements about payment limit managers' capacity to extract surplus by hiding income. Many producers in focus groups expressed frustration that cooperative management has substantial private information and therefore de facto control over the cooperative financial account. This concern is substantiated by discrepancies between positive accounting profits and (lack of) member recall about receiving dividends. Public announcement of experimental payments likely limits the control managers have over revenue from the experiment, and many secretaries worried that announcing payments may lead members to seek out financial information about the cooperative account more generally. Such revelation would be more costly for managers with lower social status who have fewer alternate ways to claim cooperative surplus[22], and the small bump in revenue from our experiment may not have been worth the risk of losing a larger and more regular stream of private income. This explanation would indicate that information revelation lowers managers' share of surplus in a way that the network cannot commit to compensating after the information is revealed.

[21] The information content of our announcement could diverge from messaging by cooperative management either because our communication was imprecise, leading farmers to be misinformed about the size of payments, or because the cooperative management shared incomplete/inaccurate information about payments and the return to cleanliness.

[22] See Appendix D for one possible formalization of the substitutability between extraction through surplus-sharing and extraction through hiding income.

While we cannot quantitatively distinguish between these explanations, both provide a cautionary note regarding the potential for quality upgrading as a development policy. The quality improvements among cooperatives in the private payment arm indicate that aggregate outcomes can be affected by aggregate returns. However, the high frequency of foregoing payment in the public payment arm indicates that this response is sensitive to the way in which surplus is delivered. In particular, we find that incentives are more effective when discretionary control is left in the hands of cooperative management. In effect, the institutional design that allows more elite capture may be the most successful at achieving policy goals.

## 6 Conclusion

In this paper, we experimentally evaluate the effectiveness of group incentive contracts for quality upgrading in the context of village dairy cooperatives in Karnataka, India. We find that group incentives substantially improve production outcomes. A marginal payment of one percent of cooperative revenue over a two-week period induces an increase in cleanliness of up to 0.64 standard deviations. The improvement corresponds to nearly doubling the fraction of production suitable for high-value processing.

This first result offers hope for development initiatives targeted at small-scale producers. Beyond quality upgrading, many programs center around the transfer of assets such as livestock (e.g. Argent et al., 2014; Janzen et al., 2018; Phadera et al., 2019) or business capital (e.g. Banerjee et al., 2015; Bandiera et al., 2017) with the intent of establishing a source of revenue for recipients. Such initiatives rely on market access for program beneficiaries. We show that trade groups formed to enable market access in such settings can effectively respond to group-level price signals, even when individual output cannot be verifiably measured within the group.

However, we find the potential for success in production teams is tempered by the role of elites within the team. Quality upgrading was achieved in our study without explicit transfers to dairy producers. Indeed, in the private treatment arm, producers did not even know incentive contracts existed. Thus, quality improvement likely resulted from informal influence exerted by cooperative managers. The nature of this informal influence remains an open question for future research.

Our study also presents a case in which transparency places a binding check on elite power. Cooperative secretaries' choice to forego payment suggests that public information constrains the capacity to allocate surplus within the cooperative. In our setting, this constraint is so severe that a substantial fraction of secretaries are willing to sacrifice a potential revenue stream in its entirety.

This second result indicates that for a development initiative to succeed, delivering net positive returns in the aggregate is not sufficient. Development programs must also guarantee positive private return to elites with blocking power. We provide evidence that compensation to elites is sensitive to the information environment within dairy cooperatives in a way that can derail policy goals. As a result, group incentives are more successful when managers retain full discretion over resulting incentive payment.

Our findings highlight a potential tradeoff between aggregate efficiency and distribution of rents in local policy. In our study, the most effective incentive structure is the one that admits the greatest potential for elite capture. More generally, in settings where elites have multiple ways to exert control over social surplus, efforts to promote equity by limiting elite power may have unintended consequences. It follows that policy may optimally allow for some elite capture to minimize distortion and maximize surplus. This tension is common to a broad range of policies targeted at decentralized populations and filtered through local governance.

This work provides a cautionary lesson for technological approaches to limiting corruption.

Recent advances such as electronic banking and mobile money have enabled direct cash transfers intended to circumvent the possibility of expropriation in transit. While such innovations hold promise, they will only deliver benefits if implemented in ways that are sensitive to local social structure and to alternative avenues of elite capture that may leave the intended beneficiaries even worse off. It remains an open question how to balance aggregate efficiency with distributional goals, and the optimal design of group incentives across the social hierarchy in village economies paves the way for future work.

## Disclosure Statement

This study was preregistered with the AEA RCT Registry under ID Number AEARCTR-0000700.

Research was conducted with approval from the Committee on the Use of Humans as Experimental Subjects at the Massachusetts Institute of Technology (COUHES #1405006372) and by the Institutional Review Board at the Institute for Financial Management and Research in Chennai, India.

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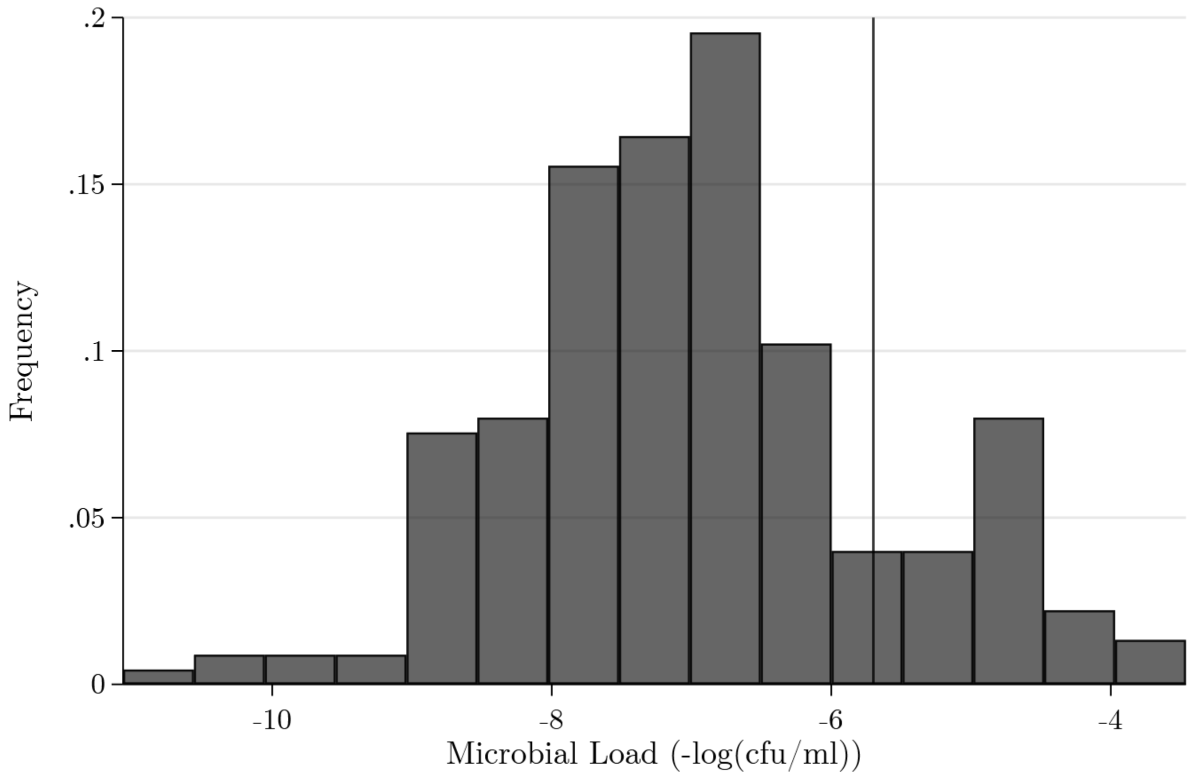
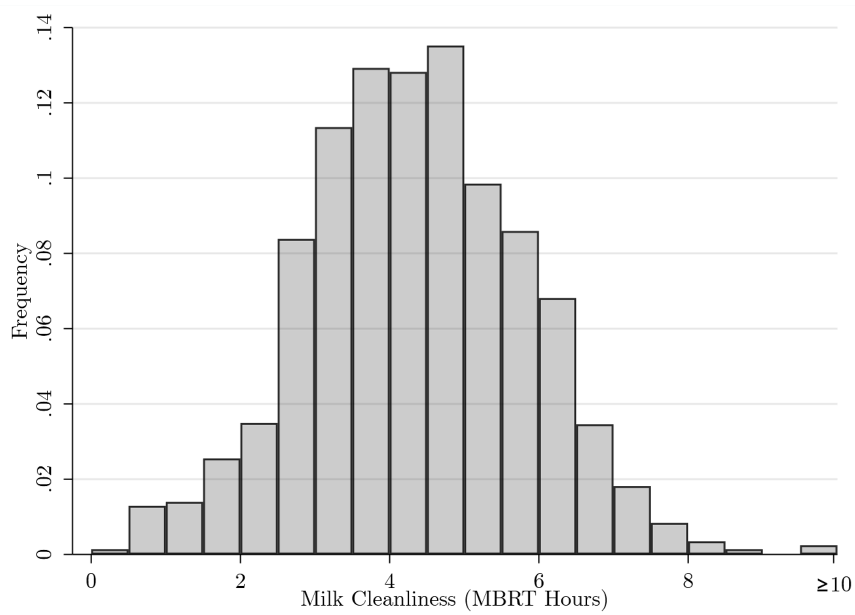
Figure 1: Microbial Load by Milk Can



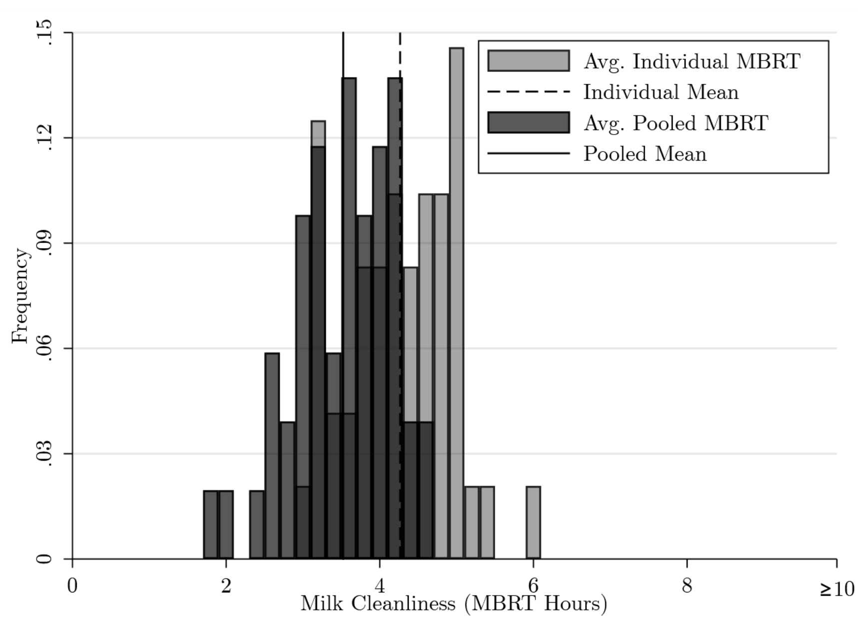

Notes: The distribution of microbial load by delivery can among cooperatives prior to intervention. Samples are collected at the time of milk collection and measurements are conducted using a standard plate count (SPC), reported in –log units so that higher values indicate cleaner milk. The vertical line represents the 500,000 cfu/ml threshold for use in value-added production. Only 37 of 225 cans tested (16%) satisfy this requirement.

Figure 2: Individual and Aggregate Distributions of Milk Quality

A. Distribution of Individual Cleanliness




B. Village-Level Mean of Individual and Pooled Milk Cleanliness




Notes: Distributions of milk cleanliness at baseline. Samples are collected during cooperative milk collection and measurements are conducted using a methylene blue reduction test (MBRT), reported in hours, so that higher values indicate cleaner milk. A. Distribution among samples from individual producers prior to contact with cooperative equipment. 14% of producers exceed the 6 hour threshold delineating high sanitation. B. Distribution of within-cooperative average of samples taken from individual producers immediately before pouring and from collective cans immediately after pouring. The dashed vertical line represents the mean among individual samples and the solid vertical line represents the mean among cooperative cans. Reduction time declines by 0.74 hours from individual to pooled milk, and a t-test rejects equality with a t-statistic of 5.6 ($p < 0.01$).

Figure 3: Experiment Timeline and Randomization Design

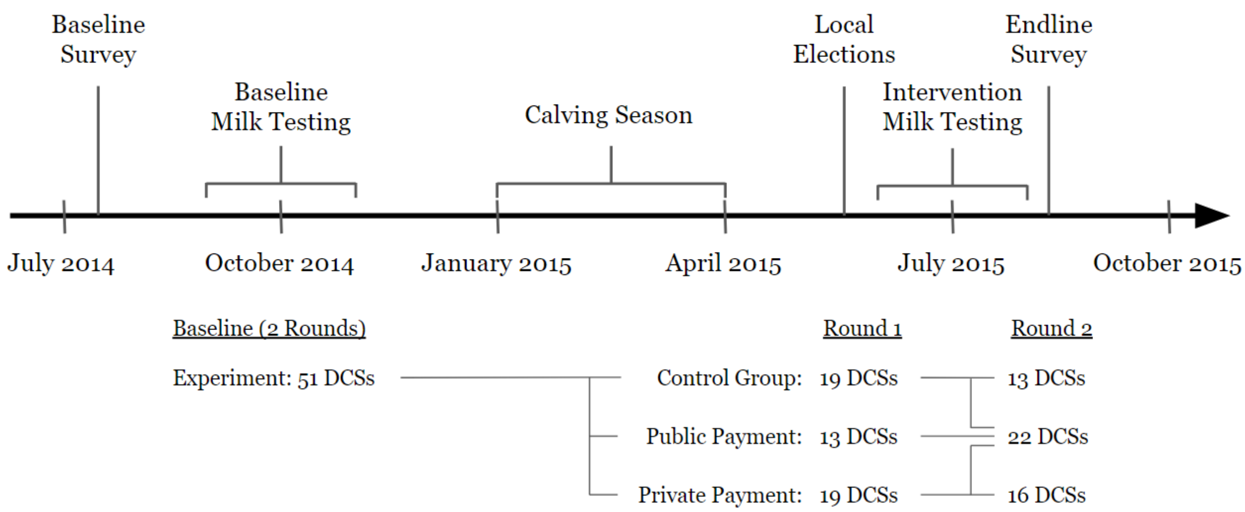
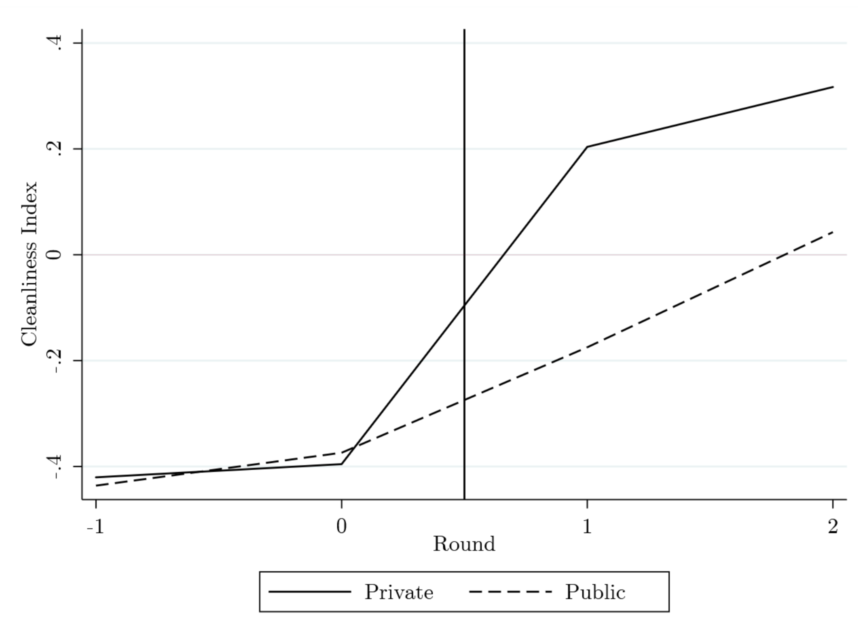
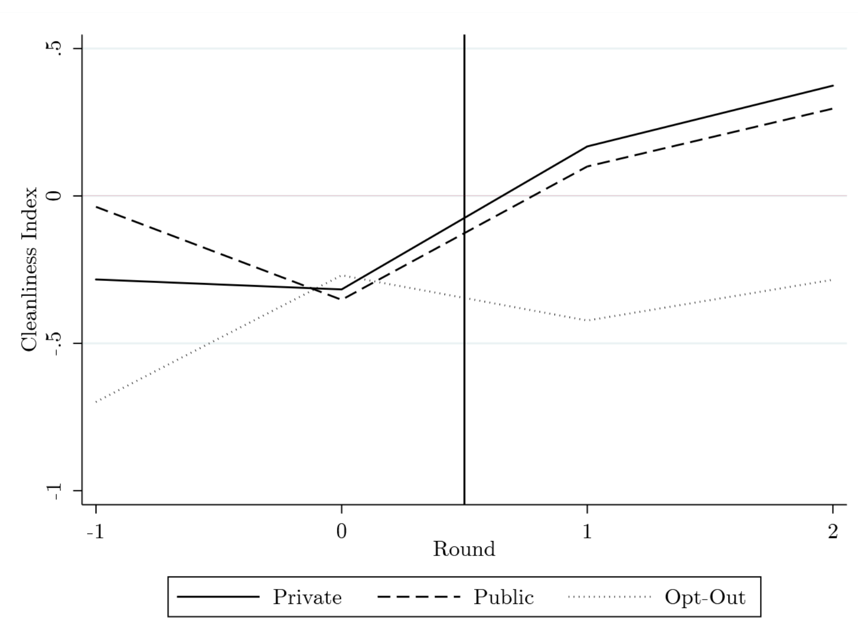


Figure 4: Event Study of Cleanliness by Treatment Assignment

A. Milk Cleanliness by Treatment Assignment




B. Milk Cleanliness by Treatment Status




Notes: Outcome is an index of milk quality constructed from principal components analysis of SPC and MBRT. A. Event study version of eqn. (1) by treatment assignment. B. Event study version of eqn. (1) splitting public payment arm based on decision to opt out.

Table 1: Characteristics of Cooperative Members and Managers

| | Producers | Directors | Secretary | President |
|---|---|---|---|---|
| Education | 4.4 | 5.2 | 10.9 | 8.3 |
| | (0.7) | (0.3) | (0.3) | (0.5) |
| Frac. SC/ST | 0.29 | 0.30 | 0.24 | 0.08 |
| | (0.02) | (0.03) | (0.06) | (0.04) |
| Land Owned | 6.4 | 5.4 | 4.9 | 14.8 |
| | (0.5) | (2.6) | (0.9) | (2.0) |
| Monthly Income | 11,931 | 13,256 | 14,202 | 19,248 |
| | (693) | (893) | (2,423) | (2,192) |
| Panchayat | | 0.06 | | 0.21 |
| | | (0.01) | | (0.06) |
| Observations | 1,024 | 406 | 49 | 71 |
| Social status as reported by: | | | | |
| Producers | | 3.1 | 3.7 | 3.6 |
| | | (0.05) | (0.06) | (0.06) |
| Directors | | 3.4 | 4.1 | 4.0 |
| | | (0.06) | (0.07) | (0.08) |
| Management quality as reported by: | | | | |
| Producers | | 3.0 | 3.7 | 3.5 |
| | | (0.05) | (0.07) | (0.06) |
| Directors | | 3.4 | 4.4 | 3.9 |
| | | (0.05) | (0.06) | (0.07) |
| Dairy knowledge as reported by: | | | | |
| Producers | | 3.0 | 3.8 | 3.6 |
| | | (0.06) | (0.06) | (0.07) |

Notes: Characteristics of and beliefs about member producers, directors, secretaries, and presidents at baseline. Characteristics include years of education, fraction scheduled caste/schedule tribe, acres of land owned, monthly income, and fraction that has ever been elected to the local legislative assembly (Gram Panchayat). Beliefs include perceptions of social standing, managerial capacity, and knowledge about dairy practices on a scale of one to five. Each row represents a category of respondent stating their perceptions. Directors reported perception of every other director but not of own self. President includes both current and past presidents. Standard errors clustered by village in parentheses.

Table 2: Descriptive Statistics by Treatment Status

| | Control | Treated | Difference |
|---|---|---|---|
| HH Size | 6.8 | 6.2 | −0.60 |
| | (0.30) | (0.23) | (0.38) |
| Education | 5.4 | 4.1 | −1.3 |
| | (0.34) | (1.0) | (1.1) |
| Frac. SC/ST | 0.31 | 0.28 | −0.03 |
| | (0.05) | (0.03) | (0.06) |
| Land Owned | 7.4 | 6.0 | −1.5 |
| | (0.80) | (0.56) | (0.98) |
| Cows Owned | 1.7 | 1.7 | −0.05 |
| | (0.11) | (0.04) | (0.11) |
| Monthly Income | 13,894 | 11,114 | −2,780* |
| | (1,218) | (800) | (1,458) |
| Frac. Dairy Income | 0.28 | 0.33 | 0.05*** |
| | (0.01) | (0.02) | (0.02) |
| Frac. Farmers | 0.62 | 0.63 | 0.00 |
| | (0.04) | (0.03) | (0.05) |
| Frac. Labor | 0.12 | 0.17 | 0.05 |
| | (0.02) | (0.02) | (0.03) |
| Milk Production | 6.44 | 6.17 | −0.27 |
| | (0.38) | (0.23) | (0.45) |
| Milk Cleanliness | 0.23 | −0.17 | −0.40 |
| | (0.49) | (0.39) | (0.28) |
| Num. Villages | 15 | 36 | |
| Joint F-Statistic | | | 1.5 |
| [p-value] | | | [0.17] |

Notes: Descriptive statistics at baseline for farmers in treated and control cooperatives. The third column reports the differences between the two groups. Joint F-statistic excludes milk cleanliness, which was measured separately from survey responses. Standard errors clustered by village in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 3: Impact of Treatment on Product Quality

| | (1)<br>Cleanliness | (2)<br>Cleanliness | (3)<br>SPC | (4)<br>MBRT |
|---|---|---|---|---|
| Private Payment | 0.64* | 0.63** | 0.47 | 0.36 |
| | (0.35) | (0.31) | (0.32) | (0.22) |
| | [0.1] | | | |
| Public Payment | 0.32 | 0.39 | 0.38 | 0.17 |
| | (0.32) | (0.29) | (0.32) | (0.18) |
| | [0.32] | | | |
| $H_0$ Pvt=Pub (p-val) | 0.32 | 0.4 | 0.78 | 0.35 |
| Control Mean | 0.06 | 0.06 | 6.83 | 3.44 |
| R-Squared | 0.08 | | | |
| Observations | 204 | 204 | 204 | 204 |
| Village Fixed Effects | X | X | X | X |
| Round Fixed Effects | X | X | X | X |
| Double-Lasso | | X | X | X |

Notes: The four columns report DD estimates from eqn. (1). Columns 2–4 include covariates selected using the double-lasso method introduced by Belloni et al. (2013). The control variables include flexible trends - each control variable interacted with round dummies - by management and producer wealth, by management and producer education, by management and producer caste (SC/ST), by management and producer income levels, and by management's past experience in elected office (panchayat). (1)-(2) Cleanliness is an index of milk quality constructed from principal components analysis of SPC and MBRT. (3) SPC is measured in -log(cfu/ml). (4) MBRT is hours to dye reduction. Standard errors clustered by village in parentheses. p-values from randomization inference with clustered bootstrap in square brackets. *** p<0.01, ** p<0.05, * p<0.1

Table 4: Impact of Treatment on Earnings and Quantity

| | (1) Payment Round 1 | (2) Payment Round 2 | (3) Quantity | (4) Received Bonus | (5) Opted Out Round 2 |
|---|---|---|---|---|---|
| Private Payment | 121.1 | 98.3 | -0.06 | 0.01 | 0 |
| | (106.9) | (82.7) | (0.58) | (0.09) | (.) |
| | [0.33] | [0.26] | [0.94] | [0.84] | [.] |
| Public Payment | −0.40 | 16.8 | $1.0^{**}$ | 0.03 | $0.32^{***}$ |
| | (85.4) | (81.1) | (0.49) | (0.08) | (0.10) |
| | [1.0] | [0.85] | [0.14] | [0.6] | [0.0] |
| $H_0$ Pvt=Pub (p-val) | 0.2 | 0.33 | 0.049 | 0.86 | 0.0032 |
| Control Mean | 715.8 | 676.9 | 6.43 | 0.81 | 0 |
| R-Squared | 0.05 | 0.05 | 0.01 | 0.48 | 0.21 |
| Observations | 153 | 153 | 2,006 | 2,006 | 51 |
| Village Fixed Effects | X | X | X | X | |
| Round Fixed Effects | X | X | X | X | |

Notes: First two columns report DD estimates from eqn. (1). Third and fourth columns report DD estimates from eqn. (2). Fifth column reports simple difference in second intervention round. (1) and (2) report total payment received by cooperative, and control mean reflects counterfactual payment that would have been received by cooperatives in control arm. (3) Quantity is liters per day per producer surveyed; total village quantity is unavailable. (4) Fraction of producers who report ever receiving a bonus payment. (5) Fraction of cooperatives that opt out of payment in second intervention round. Standard errors clustered by village in parentheses. p-values from randomization inference with clustered bootstrap in square brackets. *** p<0.01, ** p<0.05, * p<0.1

Table 5: Cooperative Baseline Characteristics by Study Participation

| | Treated | Opted Out | Difference |
|---|---|---|---|
| Ever Received Bonus | 0.25 | 0.19 | −0.06 |
| | (0.07) | (0.06) | (0.09) |
| Frac. Directors Known | 0.27 | 0.24 | −0.03 |
| | (0.03) | (0.03) | (0.04) |
| Directors Meetings | 1.66 | 1.27 | −0.39** |
| | (0.05) | (0.16) | (0.16) |
| Producers' opinions about: | | | |
| Dirs. Status | 3.2 | 2.7 | −0.42*** |
| | (0.05) | (0.15) | (0.15) |
| Dirs. Management | 3.1 | 2.7 | −0.32** |
| | (0.07) | (0.15) | (0.17) |
| Secy. Status | 3.7 | 3.5 | −0.20 |
| | (0.09) | (0.22) | (0.24) |
| Secy. Management | 3.6 | 3.5 | −0.10 |
| | (0.13) | (0.11) | (0.17) |
| Pres. Status | 3.63 | 3.29 | −0.34 |
| | (0.06) | (0.29) | (0.29) |
| Pres. Management | 3.48 | 3.32 | −0.16 |
| | (0.09) | (0.18) | (0.2) |
| Joint F-Statistic | | | 10.94 |
| [p-value] | | | [0.00] |
| Directors' opinions about: | | | |
| Dirs. Status | 3.4 | 3.3 | −0.07 |
| | (0.09) | (0.11) | (0.14) |
| Dirs. Management | 3.4 | 3.3 | −0.07 |
| | (0.08) | (0.11) | (0.13) |
| Secy. Status | 4.1 | 3.9 | −0.25 |
| | (0.10) | (0.18) | (0.20) |
| Secy. Management | 4.3 | 4.4 | 0.04 |
| | (0.09) | (0.13) | (0.16) |
| Pres. Status | 3.87 | 3.87 | −0.004 |
| | (0.11) | (0.16) | (0.19) |
| Pres. Management | 3.8 | 3.8 | −0.001 |
| | (0.07) | (0.09) | (0.12) |
| Joint F-Statistic | | | 0.61 |
| [p-value] | | | [0.72] |
| Num. Villages | 15 | 7 | |

Notes: Baseline measures of governance quality and perceptions of governors' social status and managerial capacity. Top three rows report fraction of producers that recall receiving a bonus, avg. fraction of directors that producers can name without prompting, and frequency of board meetings. Sample is limited to cooperatives assigned to receive public payment in the second intervention round, split by decision to opt out of payment. The third column reports differences between the two groups. Standard errors clustered by village in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 6: Impact of Treatment on Producer Beliefs at Endline

| | (1) Know about Payments | (2) Coop Gave Lessons | (3) Believe Other Prod. Clean | (4) Believe Secy. Clean | (5) Believe Secy. Good Manager |
|---|---|---|---|---|---|
| Private Payment | 0.01 | 0.09 | 0.45*** | −0.26** | 0.07 |
| | (0.01) | (0.07) | (0.11) | (0.12) | (0.21) |
| | [1.0] | [0.53] | [0.0] | [0.01] | [0.58] |
| Public Payment | 0.16*** | 0.09 | 0.30** | −0.08 | 0.24 |
| | (0.04) | (0.07) | (0.12) | (0.13) | (0.21) |
| | [0.03] | [0.47] | [0.0] | [0.3] | [0.04] |
| $H_0$ Pvt=Pub (p-val) | 0.0002 | 0.97 | 0.24 | 0.15 | 0.92 |
| Control Mean | 0.008 | 1.37 | 4.31 | 4.53 | 4.09 |
| R-Squared | 0.08 | 0.004 | 0.06 | 0.03 | 0.05 |
| Observations | 982 | 982 | 1,918 | 1,990 | 1,983 |
| Village Fixed Effects | | | X | X | X |
| Round Fixed Effects | | | X | X | X |

Notes: First two columns report simple difference at endline; remaining three columns report DD estimates from eqn. (2). (1) Fraction of respondents that know about cleanliness incentive payments. (2) Frequency with which cooperative gives lessons on clean milking practices. (3) Avg. belief among producers about cleanliness of other producers. (4) Avg. belief among producers about cleanliness of secretary. (5) Avg. belief among producers about managerial quality of secretary. Standard errors clustered by village in parentheses. p-values from randomization inference with clustered bootstrap in square brackets. *** p<0.01, ** p<0.05, * p<0.1

# Supplementary Appendix for "Got (Clean) Milk"

# For Online Publication Only

## A Daily Milk Collection

Figures S1–S5 depict the daily milk collection process at a typical cooperative. Milk collection typically takes place between 5 and 7 AM, during which time each village has a half-hour collection window when farmers deliver milk. Producers start milking shortly before this window so their milk is ready to deliver, shown in Figure S1. Potential contamination at this stage comes from bacteria on the outside of cows' udders, in farmers' containers, or on farmers' hands.

Producers deliver their milk to the cooperative headquarters where it is pooled into delivery cans. Figure S2 shows a cooperative secretary testing the density of milk to ensure it has not been diluted with water before pouring, and Figure S3 shows milk being poured into the village delivery can. Every producers' milk is density-tested before pouring, and in equilibrium milk is very rarely rejected for excessive dilution. Tests for cleanliness require lab facilities and training, and therefore cannot be conducted at the time of pouring. Individual production quantity is recorded at this stage for later payment. Contamination can be introduced by unsanitary village testing equipment or improperly washed collection cans. Many villages engage in small-scale local sales of fresh milk before collection, as depicted in Figure S4, which adds another potential source of contamination.

At the end of the collection window, a truck arrives to pick up the filled cooperative cans to deliver to a processing plant. Each truck follows a collection route that serves multiple villages; Figure S5 shows a typical collection truck, which is unrefrigerated. During transportation, existing bacterial colonies in the milk have time to proliferate. As soon as the milk reaches the processing plant, it is rapidly chilled to arrest further bacterial growth. The state sector has invested heavily in optimizing collection routes and introducing decentralized chilling technology to reduce the time that raw milk spends unrefrigerated.

Differences in position along the route and uncertainty in transportation time add variance to the cleanliness of milk as it reaches the processing facility. Therefore, it is challenging for processors to tie incentive payments to cleanliness as measured upon delivery. To scale up our pilot intervention, the supply chain would need to develop procedures to separate and chill milk samples so that lab outcomes accurately reflect local production quality at collection.

[Figure S1 about here.]

[Figure S2 about here.]

[Figure S3 about here.]

[Figure S4 about here.]

[Figure S5 about here.]

# B Supplemental Experiment Details

## B.1 Incentive Payment Schedule

Table S1 lists the full incentive structure announced to treated cooperatives. Payments are scaled so that the average cooperative in the baseline testing rounds would have received Rs. 500, roughly $10 at the time of study. The incentive was framed as a base payment of Rs. 500 with a bonus for high quality and a penalty for low quality. All payments were made into the cooperative financial account managed jointly by the secretary and president.

[Table S1 about here.]

## B.2 Construction of Cleanliness Outcome Measure

We employ two separate measures of microbial load in milk:

**Methylene Blue Reduction Test (MBRT)**: MBRT involves adding dye to a milk sample and measuring the time until the dye completely disappears. Reduction of the dye is accelerated by removal of dissolved oxygen, caused by microbes in milk. Test results are reported in hours, with a greater time to reduction indicating lower presence of bacteria. This test is cheap, fast, and requires little training to conduct. However, because different microbes affect dye reduction differently, test results do not give an exact measure of microbial load. This test is most commonly used at processing centers to quickly determine the suitability of raw milk for various products.

**Standard Plate Count (SPC)**: The SPC is performed by culturing a swab of liquid residue in a nutrient broth for 24 hours, and then counting the density of bacterial colonies under a microscope. Results are reported in colony-forming-units per milliliter (cfu/ml); in our analysis we take the negative log transformation of this measure so that increasing values are associated with cleaner milk. Unlike MBRT, SPC is not sensitive to type of microbe as all colonies on a slide are counted. However, it is significantly more expensive, takes longer to implement, and requires a higher level of training from laboratory staff. This test is typically used by food safety regulators, and is similarly used internally by procesors to verify sanitary standards.

MBRT and SPC are each noisy measures of the true microbial load in a sample of milk. Figure S6 depicts the correlation between them at the can level. The positive slope verifies that they pick up the same signal on average, as cans with a greater time to dye reduction also have lower measured SPC microbial loads.

[Figure S6 about here.]

To increase precision in our quantification of cleanliness, we combine MBRT and SCP using principal components analysis. We construct an index of cleanliness using the first principal component between the two measures. Table S2 lists the loading factors and residual variance from index construction. The first component places positive loading on both time to MBRT dye reduction and -log(cfu/ml) from SPC. These measures both correspond to higher sanitation, indicating the component is picking up improvements in quality from the two variables.

[Table S2 about here.]

## B.3 Treatment Effects on Cleanliness

We compare results from the fixed effects regression in 1 to comparable results controlling for covariates selected using the double-lasso method of Belloni et al. (2013) in Table S3. The table reports results for MBRT and SPC cleanliness measures; the main results for the quality index are reported in Table 3. Control variables include flexible time trends interacted with management and producer wealth, education, caste (SC/ST), income, and past experience in elected office. Regression estimates are of similar magnitude across both specifications and we cannot reject equality at the 10% level.

[Table S3 about here.]

We report the quantile effects of both treatment arms at the 25th, 50th, and 75th percentiles in Table S4. The effect of private payment is uniformly large across quantiles indicating a shift in the entire distribution of milk quality. In contrast, in the public payment arm, the magnitude of treatment effect increases with the quality level. This increase reflects the fact that a substantial fraction of cooperatives opted out of payment in the public treatment arm, and the propensity to opt out was negatively correlated with quality at baseline. As a result, only cooperatives at higher cleanliness quantiles actually received incentives for cleanliness in the public arm.

[Table S4 about here.]

We plot the full distribution cleanliness in the three arms in Figure S7, which confirms the quantile regression results. Comparing the cumulative density of the quality index and MBRT shows that the CDF of the private treatment group is to the right of control nearly everywhere, and significant at 10% for the MBRT measure based on Kolmogorov-Smirnov test for equality of distributions.

[Figure S7 about here.]

# C Accordance with Pre-Analaysis Plan

This study was preregistered with the AEA RCT Registry under ID Number AEARCTR-0000700. Unanticipated conditions during implementation led to deviations from the study as prespecified, which we discuss here.

## C.1 Experimental Design

In the pre-analysis plan we specify three treatment arms, but two had to be merged due to communication difficulties at the time of implementation. We initially prespecified three variations on information provision—a fully private arm in which both the ex ante payment schedule and the ex post realized payment amount were disclosed privately to the cooperative management, a second fully public arm in which both the ex ante schedule and ex post payment were disclosed publicly to farmers, and a third hybrid arm in which the ex ante payment schedule was private but the ex post payment was subsequently made public. Communication and translation difficulties with cooperative secretaries and with field implementation staff led to ex ante public disclosure of the payment schedule in villages assigned to the hybrid treatment arm during the first round of intervention. As a result, we chose to collapse both the second and third treatment arms into a single fully public disclosure arm during the second round of intervention to minimize the chance of implementation errors.

The initially planned randomization had cooperatives switch between treatment arms to maximize power. Because information once made public cannot subsequently be made private, cooperatives in the hybrid treatment arm with ex post public disclosure of payments in the first intervention round would have to switch to the fully public treatment arm for the second intervention round. Therefore, we initially planned the randomization to have a greater number of control/private and hybrid cooperatives in round one, with some of these switching to hybrid and public payment, respectively, in round two. Although this forced switching was no longer an issue after collapsing the hybrid and public payment arms, we chose to stay with the original randomization plan.

## C.2 Analysis of Outcomes

We prespecify sampling milk from both individual producers and pooled cans, and analyzing the samples using the MBRT test. However, sampling milk from individuals before pouring proved to be too disruptive to milk collection and risked delaying the delivery truck's tight timing window. As a result, we only have individual-level quality data for one baseline round, and all subsequent rounds only have data on pooled can quality. Given the substantial decrease in the number of samples to be tested, we were able to devote the extra budget to add SPC testing to the lab analysis. We prefer analysis with the principal component quality index to reduce noise from measurement error, but report treatment effects from each individual test as well.

The remaining prespecified outcomes describe administrative data on cooperative revenue and expenditures from financial accounts. Account archives are maintained at local field offices of the Karnatka Milk Federation, the governing body of the state cooperative sector, and audited annually. While we were initially optimistic about our ability to analyze these files, it became clear over the course of the experiment that we would not be granted access to the accounts data. The situation became worse after a change in governance following state-wide elections that severely limited our administrative access. As a result, we have only the primary testing and survey measures we collected and are unable to report on any prespecified outcomes based on administrative data.

In this paper we report additional unspecified outcomes related to cooperative secretaries opting out of receiving payment. This was a wholly unanticipated result that we feel is critical in understanding barriers to collective production in village cooperatives, and we added questions to the endline survey designed specifically to analyze its determinants.

# D Illustrative Model of Management Transparency

In this section, we present a stylized model of information exchange between a manager and a worker to better understand the role of constraints on managerial power.[23] The manager and worker constitute a production team embedded in a social structure. The social structure exogenously enforces a fixed sharing rule to allocate production surplus. This sharing rule eliminates moral hazard from the principal–agent relationship by incentivizing the worker to maximize social surplus. However, it also limits flexibility in the allocation of surplus, which can lead the manager to take inefficient actions.

Inefficiency arises because the manager has the choice to hide a portion of surplus from the worker, thereby circumventing the social structure. Doing so distorts output relative to the efficient benchmark by skewing the worker's return to effort, but allows the manager to appropriate a greater share of the returns. The manager chooses a level of information disclosure that balances these two competing pressures. Renegotiation of the sharing rule to compensate managers for efficiently revealing surplus may resolve inefficiency, but the social structure forbids this.[24]

The model highlights how elites can have multiple different avenues through which to influence their share of surplus, with different degrees of market distortion. Economic efficiency and welfare for other participants depend on the way in which those in power substitute between these options. The possibility for substitution leads to the counterintuitive result that increasing formal elite control may actually improve welfare for non-elites, in both absolute and relative terms, by increasing total surplus. This situation arises when increasing elite control over a non-distortionary channel leads elites to substitute away from a more distortionary channel. At the extreme, we observe evidence of this type of distortion in the decision to opt out of payment in our experiment, thereby foregoing all possible gains to all parties involved.

[23] In the context of our experiment, the manager represents the cooperative secretary and president, and the worker represents member producers.

[24] One possible explanation for the failure of renegotiation is that the size of surplus is never ex post verifiable, so managers could still hide surplus relative to the renegotiated sharing rule.

## D.1 Model Setup

Consider a team with one manager ($M$, she) and one worker ($W$, he) that share the surplus from production according to an agreed-upon rule. The manager first observes a production function, which she announces to the worker. The worker then chooses a level of effort based on the information he is provided.[25] Finally, the two parties split the surplus they generate according to the sharing rule.

Formally, let output $y$ be a function of worker effort $x$ such that $y = f(x)$ with a continuous, twice differentiable production function $f(\cdot)$ where $f(0) = 0$, $f'(\cdot) > 0$, $f''(\cdot) < 0$, and $\lim_{x\to\infty} f'(x) = 0$. These conditions guarantee there will be interior solutions to the optimal and equilibrium levels of effort.

The production function is initially observed only by the manager. She makes an announcement to the worker, but can choose how much to disclose by announcing

$$\hat{f}(x) = zf(x)$$

for some $z \in [0, 1]$ that governs the information communicated to the worker. $z = 1$ represents full disclosure and $z = 0$ represents no disclosure, effectively hiding the production opportunity from the worker entirely.

The worker then chooses a level of effort $x$ given his information set. Effort has a linear cost so the surplus generated from production is $f(x) - x$. However, the worker can only verify a portion of output $\hat{f}(\cdot)$, so he only has claims over $\hat{f}(x) - x$ of the total surplus. The remaining output is accessible to the manager alone.

The two parties split the public surplus, net of the worker's cost of effort, according to a sharing rule indexed by $\lambda \in (0, 1)$. We henceforth use the terms sharing rule and bargaining power interchangeably to refer to $\lambda$. The net value to the worker from the relationship is

$$\begin{aligned} V^W &= (1-\lambda)(\hat{f}(x) - x) \\ &= z(1-\lambda)f(x) - (1-\lambda)x \end{aligned}$$

[25] In the context of our experiment, private knowledge about the production function corresponds to the reimbursement for cleanliness and other details about the cooperative financial account.

where $\lambda$ denotes the manager's bargaining power in the relationship. The manager keeps the remainder of the public surplus as well as the additional undisclosed output, so the value to the manager is

$$\begin{aligned} V^M &= \lambda(\hat{f}(x) - x) + (f(x) - \hat{f}(x)) \\ &= (1 - z(1-\lambda))f(x) - \lambda x \end{aligned}$$

In effect, the worker and the manager share the burden of effort according to the intended sharing rule, but the manager can skew the allocation of output in her favor by hiding some production.

Every Pareto optimal outcome of this production relationship maximizes total surplus, which is achieved when

$$\begin{aligned} & x^* = \arg\max_{x \geq 0} f(x) - x \\ \implies \quad & f'(x^*) = 1 \end{aligned}$$

Note that this condition only depends on $z$ indirectly though its impact on $x$. The surplus-maximizing level of effort $x^*$ and resulting output serve as benchmarks against which to compare equilibrium outcomes.

## D.2 Equilibrium Production

Define an equilibrium conditional on the true production function $f(\cdot)$ to be a subgame-perfect set of strategies $(\tilde{z}, \tilde{x}(z))$, where tildes represent equilibrium quantities, such that neither the manager nor the worker can profitably deviate. That is, the manager chooses to announce a production function $\tilde{f}(\cdot)$ conditional on the anticipated level of worker effort. The worker chooses a profile of effort levels $\tilde{x}$ for every possible announcement of $\hat{f}(\cdot)$. Because $\hat{f}(\cdot)$ is fixed up to the choice of $z$, we represent strategy profiles as $(z, x(z))$ for ease of notation even though the worker does not directly observe $z$.

In a subgame perfect equilibrium, the worker optimizes his private return

$$\tilde{x} = \arg\max_{x \geq 0} (1-\lambda)(\hat{f}(x) - x)$$

for any given announcement $\hat{f}(\cdot)$. The worker's first order condition implies

$$\hat{f}'(\tilde{x}) = 1 \quad \implies \quad f'(\tilde{x}(z)) = \frac{1}{z}$$

That is, the worker acts as though $\hat{f}(\cdot)$ is the true production function even if he suspects the manager is hiding information.[26]

It is clear from the worker's first order condition that effort is strictly increasing in information disclosure due to the concavity of $f(\cdot)$. The social optimum is reached only when there is full disclosure, i.e. $\tilde{x}(1) = x^*$. As long as the manager hides some portion of output, production will be inefficiently low. At the other extreme, if the manager hides all output then $\tilde{x}(0) = 0$ and the team passes up the production opportunity.

In equilibrium, the manager chooses $z$ to maximize her return given the worker's effort response. She solves

$$\tilde{z} = \arg\max_{z \in [0,1]} (1 - z(1-\lambda))f(x) - \lambda x \quad \text{s.t.} \quad f'(x) = \frac{1}{z}$$

The first order condition to the manager's problem can be written as[27]

$$(1-\tilde{z})\frac{\partial \tilde{x}}{\partial z} - \tilde{z}(1-\lambda)f(\tilde{x}(\tilde{z})) = 0$$

[26] If we relax the requirement of subgame-perfection, there may be equilibria where the worker underperforms for low announcements of $\hat{f}(\cdot)$ in order to encourage more truth-telling when $f(\cdot)$ is high. Such a strategy could increase ex ante expected surplus given the distribution of possible $f(\cdot)$. It is sustainable as a subgame-perfect equilibrium in a repeated game where the production function evolves stochastically in each period if participants are sufficiently patient. This dynamic equilibrium, which is a special case of the class of repeated games with imperfect monitoring analyzed by Abreu, Pearce, and Stacchetti (1990), is beyond the scope of our discussion here.

Reference: Abreu, Dilip, Davis Pearce, and Ennio Stacchetti. 1990. "Toward a Theory of Discounted Repeated Fames with Imperfect Monitoring," *Econometrica* 58(5): 1041–63.

[27] See Appendix D for a full derivation and proofs of all results.

This expression gives intuition for the two factors the manager balances. The first term represents worker effort, which determines the total surplus in the relationship, and the second term represents the manager's portion of that surplus. By increasing the amount of information disclosure, the manager induces more effort from the worker but must share more of the fruits of that effort.

**Result 1.** $0 < \tilde{z} < 1$. *In equilibrium the manager discloses a suboptimal level of information.*

*Proof.* The manager solves

$$\begin{aligned}\tilde{z} &= \arg\max_{z\in[0,1]} (1 - z(1-\lambda))f(x) - \lambda x \quad \text{s.t.} \quad f'(x) = \frac{1}{z};\ x(0) = 0 \\ &= \arg\max_{z\in[0,1]} (1 - z(1-\lambda))f(\tilde{x}(z)) - \lambda\tilde{x}(z)\end{aligned}$$

This is a continuous function on a compact space so an optimal $\tilde{z}$ must exist.

Totally differentiating the maximand with respect to $z$ gives

$$\begin{aligned}0 &= -(1-\lambda)f(\tilde{x}) + (1 - \tilde{z}(1-\lambda))f'(\tilde{x})\frac{\partial\tilde{x}}{\partial z} - \lambda\frac{\partial\tilde{x}}{\partial z} \\ &= -(1-\lambda)f(\tilde{x}) + \left[(1 - \tilde{z}(1-\lambda))f'(\tilde{x}) - \lambda\right]\frac{\partial\tilde{x}}{\partial z}\end{aligned}$$

Substituting for $f'(\tilde{x})$ from the worker's first order condition gives

$$\begin{aligned}0 &= -(1-\lambda)f(\tilde{x}) + \left[(1 - \tilde{z}(1-\lambda))\frac{1}{\tilde{z}} - \lambda\right]\frac{\partial\tilde{x}}{\partial z} \\ &= \frac{(1-\tilde{z})}{\tilde{z}}\frac{\partial\tilde{x}}{\partial z} - (1-\lambda)f(\tilde{x}(\tilde{z})) \\ \iff 0 &= \frac{(1-\tilde{z})}{\tilde{z}}\frac{\partial\tilde{x}}{\partial z} - (1-\lambda)f(\tilde{x}(\tilde{z})) \equiv g(z)\end{aligned}$$

It is clear $g(1) = -(1-\lambda)f(x^*) < 0$ so $\tilde{z} \neq 1$. Moreover, $V^M(1) > V^M(0) = 0$ so $\tilde{z} \neq 0$. Therefore, there must be an interior solution to the manager's problem. □

Intuitively, this result follows from the first order condition. When $z = 0$, there is no surplus so the manager certainly prefers some production to no production. When $z = 1$, the first order condition reduces to $-(1-\lambda)f(x^*) < 0$. That is, at the social optimum, the first-order gain from hiding output exceeds the second-order decline in surplus. Therefore, the equilibrium $\tilde{z}$ must lie between two extremes.

Inefficiency in this team stems from the rigidity of the sharing rule $\lambda$. In theory, the manager could propose a Pareto improving deviation by asking the worker to increase his effort from $\tilde{x}$ to $x^*$ in exchange for an additional $x^* - \tilde{x} + \epsilon$ in compensation. This arrangement would be profitable for the manager, who could keep the rest of the output and end up with a share greater than $\lambda$ of total surplus. Such deviation does not depend on the verifiability or contractability of $f(\cdot)$; the manager could propose it unilaterally to the benefit of both parties.[28] The equilibrium is only inefficient if this deviation is prohibited.

## D.3 Comparative Statics

As a direct corollary of Result 1, output is suboptimally low when the manager controls information about the production function. Similarly, the distribution of surplus is skewed toward the manager relative to the full-information benchmark, and the worker derives less total value from the relationship. We next explore how these outcomes evolve with the bargaining power of the two parties. Recall that the manager's bargaining power is increasing in $\lambda$.

**Result 2.** *As long as the curvature of $f(\cdot)$ is not too great, $\frac{\partial \tilde{y}}{\partial \lambda} > 0$. Total output increases toward the efficient benchmark with the manager's bargaining power.*

*Proof.* Define the curvature of the production function to be

$$c(x) = \frac{f'(x)}{f''(x)}$$

[28]Rigidity in the sharing rule is closely related to the issue of noncontractability that arises in typical models of hidden information. The manager initially hides a portion of output so that it is unverifiable and therefore excluded from surplus sharing, even if the worker suspects it exists. If proposing a deviation makes this additional output verifiable, e.g. by eliminating the plausible deniability of the manager, then the motivation to keep it hidden from contracts would preclude such a deviation.

Note that this function is closely related to the Coefficient of Absolute Risk Aversion in utility theory.

$$\begin{aligned}\frac{\partial z}{\partial \lambda} > 0 &\iff c'(\tilde{x}(z)) > -\frac{2-\lambda z}{1-z} \\ &\iff \frac{f'''(\tilde{x}(z))}{f''(\tilde{x}(z))^2} < \frac{(3-z+\lambda z)z}{1-z}\end{aligned}$$

These conditions follow from implicitly differentiating the manager's first order condition, and then substituting in the worker's first order condition. It is difficult to give an intuitive interpretation of $c'(x)$ because it depends on the third derivative of the production function. Note that as $z \to 1$, the denominator of the right hand side approaches 0 verifying that the condition is satisfied. As a result, $\tilde{z}$ continuously approaches 1 as $\lambda \to 1$. However, away from the optimum, information disclosure may not increase monotonically with the manager's bargaining power. □

Intuitively, as the manager's bargaining power grows, she receives a greater share of surplus. As long as the return to effort in the production function does not die out too quickly, then an increase in bargaining power induces her to prioritize incentivizing the worker over hiding output. See Appendix D for a precise condition regarding the curvature of the production function; this condition is guaranteed to be satisfied as $\lambda$ approaches 1. As a corollary, increasing the manager's bargaining power may lower overall efficiency if the curvature in the production function is large. High curvature indicates the incentive effect of the return to effort rapidly decreases in the level of effort, offsetting any potential gains in production.

**Result 3.** $\frac{\partial V^M}{\partial \lambda} > 0$. *The manager's value from the production team is increasing in her bargaining power.*

This result is unsurprising. For any given choice of information disclosure $z$, the manager's value is strictly increasing in her share of surplus $\lambda$. Therefore, it must be the case that higher values of $\lambda$ correspond to higher value for the manager after optimizing $z$.

*Proof.* Consider two values $\lambda$ and $\lambda' > \lambda$. Further, let

$$\tilde{z} = \arg\max_{z\in[0,1]} (1 - z(1-\lambda))f(\tilde{x}(z)) - (1-\lambda)\tilde{x}(z)$$

It immediately follows that

$$(1-\tilde{z}(1-\lambda'))f(\tilde{x}(\tilde{z}))-\lambda'\tilde{x}(\tilde{z})>(1-\tilde{z}(1-\lambda))f(\tilde{x}(\tilde{z}))-\lambda\tilde{x}(\tilde{z})$$

therefore

$$\begin{aligned}V^M(\lambda') &= \max_{z\in[0,1]}(1-z(1-\lambda'))f(\tilde{x}(z))-\lambda'\tilde{x}(z)\\ &\geq (1-\tilde{z}(1-\lambda'))f(\tilde{x}(\tilde{z}))-\lambda'\tilde{x}(\tilde{z})\\ &> (1-\tilde{z}(1-\lambda))f(\tilde{x}(\tilde{z}))-\lambda\tilde{x}(\tilde{z})=V^M(\lambda)\end{aligned}$$

□

**Result 4.** *The sign of* $\frac{\partial V^F}{\partial\lambda}$ *is ambiguous. The worker's value from the production team may be increasing or decreasing in his bargaining power.*

*Proof.* The worker's value from production is

$$V^W=(1-\lambda\tilde{z})f(\tilde{x}(\tilde{z}))-(1-\lambda)\tilde{x}(\tilde{z})$$

Differentiating this with respect to $\lambda$ and applying the envelope theorem gives

$$\frac{\partial V^W}{\partial\lambda}=\tilde{z}f(\tilde{x}(\tilde{z}))-\tilde{x}(\tilde{z})+(1-\lambda)f(\tilde{x}(\tilde{z}))\frac{\partial\tilde{z}}{\partial\lambda}$$

Therefore,

$$\begin{aligned}&\frac{\partial V^W}{\partial\lambda}>0\\ \iff\ &\frac{\partial\tilde{z}}{\partial\lambda}<\frac{\tilde{z}f(\tilde{x}(\tilde{z}))-\tilde{x}(\tilde{z})}{(1-\lambda)f(\tilde{x}(\tilde{z}))}\end{aligned}$$

That is, when the social surplus from production grows relatively faster than the share the manager appropriates. This condition will not be satisfied as $\lambda \to 1$, but it may not evolve monotonically away from that extreme. □

This unintuitive result follows from the factors that determine the manager's information disclosure. When the manager's bargaining power increases, she may choose to disclose more information to the worker to induce more effort. If the gain in total surplus from this disclosure exceeds the loss in the worker's share from lower bargaining power by a large enough margin, then the worker will be better off in an environment with a more powerful manager who endogenously chooses to cede more control.[29] As a corollary, the worker's share of the total surplus may similarly increase or decrease with his bargaining power depending on the change in information disclosure relative to his claim on the surplus of production. Both of these values unambiguously fall to 0 as $\lambda \to 1$, but not necessarily monotonically so.

Taken together, these comparative statics highlight an important policy tradeoff in this production environment. Managers have two tools with which to manipulate their private returns: they can formally bargain over the surplus of production, characterized by $\lambda$, or they can informally appropriate output, characterized by $z$. Crucially, appropriation ($z$) distorts production incentives while formal bargaining ($\lambda$) does not. Intuitively, increasing the returns to formal bargaining will encourage the manager to prefer this tool, raising overall surplus as long as it is not too damaging to the worker's incentives. A less obvious implication is that this increase in the manager's formal bargaining power may induce enough of a shift from appropriation to bargaining that it is on net beneficial to the worker as well.

[29] Appendix D precisely defines the conditions under which this situation occurs. It depends on the third derivative of the production function, and is therefore difficult to interpret intuitively.

Figure S1: Morning Dairy Collection: A Couple Milking their Cow

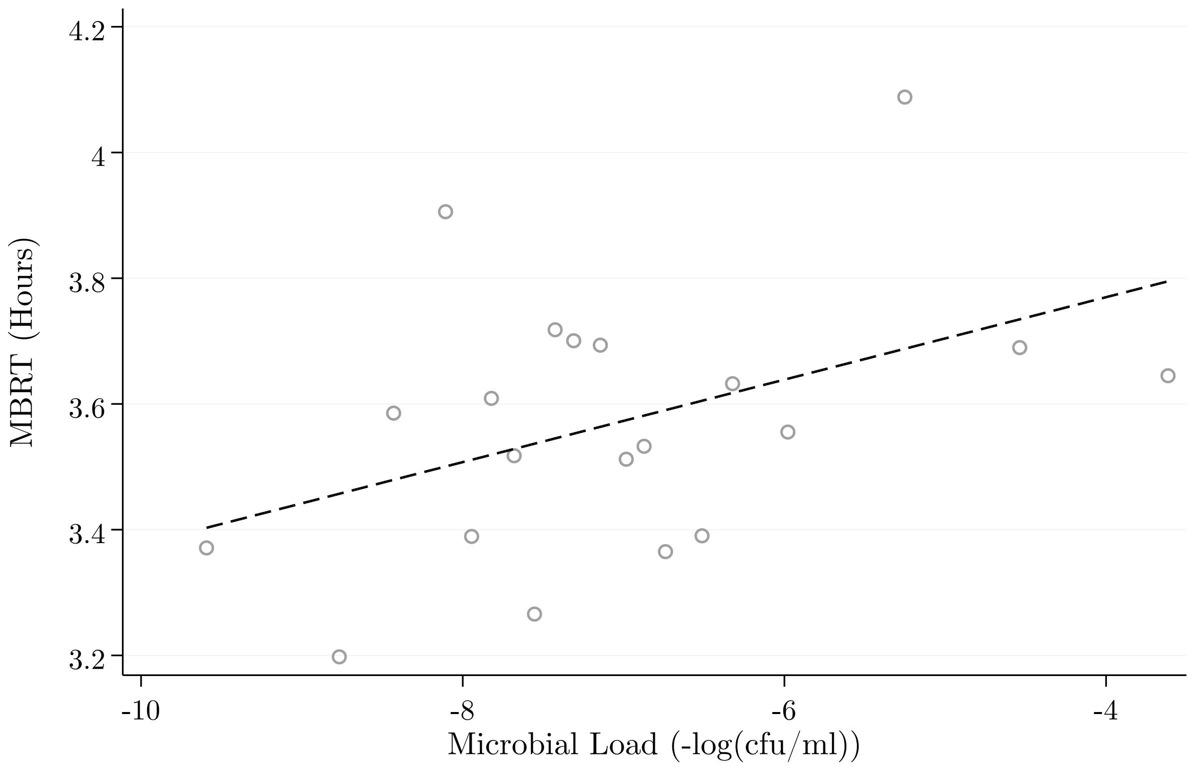
Figure S2: Morning Dairy Collection: Density Testing at the Cooperative Headquarters

Figure S3: Morning Dairy Collection: Milk Poured into a Cooperative Can

Figure S4: Morning Dairy Collection: Small-Scale Local Sales

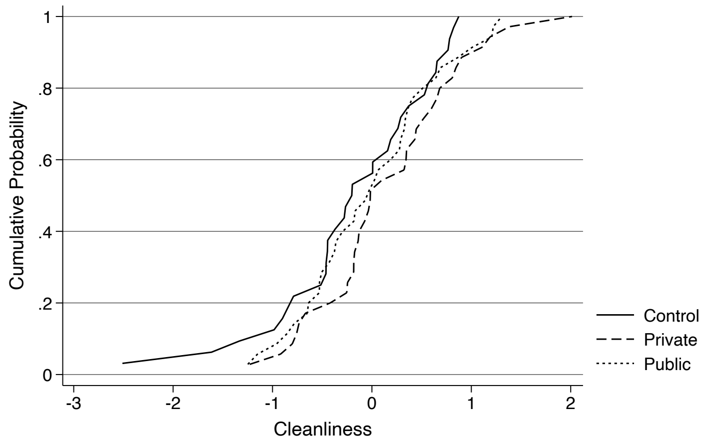
Figure S5: Morning Dairy Collection: Can Truck for Delivery to Processing Plant

Figure S6: Correlation between MBRT and SPC

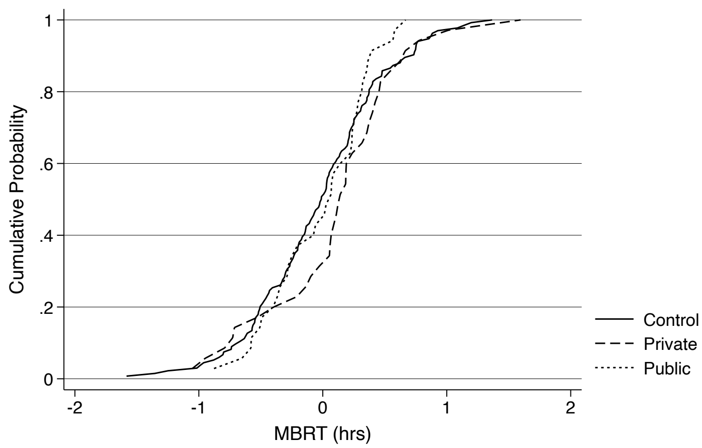



Notes: Binned scatterplot of MBRT and SPC measurements from 522 milk cans. MBRT is measured in time to dye reduction, and SPC is measured in –log(colony-forming-units per milliliter). The correlation coefficient between the two measures is 0.16, with a regression coefficient that is significant at the 5% level in the cross-section, and at the 10% level after accounting for serial correlation in samples from the same cooperative.

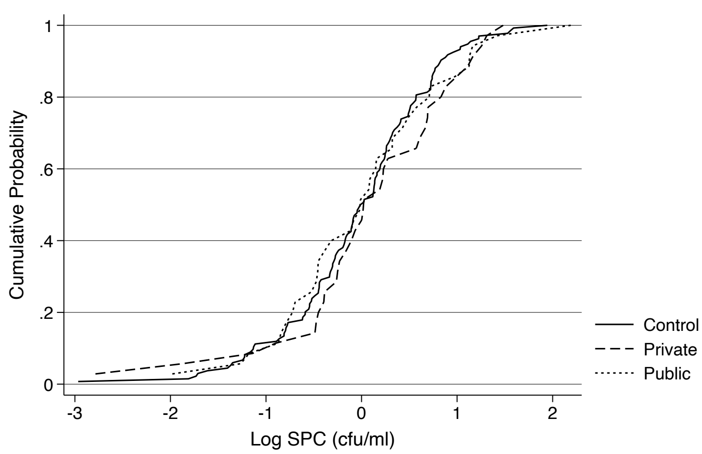
Figure S7: Comparison of Cumulative Density Functions




K-S test p-value between Private and Control is 0.16, and Public and Control is 0.94




K-S test p-value between Private and Control is .05, and Public and Control is .92.




K-S test p-value between Private and Control is .35, and Public and Control is .96.

Notes: Cumulative density function by treatment arm for the cleanliness quality index, MRBT time, and SPC microbial level. District and round fixed effects are netted out from each of these variables. The CDF of the private payment group is to the right of the control group across nearly the entire distribution for the quality index and MBRT. Kolmogorov-Smirnov tests of equality of distributions between private and control result in p-value of 0.16 and 0.05 for these measures, respectively.

Table S1: Payment Schedule for Incentive Structure

| Structure: | Avg MBRT (hrs) | Base | Penalty/Bonus | Net Incentive |
|---|---|---|---|---|
| 1 | 0–2 hrs | 500 | -500 | 0 |
| 2 | 2–3 hrs | 500 | -100 | 400 |
| 3 | 3–4 hrs | 500 | +200 | 700 |
| 4 | 4–5 hrs | 500 | +500 | 1000 |
| 5 | 5–6 hrs | 500 | +1100 | 1600 |
| 6 | 6+ hrs | 500 | +1500 | 2000 |

Notes: Size of incentive to cooperative as a function of milk cleanliness measured by MBRT hours in treatment arms. Incentives were framed as a base payment of Rs. 500 with additional bonus (penalty) for high (low) quality milk.

Table S2: Principal Component Analysis for Cleanliness Index

| Measure | Loading | Unexplained Variance |
|---|---|---|
| MBRT (hrs) | 0.707 | 0.427 |
| Log SPC (cfu/ml) | 0.707 | 0.427 |

Notes: Loading weights on each measure of quality in the first principal component used to construct a quality index.

Table S3: MBRT and SPC Outcomes with and without Lasso

| | MBRT | MBRT | SPC | SPC |
|---|---|---|---|---|
| Private Payment | 0.402 | 0.36 | 0.415 | 0.47 |
| | (0.242) | (0.22) | (0.36) | (0.32) |
| | [0.11] | | [0.32] | |
| Public Payment | 0.163 | 0.17 | 0.275 | 0.38 |
| | (0.18) | (0.18) | (0.331) | (0.32) |
| | [0.43] | | [0.41] | |
| Control Mean | 3.44 | 3.44 | 6.83 | 6.83 |
| R-Squared | 0.066 | | 0.032 | |
| Observations | 204 | 204 | 204 | 204 |
| Village Fixed Effects | X | X | X | X |
| Round Fixed Effects | X | X | X | X |
| Double-Lasso | | X | | X |

Notes: All four columns report DD estimates from eqn. (1). Columns 2 and 4 include covariates selected using the double-lasso method introduced by Belloni et al. (2013). Control variables include flexible time trends interacted with management and producer wealth, education, caste (SC/ST), income, and past experience in elected office. (1) and (2) MBRT is hours to dye reduction. (3) and (4) SPC is measured in -log(cfu/ml). Standard errors clustered by village in parentheses. p-values from randomization inference with clustered bootstrap in square brackets. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table S4: Quantile Regression

| | Cleanliness | | | |
|---|---|---|---|---|
| | Mean | 25th pctile | 50th pctile | 75th pctile |
| Private Payment | 0.64* | 0.82** | 0.41** | 0.7*** |
| | (0.35) | (0.3) | (0.19) | (0.21) |
| | [0.1] | [0.071] | [0.394] | [0.019] |
| Public Payment | 0.32 | 0.19 | 0.38* | 0.49** |
| | (0.32) | (0.38) | (0.22) | (0.21) |
| | [0.32] | [0.648] | [0.464] | [0.092] |
| Observations | 204 | 204 | 204 | 204 |
| Cooperative Fixed Effects | X | X | X | X |
| Round Fixed Effects | X | X | X | X |

Notes: DD estimates with index of milk cleanliness as the dependent variable using quantile regression at 25th, 50th, and 75th percentiles, respectively. Heteroskedasticity robust standard errors in parentheses and bootstrapped p-values in square brackets. *** p<0.01, ** p<0.05, * p<0.1