Skimming Off the Top: The Unintended Consequences of Market Expansion in the Indian Dairy Industry

Ashish Shenoy*
University of California, Davis

October, 2019

Abstract

In India, village dairy cooperatives collect milk from rural producers and sell it in bulk to the regional market. In the last decade the Karnataka Milk Federation, the largest organizer of cooperatives in the Indian state of Karnataka, has invested heavily in bulk milk chillers (BMCs) that drastically lower the time between production and refrigeration. These chillers, by lowering the perceived risk of penalty for spoilage, both raise the potential returns to high quality milk and increase the temptation to engage in unsavory practices such as milk dilution. Risk declines both because chillers better preserve milk and because monitoring at chilling stations is more lax. Therefore the new technology both raises the returns to quality and lowers the cost of cheating. I investigate the net effects of village access to a BMC on the production process through a difference-in-difference approach using village-level data from the district of Kolar. I find that production quantity increases with access to a chiller but average production quality decreases, as does the likelihood of being punished for low quality. The results are consistent with a model in which villagers increase their use of dishonest practices such as dilution after being connected to a BMC because they face less risk of being punished. The effect size is strongest in villages that had the highest quality ex ante, suggesting an equilibrium shift brought on by the change in punishment probability. In addition, I find the strongest evidence of adulteration in villages with fewer outside agricultural options.

*I thank I thank Emily Breza and Arun Chandrasekhar for their work on an earlier version of this paper; Manaswini Rao, Vikas Dimble, Madhumitha Hebbar, and Ben Marx for excellent research support; and Abhijit Banerjee, Esther Duflo, and Tavneet Suri for helpful comments.

1 Introduction

In India, dairy production is a major source of earnings for approximately 20% of rural households. Many producers operate at extremely small scale, with the typical household owning fewer than three cows. The small, decentralized nature of production with high per-unit costs generates a considerable challenge in bringing milk profitably to market.

Dairy cooperatives have gained prominence as an organizational solution to facilitate decentralized, large-scale production. Milk producers in a village join the local Dairy Cooperative Society (DCS), which collects local output and sends it in bulk to a production facility owned by the cooperative's umbrella organization. By consolidating production the DCS alleviates the need to transact independently with each individual producer. In the Indian state of Karnataka, the the cooperative network run by the state-owned Karnataka Milk Federation (KMF) comprises over two million members from more than 11,000 DCSs statewide and procures over four million kg of milk per day.[1]

Before the existence of the KMF, villagers in Karnataka traditionally had limited ability to sell milk externally; they were otherwise restricted to selling exclusively within the village. Chartering a DCS integrates excess output into the broader retail market for dairy products. Producers that enter into the state system earn a higher price per liter both due to high demand from urban centers with little local production and due to the production of value-added goods such as yogurt, cheese, and sweets.[2]

A large technological challenge limiting market integration is the cost and spoilage risk in transporting milk, which must travel from villages with poor roads to central processing facilities located in towns up to 80 km away. Since 2003, the KMF has invested heavily in reducing transportation risks by commissioning and installing thousands of rural bulk milk chillers (BMCs) that provide refrigeration at the point of collection. Each BMC grants access to refrigeration facilities for up to 4 neighboring villages and drastically reduces the time between milk harvest and cooling.

The primary benefit of a BMC is realized in value added during processing. By the 2000's, the supply chain and pasteurization technology were sufficiently advanced that outright milk spoilage almost never occurs. However, cleaner milk can be processed into high-value products such as yogurt, sweets, and cheese. In contrast, milk with a high bacteria count is restricted to use in ultra-pasteurized, shelf-stable liquid packets. By accelerating the time to refrigeration, BMCs arrest bacteria development and improve the cleanliness of milk that reaches the processing plant.

In this paper I provide evidence that some of the gains from rapid refrigeration are offset by increases in milk adulteration. Adulteration comes about in the cooperative structure due to low capacity for individual monitoring. Farmers are paid per liter of milk produced, which creates

[1] http://www.kmfnandini.coop

[2] In recent years, private cooperatives have emerged alongside the KMF, offering an alternative marketing option.

incentives to artificially increase production by diluting milk with added water. DCSs typically combat this practice by measuring milk density at the time of collection, as milk proteins and other solid non-fats lead raw milk to be denser than water. To escape detection, farmers who dilute their milk reconstitute the density by adding adulterants. Typical adulterants include edibles such as sugar, salt, and milk powder; however, testing has also revealed the presence of more harmful chemicals such as detergents and formalin.

Field testing for density can be performed in seconds with minimal training. In contrast, chemical tests for adulterants require laboratory amenities such as temperature control, time ranging from minutes to hours, and some degree of training in both testing procedures and interpretation of results. As a result, adulteration can only feasibly be evaluated at the DCS level after milk reaches the processing facility. If adulteration is detected, it is impossible to trace the source back to the responsible culprit. Instead, the KMF uses a village-level system of penalties through which the entire DCS receives low payment if evidence of dilution or adulteration is detected. Penalties pass through to all cooperative members, creating a wedge between the private and social costs of dilution or adulteration to a single farmer. Local monitoring combined with informal social sanctions narrows this wedge, but adulteration persists nevertheless.

The introduction of BMCs improves technology along the supply chain, but it simultaneously weakens the capacity for monitoring and thereby increases the incentive to dilute and adulterate. At the BMC, milk from up to five villages is combined in a single chiller. This level of aggregation further decouples the relationship between individual behavior and collective measurement made at the central processing facility. Moreover, political considerations arising from the state-run nature of the KMF constrain it from assessing multi-village penalties based on milk testing. The KMF instead relies on local testing conducted by field officers at the time of delivery to the BMC.

While this decentralized quality control formally measures the same production and cleanliness outcomes as at the centralized facility, in practice it creases a weaker monitoring environment. At the central facility, quality testing is conducted by well-trained KMF technicians employed full-time to test milk from all DCSs in the collection zone. In contrast, measurements at BMCs are taken by part-time officers with less training and worse facilities. These field officers only oversee a single BMC, and are typically members of one of the villages in its catchment area. Thus, they have weaker incentives to provide effective quality enforcement for three reasons. First, rigorous testing takes up more time due to less adequate facilities and training, as well as carries a greater opportunity cost of foregoing alternate sources of income. Second, the career penalty to being caught shirking on the job is lower. Third, the cost of strict monitoring may be higher if they face social sanctions in retaliation for triggering costly penalties.

I evaluate the effect of BMCs on local milk production using administrative records for more than 1,600 DCSs in 2 districts of Karnataka from 2000 to 2011. The 11 years covered by the data span a period of rapid BMC growth, and I exploit the timing of the actual construction across the region in a difference-in-differences analysis. I also decompose the effects of becoming connected along pre-period quality dimensions. Furthermore, I supplement the data with records from the Karnataka Livestock Census to understand if villages with more technology and machinery respond differently to the BMC expansion than villages with more limited resources to devote to other agricultural activities.

Dilution and adulteration are not directly observable because the data are generated by the same monitoring mechanism through which payment is determined. However, I find a pattern of results consistent with greater dilution and adulteration in response to weaker oversight. Production quantity increases following the installation of a chiller, but average quality declines. The results show that while average quality declines, the number of days per month that a village faces penalties from the KMF for low quality decreases as well. In other words, DCSs that deliver to chillers are closer to the penalty threshold on average but fall below it less frequently. The results together are consistent with the effects of reduced monitoring leading to perverse behavior by dairy producers. I also find some evidence of disinvestment in quality on the part of milk producers as the fraction of the village's cow herd that is a modern cross-breed decreases after gaining BMC access. Although this change could also explain the decline in average quality, it would not simultaneously generate an increase in quantity.

There has been a growing literature estimating the impacts of infrastructure investment in a variety of settings, using an expanding set of empirical strategies. Duflo and Pande (2007) and Lipscomb et al. (2011) evaluate the incidence of the benefits of dams and hydroelectric power in India and Brazil. Transportation infrastructure such as rails and roads is evaluated by Banerjee et al. (2012), Donaldson (2010), Donaldson and Hornbeck (2012) and Datta (2011). This project is also related to the empirical trade literature studying market integration such as Costinot and Donaldson (2012) and Michaels (2008).

The analysis also has connections with political economy and contract theory questions. This paper follows the of the analysis of the PE of sugar cooperatives by Banerjee et al. (2001) and that of public goods allocation by Banerjee and Somanathan (2007). Finally, a set of papers including Banerjee et al. (2008) and Glewwe et al. (2010) describes the pitfalls of decentralizing incentives in sectors such as education and health. These studies show that individuals are quite apt at gaming incentive systems.

The remainder of the paper is organized as follows. In Section 2, I describe the experimental subjects, network and survey data sources and the experimental design. Section 3 lays out a model with which to think about potential BMC effects. Section 4 discusses the reduced form empirical approach. In section 5 I present the results, and 6 concludes.

2 Institutional Setting and Data

2.1 Setting

The Karnataka Milk Federation

The KMF has used the same model for milk procurement and governance across the state of Karnataka since its inception in the 1970's . In viable milk-producing villages, farmers are invited to join a DCS. Once a new village DCS is chartered, each member becomes a shareholder in the statewide institution, earning voting rights in cooperative elections and a share of annual profits. Each DCS collects milk twice a day, at both early morning and evening procurements. Producers bring their milk to the village office, where a nominal quality test is performed.[3]

In some villages, full milk cans are loaded onto a truck and delivered directly to one of the four district processing plants. There, full-time KMF employees test the milk's quality, measured by fat and solid non-fat (SNF) levels, and inspect for evidence of dilution or adulteration. In other villages, the milk cans are loaded onto smaller trucks and are delivered to a nearby chilling facility, or bulk milk chiller[4]. Milk delivered to BMCs is tested by local DCS officers where the BMC is located. The milk is then combined with the milk from other villages and chilled. Once per day, a refrigerated tanker truck delivers milk from the chillers to one of the four production facilities. The average contents of the refrigerated truck are tested by the full-time KMF employees, but measurements cannot be traced back to individual villages. Figure 2 details this procurement process in a flow chart.

Bulk Milk Chiller (BMC) Expansion

Transportation costs and milk spoilage are significant barriers to expansion for the KMF. As a result, with the help of the Government of India, the organization has invested heavily in bringing refrigeration technology to remote villages. Each new BMC constructed produces 5 villages that are connected to refrigeration technology. With the chillers, milk only needs to be collected once daily, further reducing costs. In the past decade, the KMF has built more than 100 BMCs in the two districts I study. Figure 3 shows the frequency of new BMCs over time. I seek to estimate the value in terms of milk quality and farmer co-investment of a village being connected to a BMC.

It is important to note that the selection criteria for receiving a BMC are not random. Some of the determinants are minimum levels of daily milk procurement, the presence of other producing villages nearby, ownership of a structure that could accommodate a BMC, proximity to a road where tanker trucks can pass, and reliable power supply. The KMF banks the biggest gain from installing BMCs farther away from the processing plants where spoilage risk en route to the processor is high.

[3] The DCS secretary measures the CLR, or corrected lacto-meter reading. This is a temperature-adjusted density measure. However, the field test is highly manipulable.

[4] See Figure 1 for a picture of a BMC.

Incentives for Quality and Milk Pricing

The processing center pays each DCS a per liter rate based on milk quality. The procurement price is increasing in both quality dimensions, fat and SNF. If either the fat or SNF levels falls below some pre-specified threshold, then the DCS is punished with a discretely lower payment. Low payment or no payment is also given if milk is spoiled, though this occurs extremely infrequently in practice. Milk that is nearly spoiled can only be used for cheap retail products such as highly pasteurized shelf-stable milk packets, and therefore lowers the state organization's annual profitability. However, individual villages are rarely penalized for such occurrences. Qualitative surveys suggest that farmers believe spoilage to pose a large threat to their income, perhaps due to past payment schemes before the availability of high-quality pasteurization technology, despite the low prevalence of reported spoilage in the current data.

While village-level milk prices are increasing in quality, two problems limit the power of these incentives. First, villagers are only paid directly for quantity. They may receive year-end bonuses if the average village quality is high, but individual incentives are weak. Furthermore, the power of the quality incentives are quite low in terms of the marginal village-level price for quality. A 2 standard deviation increase in quality is only accompanied by a small increase in price, on the order of magnitude of 2%. The incentive is much steeper when quality falls below a certain threshold, resulting in a payment decrease of 50 or even 100%. Thus, there are high returns to producing milk that meets a certain standard, but weak incentives to exceed the standard.

Milk quality and yield are determined by several factors including breed of cow, feed type, health and vaccination record of the animals, and water availability. Producers may also choose to dilute their milk to increase their supplied quantities. Because thinning the milk decreases both fat and SNF, other adulterants may be added with the water such as milk powder, butter, salt, sugar, urea or even shampoo to avoid detection. The most common adulterants, salt, sugar and urea all increase SNF. Thus, most dilution yields higher volume and lower fat content, while SNF may either decrease or remain unchanged. Adulterant testing is costly, so only a small subsample of pooled DCS milk is tested, with no payment given for milk found to be adulterated. Anecdotal evidence suggests that milk dilution and adulteration is relatively common but rarely punished. External audits suggest that in Karnataka, approximately 20% of samples contain adulterants.[5] Determining the effects of BMC expansion on quality, quantity, and production behavior is a key goal of this paper.

Each DCS's net earnings comprise the difference between the price received from the KMF and the price paid to the farmer, plus a year-end bonus based on the KMF's annual profits. A portion of these earnings go to DCS building maintenance and staff payments at the DCS president's discretion. The remainder are returned to farmers on a per-liter basis, again independent

[5] Times of India, 01/12/2012

of individual quality.

When a village is connected to a BMC, the monitoring of quality is transferred from the processing plant to the village where the BMC is located. Thus, villages connected to a BMC are paid based on measurements taken at the BMC by local officers while villages that deliver directly to processing centers are paid based on measurements taken by central staff. This creates additional incentive problems. It is possible that village personnel help their own members and the members of contributing DCSs by inflating certain quality parameters. It is also possible that DCS officials dilute the milk to achieve the highest possible volume meeting still meeting minimum standard for normal payment. While the bulk milk chiller facilitates market expansion and consolidates transportation costs, it also decentralizes the monitoring process.

2.2 Data

I use four main data sources in analysis.

KMF Administrative Records

The KMF has generously shared administrative records with us for the districts of Kolar and Chikballapur. These districts, formerly a single district until 2009, are both managed by the Kolar Milk Union; thus the same policies and prices apply to all villages in the sample. The administrative records detail village-level quantity and quality for each morning and evening collection from April 1, 2000 to March 31, 2011. I restrict analysis to a balanced panel of DCSs that report data in every month of the study period, consisting of 842 villages. The reported quality characteristics include fat and SNF as well as the per liter price paid to each DCSs milk on a twice-daily basis, including penalty payments for low quality or spoilage. The KMF also provided us with a list of all of the villages with BMCs as of July 2011.

While the data reported for each village is the same, the measurement procedure changes when a village starts delivering to a BMC. For standard villages, milk is tested at a central lab by a career KMF employee when it reaches the processing plant. For BMC villages this is not possible since milk from multiple villages is pooled in the chiller. Instead, milk from these villages is tested locally before entering the chiller. This testing is preformed by a part-time, local employee with close ties to the village. Therefore, the administrative data must be interpreted with the change in measurement procedure in mind.

Survey of BMC Villages

Using the list of BMCs provided by the KMF, I surveyed the DCS secretary in each of the 100 villages. From these personnel, I collected the number of members at the time of the survey, the date of commissioning of the BMC, the date of installation of the BMC, and the names of the other DCSs that contribute milk to their BMC.

Department of Animal Husbandry Records

To measure the composition of each DCS's herd of cattle, I obtained livestock census data from the Karnataka Department of Animal Husbandry. The organization records detailed information at the village-level on types and breeds of cows and buffaloes, along with animal husbandry participation rates by households in the village. The censuses are collected every 5 years, and I use the 2002 and 2007 data for analysis.

Census of India

Finally, I use data from the 2001 Village Census of India. The key variables available from the census are GPS coordinates (used to calculate distances between villages), population, number of scheduled castes and scheduled tribes members, total land area, total cultivated land, and total irrigated land. I are waiting for the 2011 village census data to become available so that I can use other variables in the difference-in-differences analysis. I supplement the geographical data with GPS coordinates of the four district milk processing plants read from Google Maps. Census and livestock census data are easily matched using the national census codes. These data are then matched to the KMF production data by village name and location. I am able to match 761 out of 842 of the KMF records to the census.

2.3 Descriptive Statistics

Table 1 displays an overview of the final data set. The first column contains means of the pertinent variables for villages that receive a BMC by 2011, the second for villages eventually connected to another village's BMC, and the third for never-connected villages. Note that in this sample, 104 villages ever receive a BMC, 185 villages become connected to another village's BMC, while 553 villages remain unconnected. The average fat levels tend to hover around 4.10 with 8.45 SNF in all categories of village. The high variance in rate paid stems from rate chart adjustments over time (with the average payment increasing from Rs. 10/ltr. to Rs. 18/ltr. over this period) rather than differences between villages. There are substantial differences between the composition of villages which receive a BMC and that of the other two categories. BMC villages tend to be bigger with smaller scheduled tribes populations. This is not surprising in light of KMF's selection criteria.

3 Model

I use a simple model to illustrate the effects of opening a BMC in a village's neighborhood. I model the decision to adulterate as a coordination game with multiple equilibria played by members of each DCS and focus on the risk-dominant equilibrium of the game. I compare the risk dominant equilibrium before and after the installation of a BMC in or near the DCS. The main effect of the BMC is to reduce the probability of spoilage (or of detection in a world of decentralized incentives and corruption). I show that this change in spoilage probability may have differential effects depending on the initial conditions of the village. First, the installation of a chiller may make the prospect of not adulterating less risky (in the sense of risk-dominance) and therefore may push a village which was previously stuck in the bad equilibrium towards cooperation. Second, the reduction in probability of spoilage (or of detection of low quality milk) may make a village previously stuck in a good equilibrium now more likely to increase quantity through adulteration, as the reduction in spoilage probability provides some slack in incentives. Here, the adulteration equilibrium may become selected.

Let $1-p$ be the spoilage probability of adulterated milk and $1-p'$ be the spoilage probability of unadulterated milk. For simplicity, I let $p' = p + \delta$ for $\delta \in (0, 1-p)$ some fixed constant. Let c denote the cost of providing high quality (unadulterated) milk.

Suppose that the village is compensated based on the overall quality of the milk and that the overall quality is the minimum of the qualities supplied by each producer.[6] Therefore, if any one producer adulterates, the unit price of milk is a, while if nobody adulterates, the unit price is $b > a$. Thus, without a BMC, two (easily generalized to n) villagers face

Payoffs without a BMC		
	Adulterate	Not
Adulterate	(ap, ap)	$(ap, ap - c)$
Not	$(ap - c, ap)$	$(bp' - c, bp' - c)$

whereas with a BMC, they face

Payoffs with a BMC		
	Adulterate	Not
Adulterate	(a, a)	$(a, a - c)$
Not	$(a - c, a)$	$(b - c, b - c)$

The risk-dominant pure strategy equilibrium without a BMC is (Adulterate, Adulterate) when

$$ap - c + bp' - c < 2ap \iff c > \frac{bp' - ap}{2} = \frac{(b-a)}{2}p + \frac{b}{2}\delta.$$

[6]The only requirement for the results to go through is complementarity in payoffs as a function of others' qualities.

Now suppose that with a BMC, $p = p' = 1$. Then, the risk-dominant pure strategy equilibrium with a BMC is (Adulterate, Adulterate) when

$$a - c + b - c < 2a \iff c > \frac{b-a}{2}.$$

This implies that there can be villages that move from the bad equilibrium to the good equilibrium, but also that there can be villages which move from the good equilibrium to the bad equilibrium.

To make this concrete, let us consider an example where $b = 10$, $a = 7$, $\delta = 0.1$. There are two sorts of villages, $p = 0.3$ and $p = 0.7$, corresponding to ex-ante low quality and high quality milk, respectively. Observe that an ex ante low quality village is in the adulteration equilibrium if

$$c > \frac{3}{2}0.3 + \frac{10}{2}0.1 = 0.95.$$

Meanwhile an ex ante high village is in the adulteration equilibrium if

$$c > \frac{3}{2}0.7 + \frac{10}{2}0.1 = 1.55.$$

With a BMC, however, the threshold is given by

$$c > \frac{b-a}{2} = 1.5.$$

This means that if $1.5 < c < 1.55$, then a high village in the ex ante good equilibrium will migrate to the adulteration equilibrium with the BMC. Meanwhile, if $1.5 > c > 0.95$, then a low village in the ex ante adulteration equilibrium migrates to the good equilibrium with the BMC.

More generally,

$$c \in \left(\frac{(b-a)}{2} p_v + \frac{b}{2}\delta, \frac{b-a}{2} \right) := \mathcal{C}$$

will lead to migration from a bad equilibrium to a good equilibrium for village v.

Let $\mathcal{C}_L = \left(\frac{(b-a)}{2} p_L + \frac{b}{2}\delta, \frac{b-a}{2} \right)$ and $\mathcal{C}_H = \left(\frac{b-a}{2}, \frac{(b-a)}{2} p_H + \frac{b}{2}\delta \right)$. Assume c are i.i.d. draws from $F(c)$ with $\operatorname{supp}(F)$ satisfying $\{\mathcal{C}_L \cup \mathcal{C}_H\} \subset \operatorname{supp}(F)$. Then by $p_v \perp c_v$ and observing that (a) for any value of c for which an ex ante high quality village is in the adulteration equilibrium also has the ex ante low quality village in the adulteration equilibrium and (b) for any value of c for which an ex ante low quality village is in the good equilibrium also implies that the ex ante high quality village is in the good equilibrium, the following hold.

1. The share of ex ante low quality villages that move from the adulteration to the good equilibrium is higher than the share of ex ante high villages.

2. The share of ex ante high quality villages that move from the good equilibrium to the adulteration equilibrium is higher than the share of ex ante low villages.

That is, the following lemma holds:

Lemma 3.1 *Let $p_L < p_H$ denote the probability of spoilage for adulterated milk and let $\delta_j \in (0, 1-p_j)$ denote a constant such that $p_j + \delta_j$ denotes the probability of milk spoiling when it is unadulterated. Let the costs associated with producing high quality milk be drawn i.i.d. from distribution $F(c)$ satisfying $\{\mathcal{C}_L \cup \mathcal{C}_H\} \subset \operatorname{supp}(F)$. Then*

1. $\int 1\left\{c \in \left(\frac{(b-a)}{2}p_L + \frac{b}{2}\delta, \frac{b-a}{2}\right)\right\} dF(c) \,/ \int 1\left\{c \in \left(\frac{(b-a)}{2}p_H + \frac{b}{2}\delta, \frac{b-a}{2}\right)\right\} dF(c) > 1.$

2. $\int 1\left\{c \in \left(\frac{b-a}{2}, \frac{(b-a)}{2}p_H + \frac{b}{2}\delta\right)\right\} dF(c) \,/ \int 1\left\{c \in \left(\frac{b-a}{2}, \frac{(b-a)}{2}p_L + \frac{b}{2}\delta\right)\right\} dF(c) > 1.$

I interpret adulteration as the pairing of adding water to the milk and then compensating by adding particulates (such as urea, starch, etc.). This implies that I should expect certain heterogeneous effects when I condition on ex-ante quality of villages.

Empirical Predictions Under the above assumptions, the following should hold:

1. Quantity of milk should increase in ex ante high villages and decrease in ex ante low villages.

2. Quality of milk should decrease in ex ante high villages and decrease in ex ante low villages.

3. The share of times in the top quartile of fat content should decrease in ex ante high villages and increase in ex ante low villages.

4. The share of times in the bottom quartile of fat content should decrease in ex ante high villages and increase in ex ante low villages.

5. Solid non-fats should decrease in ex ante high villages and decrease in ex ante low villages.

These predictions follow from two possible effects that chillers may have. First, chillers directly lower the likelihood of rejection due to spoilage. This raises the returns to effort in milk production and therefore makes it more likely that villages try for high production quality. This effect is stronger in villages that have an ex ante higher risk of spoilage since they benefit the most from the technology.

Second, chillers make the measurement technology more lax since part-time, local employees are less likely to enforce penalties than full-time central employees. This lowers the costs of adulteration, making it more attractive to cheat instead of spending effort on quality. This effect is stronger among villages with ex ante lower spoilage risk since villages with high spoilage risk were more likely to be cheating already.

In the data, cheating is ideally represented by rejection or penalty payments. Unfortunately, due to the changing measurement procedure, this measure is no longer reliable. Instead, I think cheating is likely when production quantity increases (due to dilution) and SNFs increase (due to adulteration), but fat content decreases (since it is more difficult to manipulate a fat measurement). In contrast, higher effort would lead to a modest, if any, increase in quantity accompanied by rises in both SNFs and fat.

4 Empirical Strategy: Differences-in-Differences

I first evaluate the village-level production response to chilling centers using regression analysis. All regressions are run on a balanced panel of village-month observations ranging from April, 2000, to March, 2011, with errors clustered at the village level. In all reduced-form analysis, I employ a differences-in-differences approach. My key regression of interest is

$$y_{v,t} = \alpha_v + \alpha_t + \beta BMC_{v,t} + \epsilon_{v,t} \tag{1}$$

v indexes the village or DCS and t indexes the month. $BMC_{v,t}$ is an indicator for whether village v in month t is connected to a BMC (either has a BMC in the village or delivers to a nearby village with one).

The coefficient β is the effect of having access to a BMC on a given outcome, $y_{v,t}$. Time fixed effects, α_t, partial out any time-generated variation, including overall trends and seasonal variation. Village fixed effects, α_v, partial out level differences between villages. The remaining identifying assumption is that villages that become connected to a BMC would have followed the same production trend as unconnected villages were they not connected to a BMC.

To study the heterogeneous effect by ex ante high and low quality villages, I look at

$$y_{v,t} = \alpha_v + \alpha_t + \beta BMC_{v,t} + \sum \gamma_q BMC_{v,t} \times 1\left\{quartile_v = q\right\} + \epsilon_{v,t} \tag{2}$$

where $1\left\{quartile_v = q\right\}$ indicates that a village was in the qth quartile of production quality ex ante. Here γ gives the relative effect of getting a BMC in one's neighborhood compared to ex ante low quality villages, and the full effect is given by $\beta + \gamma_v$.

4.1 Milk Production Outcomes

I am primarily interested in the effect of the commissioning and the installation of a BMC on milk production and the subsequent investment response of producers. Village-level outcomes include average milk fat, SNFs, monthly volume produced, monthly value of production, days in which some milk is flagged as low quality, and total portion of milk for which villages receive low payment. The first two outcomes represent village average milk quality, and the third total quantity. The fifth if the monetary value of the milk, the fourth comprises the portion of days in which some milk receives low payment, and the fifth the total portion of milk for which low payment is received.

It is never the case that a village receives low payment for its entire milk production in a day. Low payment is only meted to those cans from which low measurements are taken; the remaining cans receive full payment. Low payment very rarely stems from spoilage; the vast majority of low payment instances are caused by low quality, as measured by fat and SNF content.

4.2 Livestock Outcomes

I supplement analysis of village-level outcomes using village livestock censuses. In the period of study, censuses were conducted in 2002 and 2007. Using these, I implement a simple difference-in-difference taking villages that had a BMC installed in the interim period as the treatment group and those that did not have access to a BMC in 2007 as control. If villages respond to chilling facilities by improving production, I would expect to see a shift in herd composition from indigenous cow varieties to crossbreeds, which require greater investment in feed and care but also provide higher quality milk. Inversely, if BMCs degrade the ability for the KMF to monitor quality, I would expect a decline in livestock investment.

For a subset of the data, I also have information on the quantity and type of feed purchased by DCS members. I can distinguish between expensive, high quality feed and the cheaper, standard feed. I use feed purchases to measure changes in inputs in response to BMC networking.

4.3 Heterogeneous Effects and Income Risk

I predict that access to a BMC changes the riskiness of dairy production. As a result, the effects of becoming networked to a chiller may differ depending on the total risk profile of a household's income-generating activities. For agricultural households with access to a range of crops and new technologies, less dairy risk may lead to risk shifting into other activities. However, for those households with few outside options, it may be optimal to increase effort and inputs to dairy production in response to the BMC.

I test this hypothesis using data on machinery recorded in the 2002 Karnataka Livestock Census. In addition to information about animals, the dataset includes village-wide availability of 43 different types of farm implements used for different types of agricultural activities. Examples include tractors, wooden plows and power hay bailing machines. I construct an index of machinery and proxy a village's set of income opportunities with more access to machinery.

5 Results: Differences-in-Differences

5.1 Graphical Analysis

Figures 4 through 8 present the main results in graphical form. These graphs represent differences in differences estimators. DCS and time effects are partialled out of each outcome variable, and the graphs are centered at the period at which the "treatment" BMC is built. The x-axis represents months since becoming connected. All outcome data normalized in each month by the mean of villages that never gain BMC access. Deviations from 0 represent differences between BMC villages and control villages. Finally, a vertical bar is placed at 9 months prior to the installation of a BMC to indicate anticipation effects. Village DCS officials may make sure not to jeopardize the arrival of the BMC before it is installed, making some anticipatory effects likely. Once the chiller is installed, it is very hard to remove.

Figure 4 shows the effects of BMC connections on days with low quality penalties. The pattern is quite clear. Villages have far less low quality/low payment milk once they become connected to a BMC. This result alone could either be driven by improved quality or lax monitoring at BMCs. Figure 5 shows the same type of specification but using quantity as the outcome variable. It appears that quantity increases over time once the villages are connected. Despite the increase in quantity, I see no corresponding increase in fat content, as shown in Figure 6. The reason for this is made clear in the discussion on heterogeneity below.

I next present a preliminary investigation into heterogeneous effects in Figures **??** through 8. In these regressions, the "treatment effect" is split between villages that were in the bottom quartile of the fat distribution in the pre-period and villages in the top quartile.

First, Figure 7 shows that both types of villages face comparable declines in penalty payments after gaining BMC access. However, the remaining two graphs reveal very different causes for these declines. Figure 9 shows the heterogeneous effects of becoming connected on fat. The results are quite striking. The worst villages see moderate quality improvements after the connection, but the previous best performers experience a reduction in average fat content. In Figure 8, it also appears that previously high quality villages also increase production quantity by more after BMC introduction. In contrast, the previous low performers do not see large quantity gains. Together, these results are suggestive of quality improvements among low performers and dilution by high performers.

5.2 Regression Results

The patterns in the graphical analysis carry over to the regression results. Table 2 displays the preliminary OLS and Differences-in-Differences results. The top panel does not include any time or DCS fixed effects, thus the parameter estimates should be thought of as simple correlations. Villages that become connected tend to have higher production quantities and lower fat content. In panel B, I add time fixed effects, and the patterns look similar. In panel C, I run the full Differences-in-differences specification. I find that average fat increases during the commissioning time, but the gains are erased after BMC installation. I also find that connections to a BMC slightly decrease SNF, significantly increase quantity, and also significantly decrease the number of low payments received by the DCS. The increase in quantity is on the order of adding 2 new farmers to the DCS. Finally, panel D presents the differences-in-differences results for those villages that become connected but do not themselves receive a BMC. The results are smaller, but sill qualitatively the same. Table 3 shows the same specifications restricting the observations to only those villages that eventually become networked. The identification in this specification is only coming from the timing of BMC placement. The results are very similar.

The results presented in Table 4 suggest that the change in quantity is likely not driven by the addition of new members or livestock to the DCS. If anything, the number of cows in the village declines after BMC installation. In addition, the portion of cross-breed cattle, which produce more milk but require greater investment, declines with BMC installation. These changes are consistent with the prediction that farmers take advantage of the lax monitoring by BMC staff to substitute low effort and dilution for high effort in milk production.

Next I look at results that correspond to the framework discussed in Section 3. In Table 5 I show production outcomes broken down by pre-period fat quartile. In line with the predictions of Lemma3.1, for ex ante high quality village (those that are in the fourth quartile by avg fat content from 2000-2002), I find increases the liters of milk per month as well as decreases in the average SNF rate and the average fat rate. Similarly, for ex ante low quality villages (Q1), I find that the average fat increases though I do not detect any effects in SNF nor in quantity.

Finally, Table 6 shows additional heterogeneous results. Here I are interested in whether the outside option of a village affects how much it benefits from being networked to a BMC. For instance, villages with higher outside options may be less incentivized (e.g., work less hard) in terms of dairy production. One interpretation is that though everyone misbehaves (i.e. dilutes or shirks), whether one dilutes or shirks depends on outside options. For instance, those who have low outside options may dilute whereas those who have outside options may dilute somewhat, but more prominently may switch to other tasks (e.g., agriculture). As such, their quantity may not increase as much. To study this, I compute an agricultural machine index based on a principal component analysis using 45 variables from the village agricultural census. I find that both revenue and volume increase by significantly less when the village has a higher agricultural machine index, though I do not find any differential affects on fat, SNF, rate and low quality days.

5.3 Bootstrapped Distribution of Diff-in-Diff Parameters

Ideally, I would see no differential pretrends between BMC and non-BMC villages. To examine pretrends in relation to estimated coefficients, I randomly simulate the date of introduction of each BMC and investigate the distribution of estimated “placebo” coefficients. I find that almost all results are significant relative to the placebo regressions.

I run 100 simulations in which I estimate the difference-in-difference coefficient on a set of data for which villages connected to a BMC are assigned a random connection date drawn uniformly from the period 2002-2010, which represents the period over which BMCs are constructed in the data. Table 7 reports results from a simulation including the actual villages in which the BMC is built in Panel A, and results dropping the actual villages in which a BMC is built in Panel B. Control villages, those that never gain access to a BMC, are treated the same in both simulation and actual estimation. In both tables, the first column represents the original DD estimate. The second and third columns represent the mean estimate and standard deviation of the estimate in 100 simulations. The final column reports the t statistic under the null hypothesis that my estimate is equal to the simulation mean. In all cases, the estimate is significantly farther from 0 than the simulation mean, supporting the DD findings.

6 Conclusion

I document potential perverse effects associated with infrastructure investment. Using data from the Karnataka Milk Federation, I evaluate how village-level production responds to the installation of bulk chilling facilities. Absent any behavioral response, BMCs should lower the risk of milk spoiling, raising the overall quality of milk received by the KMF.

I present a simple model in which producers' response to the change in spoilage probability may undermine the benefits of refrigeration. It is possible that by decreasing spoilage risk, or decreasing the rejection risk through lax monitoring, decentralized refrigeration shifts the risk-dominant equilibrium form one in which farmers honestly deliver high quality milk to one in which farmers shirk and attempt to dilute milk for private gain. In practice, such behavior would result in greater quantities of milk with lower fat content.

Using difference-in-difference analysis, I find evidence that production quantity increases while quality decreases when villages connect to a BMC. The effect is especially pronounced in villages that had high quality prior to the introduction of refrigeration, while the trend may go the opposite way in villages that performed poorly ex ante. In all cases, I find the likelihood of punishment for poor quality decreases int he presence of a BMC. Together, these results are consistent with equilibrium shift spurred by lax monitoring at chillers, with the shift from high to low equilibrium dominating on net.

In addition, I find the strongest evidence of bad behavior in villages with fewer alternative means of generating income. Producers in these villages likely earn the largest share of their income through dairy, and thus take the greatest advantage of changes to monitoring. Farmers with more outside options seem more likely to invest less in quality production in favor of other occupations.

The results offer several lessons to policymakers planning infrastructure investments. First, infrastructure is not build in a vacuum. The impact of an investment is shaped by endogenous responses in the behavior of stakeholders. In this case, potential gains from reduced spoilage are significantly offset by increased dilution and poor milking practices. Second, implementation details undermine well intentioned policy. I find evidence that detrimental equilibrium shifts are generated in part by lax monitoring at decentralized chillers. If monitoring at these stations was as strong as at the central processing plant, dilution practices may be curtailed. Finally, the targeting of infrastructure influences its efficacy. I identify types of villages – those with poor milking practices ex ante – for whom access to a BMC improves production. Ultimately, the value of infrastructure investments is determined by the way in which they are implemented and the population they aim to serve.

References

Banerjee, A., E. Duflo, and R. Glennerster (2008): "Putting a Band-Aid on a corpse: Incentives for nurses in the Indian public health care system," *Journal of the European Economic Association*, 6, 487–500.

Banerjee, A., E. Duflo, and N. Qian (2012): "On the road: Access to transportation infrastructure and economic growth in China," *NBER Working Paper*.

Banerjee, A., D. Mookherjee, K. Munshi, and D. Ray (2001): "Inequality, control rights, and rent seeking: sugar cooperatives in Maharashtra," *Journal of Political Economy*, 109, 138–190.

Banerjee, A. and R. Somanathan (2007): "The political economy of public goods: Some evidence from India," *Journal of Development Economics*, 82, 287–314.

Costinot, A. and D. Donaldson (2012): "How Large are the Gains from Economic Integration? Theory and Evidence from US Agriculture, 1840-2002," *Working Paper*.

Datta, S. (2011): "The impact of improved highways on Indian firms," *Journal of Development Economics*.

Donaldson, D. (2010): "Railroads of the Raj: Estimating the impact of transportation infrastructure," Tech. rep.

Donaldson, D. and R. Hornbeck (2012): "Railroads and American Economic Growth: A Market Access Approach," *Working Paper*.

Duflo, E. and R. Pande (2007): "Dams*," *The Quarterly Journal of Economics*, 122, 601–646.

Glewwe, P., N. Ilias, and M. Kremer (2010): "Teacher Incentives," *American Economic Journal: Applied Economics*, 2, 205–227.

Lipscomb, M., A. Mobarak, and T. Barham (2011): "Development Effects of Electrification: Evidence from the Geologic Placement of Hydropower Plants in Brazil," *Working Paper*.

Michaels, G. (2008): "The effect of trade on the demand for skill: evidence from the Interstate Highway System," *The Review of Economics and Statistics*, 90, 683–701.

Figure 1: A picture of a Bulk Milk Chiller (BMC).

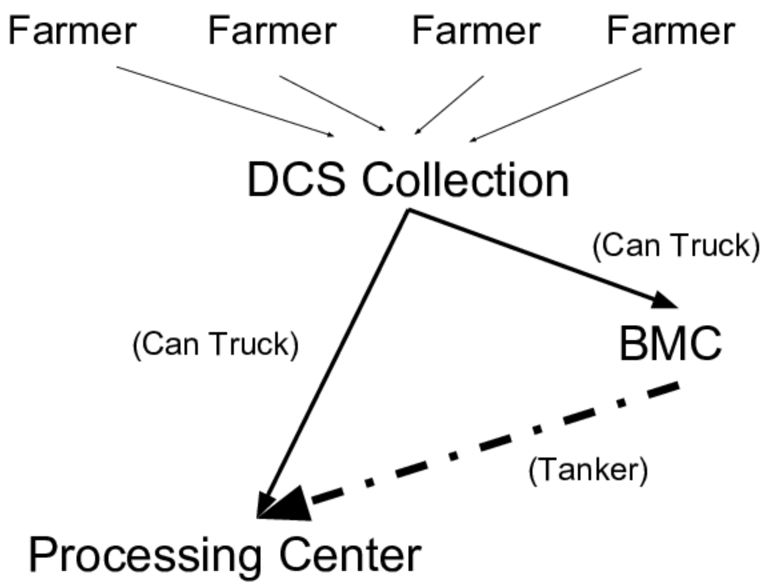

Figure 2: A schematic of the dairy production sector. First, farmers pour their milk together in the village collection. From there, the milk is transported on an open-air can truck either directly to the processing center or to a local BMC. A refrigerated tanker arrives at each BMC daily to collect milk and deliver it to the processing center.

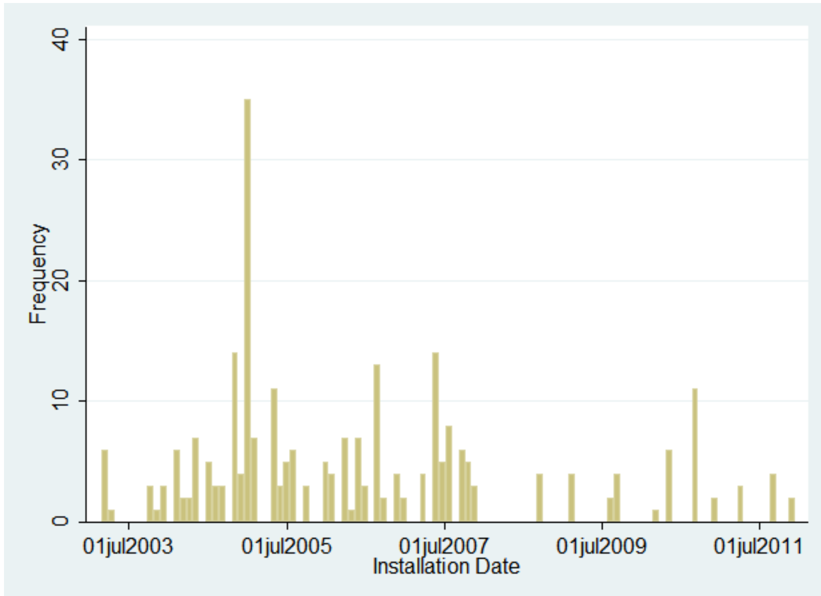

Figure 3: A histogram of BMC construction dates.

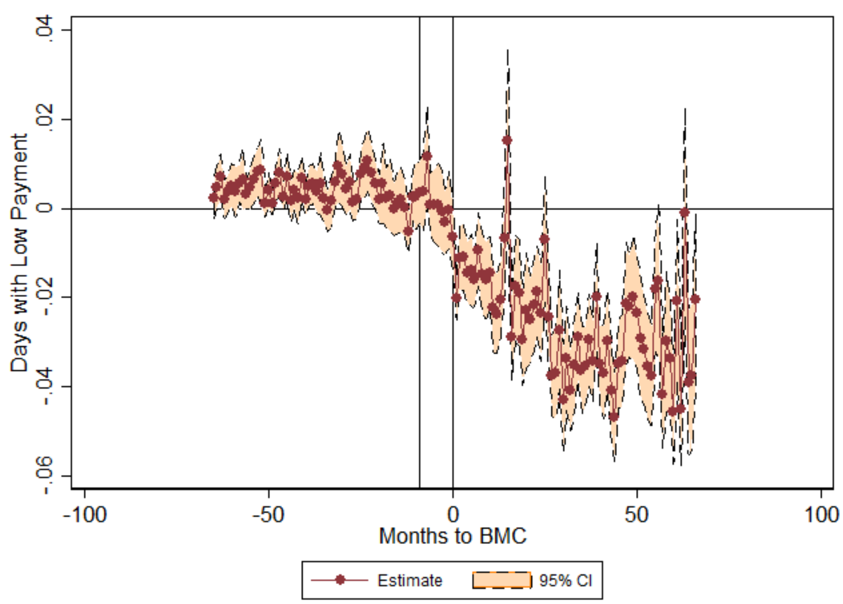

Figure 4: The effect of getting access to a BMC on the number of days with low payment penalties for bad quality. The x-axis plots the months before and after BMC access. Values are normalized by the mean of villages that never get BMC access in each period, so the "control" mean can be taken to be 0.

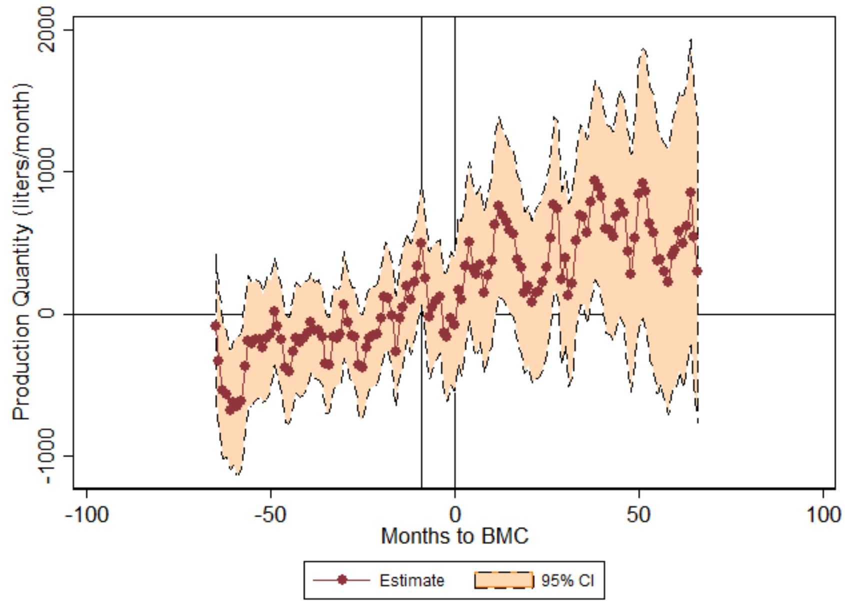

Figure 5: The effect of getting access to a BMC on quantity of milk production. The x-axis plots the months before and after BMC access. Values are normalized by the mean of villages that never get BMC access in each period, so the "control" mean can be taken to be 0.

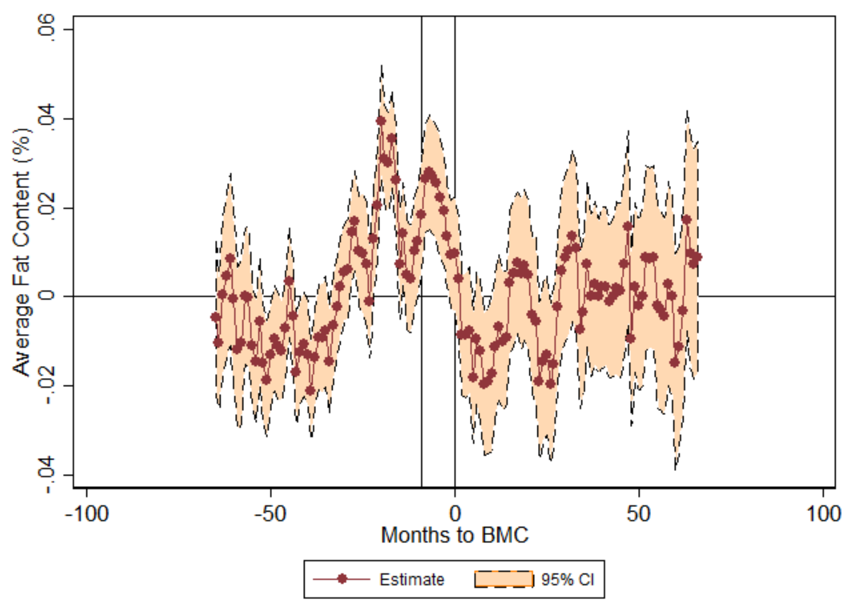

Figure 6: The effect of getting access to a BMC on the average at content. The x-axis plots the months before and after BMC access. Values are normalized by the mean of villages that never get BMC access in each period, so the "control" mean can be taken to be 0.

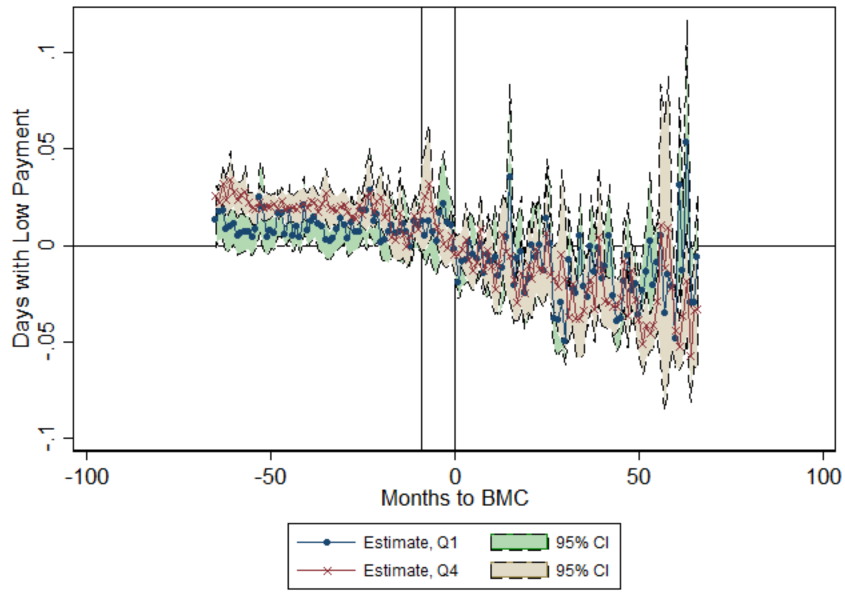

Figure 7: Effect of BMC Connection on Quantity: Top and Bottom Quartiles

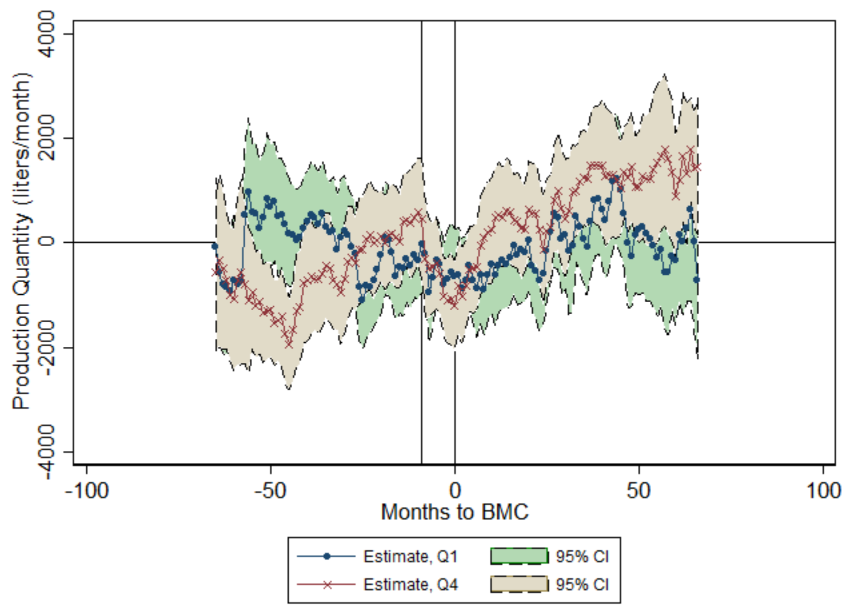

Figure 8: Effect of BMC Connection on Quantity: Top and Bottom Quartiles

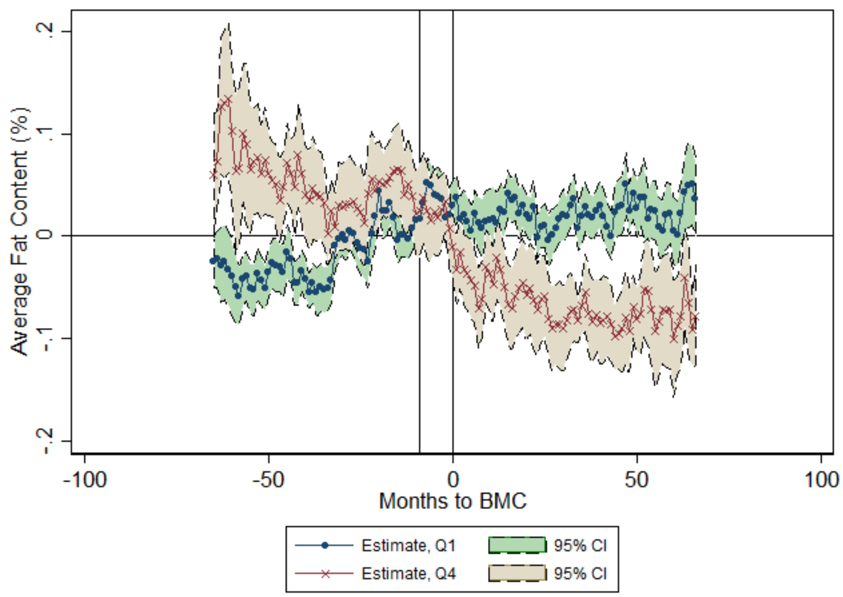

Figure 9: Effect of BMC Connection on Fat Content: Top and Bottom Quartiles

	With BMC	Connected to BMC	Direct Delivery
Earnings (Rs.)	233,309	127,370	124,288
	(134,549)	(71,854)	(81,492)
Ltrs./Month	22,421	12,369	12,156
	(11096.25)	(6220.912)	(7441.898)
Avg. Fat	4.100	4.095	4.115
	(0.152)	(0.173)	(0.177)
Avg. SNF	8.454	8.448	8.447
	(0.084)	(0.092)	(0.081)
Rs./Ltr.	10.34	10.32	10.31
	(2.49)	(2.48)	(2.48)
Days with Low	2.298	2.932	4.669
Quality (%)	(7.238)	(8.461)	(10.856)
Feed Purchased	33,484	14,388	17,683
(Kg/Year)	(33,867)	(16,083)	(20,778)
High Quality Feed	1,711	672	1,023
(Kg/Year)	(5,960)	(3,939)	(5,594)
Cost of Feed	260,000	110,179	136,967
(Rs./Year)	(285,381)	(132,642)	(175,939)
2011 Status (Number)	93	155	554
Matched to 2001 Census/2002 Livestock Census			
Population	1,517	831	814
	(1231)	(699)	(508)
Portion SC (%)	24.244	24.610	26.027
	(11.124)	(15.526)	(15.065)
Portion ST (%)	6.222	8.120	9.050
	(7.377)	(13.630)	(13.176)
Humber of HH	307	162	159
	(258.97)	(136.43)	(105.32)
Portion Owning Livestock	0.606	0.659	0.685
	(0.178)	(0.176)	(0.160)
Portion of Livestock in Dairy (%)	2.778	3.380	2.855
	(1.362)	(8.425)	(1.2621)
Milking Cows	156.89	93.61	98.32
	(111.96)	(51.15)	(56.96)
Portion Hybrid	0.846	0.821	0.739
	(0.200)	(0.210)	(0.245)
Number of Villages	93	154	450

Table 1: Village summary statistics; mean monthly values reported with standard deviations in parentheses.

	(1)	(2)	(3)	(4)	(5)	(6)
	Revenue	Ltrs./Month	Avg. Fat	Avg. SNF	Rs./Ltr.	Low Quality Days
Panel A: OLS						
BMC Access	78,654***	4,376***	-0.0761***	-0.0607***	2.026***	-0.00290
	(7,966)	(678.7)	(0.00641)	(0.00290)	(0.0535)	(0.00288)
Constant	126,812***	12,797***	4.121***	8.457***	10.03***	0.0409***
	(2,401)	(241.8)	(0.00383)	(0.00133)	(0.0182)	(0.00146)
R-squared	0.083	0.032	0.023	0.063	0.079	0.000
Panel B: Time FEs						
BMC Access	60,838***	5,092***	-0.0395***	-0.00360	0.0259**	-0.0371***
	(8,666)	(744.5)	(0.00690)	(0.00291)	(0.0113)	(0.00366)
Constant	129,272***	12,699***	4.116***	8.449***	10.31***	0.0456***
	(2,494)	(241.2)	(0.00384)	(0.00121)	(0.00488)	(0.00159)
R-squared	0.156	0.058	0.253	0.566	0.988	0.155
Panel C: Village and Time FEs (Diff in Diff)						
BMC Access	26,065***	1,233***	-0.0263***	-0.00830***	0.00856	-0.0328***
	(4,194)	(320.9)	(0.00722)	(0.00286)	(0.00991)	(0.00350)
Constant	98,310***	11,748***	4.169***	8.526***	8.369***	0.00577***
	(1,677)	(163.4)	(0.00474)	(0.00146)	(0.00556)	(0.00138)
R-squared	0.782	0.798	0.576	0.718	0.990	0.284
Observations	106,128	106,128	106,128	106,128	106,128	106,128
Panel D: Village and Time FEs (Diff in Diff) dropping BMCs						
BMC Access	8,523**	766.7**	-0.0519***	-0.0176***	-0.00315	-0.0356***
	(4,193)	(351.2)	(0.00908)	(0.00343)	(0.0118)	(0.00410)
Constant	90,662***	10,835***	4.173***	8.527***	8.370***	0.00598***
	(1,611)	(162.4)	(0.00508)	(0.00155)	(0.00586)	(0.00152)
R-squared	0.743	0.746	0.580	0.723	0.990	0.285
Observations	93,588	93,588	93,588	93,588	93,588	93,588

Table 2: Main results of the effect of BMC access on a number of outcomes. Panel A shows OLS regression results, Panel B includes time fixed effects, and Panel C includes both village and time fixed effects, corresponding to difference-in-differences. Panel D reproduces Panel C but excludes villages in which the BMC is actually placed, leaving only those that deliver to a BMC. Standard errors in parentheses, clustered at DCS level, *** p<0.01, ** p<0.05, * p<0.1

	(1) Revenue	(2) Ltrs./Month	(3) Avg. Fat	(4) Avg. SNF	(5) Rs./Ltr.	(6) Low Quality Days
Panel A: OLS						
BMC Access	69,459***	1,873***	-0.0948***	-0.0991***	3.133***	0.0200***
	(6,110)	(519.1)	(0.00711)	(0.00326)	(0.0559)	(0.00319)
Constant	136,007***	15,301***	4.139***	8.495***	8.927***	0.0180***
	(4,614)	(521.5)	(0.00711)	(0.00291)	(0.0459)	(0.00228)
R-squared	0.094	0.009	0.081	0.305	0.394	0.015
Panel B: Time FEs						
BMC Access	35,582***	3,393***	-0.0457***	-0.00595	0.00646	-0.0227***
	(10,118)	(981.6)	(0.0102)	(0.00422)	(0.0204)	(0.00748)
Constant	151,171***	14,620***	4.117***	8.453***	10.33***	0.0371***
	(5,969)	(577.5)	(0.00794)	(0.00294)	(0.0127)	(0.00443)
R-squared	0.159	0.034	0.285	0.595	0.992	0.134
Panel C: Village and Time FEs (Diff in Diff)						
BMC Access	6,588*	678.6*	-0.0236***	0.00456	0.00117	-0.0182***
	(3,629)	(353.2)	(0.00818)	(0.00328)	(0.0151)	(0.00573)
Constant	113,945***	13,613***	4.155***	8.531***	8.369***	0.00554***
	(3,531)	(325.0)	(0.00873)	(0.00273)	(0.00969)	(0.00198)
R-squared	0.816	0.841	0.561	0.742	0.994	0.245
Observations	32,736	32,736	32,736	32,736	32,736	32,736
Panel D: Village and Time FEs (Diff in Diff) dropping BMCs						
BMC Access	2,563	355.6	-0.0434***	-0.000287	0.00267	-0.0252***
	(3,666)	(383.3)	(0.0103)	(0.00406)	(0.0227)	(0.00866)
Constant	88,712***	10,598***	4.167***	8.534***	8.375***	0.00632**
	(3,329)	(333.3)	(0.0117)	(0.00352)	(0.0115)	(0.00263)
R-squared	0.745	0.728	0.577	0.763	0.993	0.248
Observations	20,328	20,328	20,328	20,328	20,328	20,328

Table 3: Results of the effect of BMC access on a number of outcomes restricting to only villages that ever receive BMC access. Panel A shows OLS regression results, Panel B includes time fixed effects, and Panel C includes both village and time fixed effects, corresponding to difference-in-differences. Panel D reproduces Panel C but excludes villages in which the BMC is actually placed, leaving only those that deliver to a BMC. Standard errors in parentheses, clustered at DCS level, *** p<0.01, ** p<0.05, * p<0.1

	(1) Milking Cows	(2) Cows per HH	(3) Portion Cross-Breed	(4) Total Livestock
Year 2007	10.62***	-0.0175	0.0639***	-4.343
	(1.874)	(0.0166)	(0.00608)	(3.547)
Treated	27.05***	-0.0447	0.0332*	44.35***
	(6.752)	(0.0299)	(0.0183)	(15.40)
2007 X Treat	-7.784	0.00272	-0.0265*	-23.85**
	(5.176)	(0.0319)	(0.0159)	(10.36)
Constant	89.86***	0.728***	0.744***	237.5***
	(1.905)	(0.0152)	(0.00783)	(4.618)
Observations	2,410	2,410	2,405	2,410
R-squared	0.019	0.002	0.019	0.008

Table 4: Difference-in-difference estimation of the effect of getting access to a BMC between the 2002 and 2007 livestock censuses. Robust standard errors clustered at the DCS level in parentheses, *** p<0.01, ** p<0.05, * p<0.1

	(1) Revenue	(2) Ltrs./Month	(3) Avg. Fat	(4) Avg. SNF	(5) Rs./Ltr.	(6) Low Quality Days
BMC Access	14,310*	61.98	0.0371***	0.00539	0.0323*	-0.0288***
	(8,659)	(634.6)	(0.0107)	(0.00477)	(0.0194)	(0.00656)
BMC×Q2	17,536	1,241	-0.0401***	-0.00704	-0.0323	0.00186
	(12,044)	(852.6)	(0.0135)	(0.00621)	(0.0226)	(0.00758)
BMC×Q3	18,597	1,626*	-0.0575***	-0.00503	-0.00992	-0.00706
	(11,902)	(860.9)	(0.0147)	(0.00680)	(0.0257)	(0.00850)
BMC×Q4	9,176	1,829**	-0.167***	-0.0462***	-0.0519**	-0.0129*
	(10,484)	(777.1)	(0.0181)	(0.00721)	(0.0227)	(0.00678)
Constant	98,310***	11,748***	4.169***	8.526***	8.369***	0.00577***
	(1,671)	(162.8)	(0.00461)	(0.00143)	(0.00555)	(0.00138)
DCS FEs	Yes	Yes	Yes	Yes	Yes	Yes
Month FEs	Yes	Yes	Yes	Yes	Yes	Yes
Observations	106,128	106,128	106,128	106,128	106,128	106,128
R-squared	0.783	0.798	0.584	0.721	0.990	0.284

Table 5: Difference-in-difference estimation of the effect of BMC access on a number of outcomes broken down by quartile of fat quality in 2002–2007. Q2 = 25th–50th percentile; Q3 = 50–75; Q4 = 75–100; Q1 (0–25) omitted. Standard errors in parentheses, clustered at DCS level, *** p<0.01, ** p<0.05, * p<0.1

	(1) Revenue	(2) Ltrs./Month	(3) Avg. Fat	(4) Avg. SNF	(5) Rs./Ltr.	(6) Low Quality Days
connected	7,270*	743.7**	-0.0550***	-0.0161***	0.000734	-0.0373***
	(4,289)	(361.7)	(0.00895)	(0.00346)	(0.0122)	(0.00430)
con. X Ag. index	-3,639***	-302.9***	0.00266	-1.02e-05	0.00590	0.000607
	(1,259)	(96.95)	(0.00354)	(0.00146)	(0.00655)	(0.00188)
Constant	92,672***	11,075***	4.166***	8.528***	8.369***	0.00612***
	(1,767)	(177.3)	(0.00543)	(0.00166)	(0.00638)	(0.00164)
DCS FEs	Yes	Yes	Yes	Yes	Yes	Yes
Month FEs	Yes	Yes	Yes	Yes	Yes	Yes
Observations	79,200	79,200	79,200	79,200	79,200	79,200
R-squared	0.748	0.750	0.585	0.728	0.990	0.285

Table 6: Difference-in-difference estimation of the effect of BMC access on a number of outcomes interacted with agricultural capacity. Agricultural capacity index based on principal components analysis using 45 measures of agricultural capital from 2002 village agricultural census. Standard errors in parentheses, clustered at DCS level, *** p<0.01, ** p<0.05, * p<0.1

	DD	Simulation		
Outcome	Estimate	Mean Estimate	Std. Error	t-stat
Panel A: All villages				
Earnings	26,065	18,755.66	430.2215	16.99
Ltrs./Month	1,233	740.2372	36.70669	13.42
Avg. Fat	-0.0263	-.0115863	.0010627	-13.85
Avg. SNF	-0.00830	-.0076142	.000468	-1.47
Rs./Ltr.	0.00856	.0114061	.0019313	-1.47
Low Quality Days	-0.0328	-.0199521	.0007042	-18.24
Kg Feed Purchased	1.226	1.238	.4266	-0.03
Kg Good Feed	0.02739	.1031	.1343	-0.56
Panel B: Excluding villages with BMC unit				
Earnings	8,523	5654.3	379.64	7.56
Ltrs./Month	766.7	456.4	35.520	8.74
Avg. Fat	-0.0519	-0.0249	0.00130	-20.77
Avg. SNF	-0.0176	-0.0126	0.00053	-9.43
Rs./Ltr.	-0.00315	0.00614	.00254	-3.66
Low Quality Days	-0.0356	-0.02186	.00095	-14.46
Kg Feed Purchased	-0.8553	-0.0986	0.3840	-1.97
Kg Good Feed	-0.1731	-0.00310	0.0895	-1.90

Table 7: Simulation of difference-in-difference parameters assigning random BMC connection dates to villages that gain BMC access other the period of study. Panel A includes all villages, while Panel B excludes village sin which the BMC is actually built. Bootstrapped means, standard errors, and t-stats based on 100 simulations assigning random networked dates to connected villages.