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Impact of Third-Party Enforcement of Contracts in Agricultural Markets – A Field Experiment in Vietnam

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Abstract: We study the effect of alleviating information asymmetry regarding product quality that is widespread in developing-country agricultural markets. Opportunistic buyers may underreport quality levels back to farmers to reduce the price they have to pay. In response, farmers may curb investment, negatively affecting farm productivity. In an experiment, we entitle randomly selected smallholder dairy farmers in Vietnam to independently verify milk testing results. Treatment farmers use 13 percent more inputs and also increase their output. We show that the buying company had initially not underreported product quality, which is why third-party monitoring led to a Pareto improvement in the supply chain.

JEL Codes: C93, D86, L14, O13, Q12, Q13

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Introduction

Since Akerlof's (1970) seminal paper on the market for used automobiles, the economics of information has received considerable attention. Models of moral hazard, adverse selection and signaling have been applied to study various domains of economic interaction, as diverse as markets for labor, insurance, credit, real estate and even art (Ross 1973; Spence 1973; Rothschild and Stiglitz 1976; Stiglitz and Weiss 1981; Grossmann 1981; Throsby 1994).

However, information asymmetry regarding product attributes is not only important in transactions with metaphorical fruit such as lemons, but is also critical in markets for actual agricultural produce, for example if special technology is required to assess non-visible quality attributes, such as nutrient content or bacterial contamination, and costs of analysis and measurement are prohibitively high for the selling farmer. Hence, in many agricultural markets in which supply chain relations are facilitated through production contracts, the principal (e.g. buying processor or wholesaler) has more information about output quality than the agent (selling farmer). This information asymmetry gives scope for opportunistic behavior on the side of the buyer who can accrue information rents from reporting lower than actual quality levels, thus downgrading the price paid to the seller. Rational sellers forming the belief that the buyer cheats will factor in the buyer's opportunistic behavior, lowering their expectations about product price. Thus, weak contract enforcement can induce sellers to underinvest (Gow, Streeter and Swinnen 2000; Vukina and Leegomonchai 2006; Cungu et al. 2008). Underinvestment, i.e. suboptimal short-term input use or downsizing of investment in long-term productive assets, leads to lower output, negatively affecting not only the agent's outcome but also increasing the principal's per-unit transaction costs from procurement (Saenger et al. 2013).

To overcome information asymmetry in the supply chain, more transparency, e.g. through third-party quality measurement and verification, is one possible solution (Balbach 1998; Sykuta and Cook 2001; Young and Hobbs 2002). In a laboratory experiment, Wu and Roe (2007) have shown that third-party contract enforcement can be one way to successfully mitigate underinvestment and enhance social efficiency. But as the laboratory systematically differs from natural environments, external validity of this type of studies may be limited (Levitt and List 2007). Over the past decade, randomized control trials (RCTs), in which subjects take decisions in their natural environment, have been used extensively. Only recently, RCTs have been carried out in the field of agriculture (Duflo, Kremer and Robinson 2008; 2011; Ashraf, Giné and Karlan 2009).

We contribute to the literature on RCTs in agriculture and information asymmetry in contracts through a randomized field experiment, using the example of the fast growing Vietnamese dairy industry in which third-party enforcement is missing. The industry is characterized by a great number of small-scale dairy farmers who are contracted by a large milk processing company. This is a typical situation for emerging markets for high-value agricultural products in developing countries (Reardon et al. 2009; Rao, Brümmer and Qaim 2012; Bellemare 2012). In this field experiment, the contract of a randomly chosen subsample of farmers, the treatment group, is altered such that it becomes third-party-enforced; previously unobservable quality attributes are now measured and verified by an independent and certified laboratory. Control group farmers continue to produce under the initial contract. By comparing the outcomes of both groups we address the following research questions: (i) Does contract enforcement through third-party verification of quality attributes lead to increased production intensity and higher milk output, and (ii) does this intervention increase the welfare of the smallholder milk producers?

For the field experiment we collaborated with a private dairy company that provided access to weekly farm-level output data. These data are complemented with data from own household surveys. We find that our intervention leads to higher input use and increased dairy output. There is also a positive treatment effect with respect to household consumption expenditures for a specific subgroup of the sample. We are able to attribute observed differences in output to a behavioral change of farmers rather than the reporting strategy of the buying company. Hence, in this specific case the buying company did not behave opportunistically, but failed to signal its fair type to farmers. Third-party enforcement with incomplete contracts can lead to Pareto improvement, as smallholders and buying companies both benefit from increased farm productivity.

The Vietnamese Dairy Industry

In Vietnam, much like in other countries of Asia, milk is becoming an increasingly popular food item leading to high growth rates in the dairy sector. For example, only two decades ago the consumption levels of milk and dairy products were almost nil due to cultural practices and low incomes. But with increasing income, urbanization tendencies and the spread of Western lifestyle the demand for milk has increased tremendously (Saenger et al. 2013). Today's per-capita consumption of milk in Vietnam has reached 15 kg per annum, which is about 8 percent of the amount being consumed in the US or Europe. Currently, the Vietnamese dairy sector is dominated by local processing companies importing large quantities of powdered milk from overseas to satisfy domestic demand. However, more and more milk is produced domestically, especially by small-scale farmers. Fresh milk production in Vietnam has tripled between 2003 and 2009, but it still meets only one-fifth of domestic consumption (USDA 2011).

The leader in the dynamic dairy industry—and the cooperation partner in this field experiment—is the formerly state-owned company *Vinamilk*. Vinamilk collects the major share of milk produced in Vietnam and is also a main importer of powdered milk. Currently, the company has contracted more than 5,000 small-scale dairy producers, most of them located around Vietnam's largest city and commercial capital Ho-Chi-Minh City (HCMC).

Supply-chain Architecture and the Standard Contract

In Vietnam, milk is produced mainly on specialized small-scale farms. Crossbreed dairy cows are held in stables all year round. The major input is fodder; rations usually consist of forage produced on farms, complemented with purchased fodder, primarily concentrate. Farmers usually sell the entire milk output to one dairy processor. Alternative sales options are very limited. Informal channels exist but can absorb only small quantities due to low demand for highly perishable raw milk in rural areas. Hence, small-scale dairy farmers, who have undertaken relationship-specific investment, have little bargaining power vis-à-vis large monopsonistic dairy processors.

The raw milk is channeled through milk collection centers (MCC) located in the vicinity of the dairy farms. An average MCC is supplied by about 100 farmers and is operated by a private entrepreneur working on commission for the dairy processor, in our case Vinamilk. Each MCC carries out the following tasks: collection and handling of the milk twice a day, sampling of the milk, initial testing of quality (through staff deployed by the dairy processor) as well as daily transport of raw milk to Vinamilk's dairies in urban centers. The MCCs also process the weekly payments to farmers.

The production contract between Vinamilk and dairy farmers is a country-wide standardized, written agreement, determining how much milk of what quality is purchased at which price. Until recently, it was quite costly to assess milk quality for each smallholder farmer. Today, cheaper quality testing devices allow dairy companies to assess quality individually for each farmer, which is a key requirement for traceability, quality management and incentive pay. The output price for milk p received by farmers is a function of milk quality θ:

(1) $$p = f(\theta) .$$

Quality is a composite measure of several parameters, most importantly milk fat content and total solid, which depend on input use x and a random shock s (e.g. animal disease, changing fodder quality):

(2) $$\theta = f(x, s) .$$

On a daily basis, Vinamilk staff deployed at the MCC takes milk samples individually for each farmer; one sample per week is randomly selected and analyzed in the dairy plant employing sophisticated laboratory methods. Producers have unique identification numbers and are paid individually according to their own output (q and θ). The base price for top-quality milk is subject to harsh deductions if one or more of the quality parameters fall short of the requirements set by the company. One-tenth of a gram of milk fat below the threshold—a deviation far too small to be visually detected even by experienced farmers—can trigger financial penalties. As milk analyses are carried out in the company's own laboratory and cannot be observed by farmers, milk quality remains private information of the dairy company. Currently, smallholders cannot overcome the asymmetry of information regarding milk quality by systematically cross-checking the results provided by the processor, because individual milk testing is prohibitively costly, and collective action fails.

A Simple Model of Underinvestment

Building on a model described by Sandmo (1971), we formally derive how the asymmetric information on quality attributes leads to lower input use and suboptimal output compared to a situation of symmetric information. It is assumed that farmers maximize expected utility of profits. The utility function is a well behaved, i.e. concave, continuous and differentiable function of dairy farming profits.

The farmer's cost function is defined as

(3) $$T(q) = V(q) + F,$$

where q is output, $V(q)$ is the variable cost function and F represents the fixed cost. Further we assume that the cost function has the following properties:

(4) $$V(0) = 0, \quad V'(q) > 0.$$

In a contract with incomplete but symmetric information the profit function can be defined as

(5) $$\pi(q) = pq - [V(q) + F],$$

where the product of p and q is the total revenue (TR). Farmers maximize profits where marginal revenue (MR) equals marginal cost (MC)

(6) $$MR = MC,$$

where

$$MR = \frac{\partial TR}{\partial q} = p \tag{7}$$

$$MC = \frac{\partial T}{\partial q} = T'(q). \tag{8}$$

In this situation, θ is known to both participants in the transaction. We take this as the benchmark and analyze how optimal input use changes when the buying company has private information about θ. Exploiting its informational advantage, a rational dairy processor may report a lower level of quality to the farmer than the quality actually assessed in the laboratory. According to (1), withholding private information negatively affects the output price, while increasing the residual income for the dairy processor. When there is asymmetric information, a rational dairy producer i will form a specific belief to what degree the processor underreports. This is represented by

$$p_i^{reported} = \gamma_i p_i^{true} + \lambda_i, \tag{9}$$

where the reported milk price $p_i^{reported}$ is the actual price p_i^{true} based on the milk quality assessed in the laboratory, corrected by multiplicative and additive shift factors γ_i and λ_i. If $\gamma_i < 1$ then p_i^{true} is reduced proportionally; if $\lambda_i < 0$ a lump sum is deducted at any given level of p_i^{true}. For those farmer who believe that Vinamilk cheats we follow that

$$p_i^{reported} < p_i^{true}. \tag{10}$$

If farmers maximize expected utility by setting marginal cost equal to marginal revenue, the lower expected product price translates into lower marginal revenue. Hence, the optimal output level q decreases given that farmers are price takers for inputs, and input prices remain unchanged.

Third-party contract enforcement would mitigate the negative effect on the expected output price level, because formerly unobservable quality attributes become verifiable for farmers, forcing the dairy company to report the real output quality and thus output price. In terms of the shift parameters, this implies that γ_i takes the value 1, while λ_i takes the value 0. If plugged into the profit function, the higher expected output price would according to (6) lead to more input use and higher output than in the current situation with information asymmetry.

How can farmers practically respond to higher expected output prices? Generally, they can raise the output of milk fat and total solid—the value defining parts of the raw milk—in three ways: (a) Increase the quality (milk composition) while keeping the milk quantity constant, (b) keep the quality constant while increasing the quantity, or (c) simultaneously increase quality and quantity. At the farm level, the goal of increasing the absolute quantity of milk fat and total solid can be achieved in different ways. For example, in the short run, farmers can increase the amount of purchased fodder (e.g. concentrate) to make the ration more nutritious. All other inputs are de-facto fixed in the short term. The supply of forage produced on the farm can only be increased in the medium or long run, as additional land would have to be acquired. Likewise, total herd output could be raised by increasing the herd size through buying cattle on the market or breeding. In the long run, selective breeding may also improve the herd's overall genetic potential for milk production.

Experimental Design and Implementation

After having outlined the theoretical framework of third-party contract enforcement, we now describe the design and practical implementation of the intervention in which randomly selected dairy producers were provided with the opportunity to verify milk testing results provided by Vinamilk.

Every treatment farmer received three non-transferable vouchers, each valid for one independent analysis of milk quality (milk fat and total solid). Vouchers were meant to be executed whenever eligible farmers challenged the testing results reported by Vinamilk. Providing farmers with third-party quality verification implied setting up complex transport and testing logistics. For each milk sample obtained at the MCC under the original contract (hereafter A-sample), an additional identical sample (hereafter B-sample) had to be taken for each treatment farmer. The B-sample was sent to an independent and certified laboratory in HCMC where it was stored. If a farmer executed a voucher, the B-sample was analyzed by the third-party laboratory and the testing results were reported by mail to the farmer. This allowed the farmer to compare if the results based on the A-sample reported by Vinamilk are identical to the results of the corresponding B-sample provided by the independent laboratory.

While Vinamilk knew the identity of the treatment farmers, the actual execution of vouchers could not be observed, i.e. the dairy company did not know when an individual farmer in the treatment group executed her voucher. Hence, there was a constant threat to the company that any of the farmers in the treatment group could in any given week verify their testing results, effectively eliminating the possibility that Vinamilk behaves opportunistically. Compared to validating the results of every sample analyzed by Vinamilk, the voucher mechanism enabled us to implement a system to systematically overcome the information asymmetry on milk quality attributes at relatively low cost. All outlays arising from setting up a parallel testing infrastructure for the B-samples and milk analyses were borne by the project, ruling out that farmers would not request independent milk testing for cost reasons.

The logistics of the voucher treatment are complex. Thus, it was especially important that both the treatment farmers delivering milk and the Vinamilk staff taking the B-samples thoroughly understood the procedure. During a compulsory half-day workshop, treatment farmers were informed about the independent milk testing and learned how to use the vouchers. Every treatment farmer received written instructions supplementing the information presented during the workshop and was provided with a phone number of trained field staff.

To assure that farmers regarded the third-party testing as credible and independent, we had identified a certified third-party laboratory which both farmers and Vinamilk explicitly agreed on. Further, to ensure the comparability of the A- and B-sample, we calibrated the third-party laboratory and Vinamilk's in-house laboratory using imported reference milk. By employing the same cooling technology we also assured that during transport and storage the A- and B-samples were kept in identical environments with regard to factors potentially affecting milk quality such as temperature or exposure to sunlight.

To avoid contamination, i.e. that control group farmers get access to the third-party milk testing and thus effectively become treated, the emergence of a secondary market for vouchers had to be prevented. We handed out personalized vouchers tagged with a unique identification number. Vouchers passed on to other farmers (also outside the treatment group) automatically became invalid. A scenario in which control farmers sell their milk through treatment farmers to benefit indirectly from the independent quality verification and resulting higher expected milk prices is possible but very unlikely. If a treatment farmer accepts milk from a control farmer (or an unknown source) she takes the risk of mixing milk of unknown quality with her own milk, potentially leading to lower average quality and financial loss.

If take-up is voluntary in field experiments, individuals who are assigned to the treatment group may refuse to get treated. This may lead to low compliance rates which can be a challenge for the subsequent impact analysis. Cole et al. (2012) found that adoption rates for innovative crop insurances in India were as low as 5 to 10 percent despite high potential benefits. Hill and Viceisza (2011) overcame the problem of low take-up in a framed field experiment by imposing mandatory insurance. Our intervention is unique with respect to compliance, as for the voucher treatment to be effective a high compliance, i.e. high voucher execution rate is not a necessary condition. The specific design of the third-party contract enforcement does not depend on an individual farmer's decision to execute a voucher to build a direct threat to Vinamilk. Instead, it is sufficient if farmer A believes that farmers B or C may request an analysis. This believe—from farmer A's point of view—would be an indirect but sufficiently powerful threat to the dairy processor to be monitored, ruling out underreporting. Ultimately, this implies that all farmers in the treatment group can be regarded as treated, regardless of their actual voucher execution.

It should be stressed that when designing the voucher treatment, we were interested in isolating the general effect of third-party contract enforcement, rather than evaluating a particular way of providing farmers with independent testing of quality attributes. Like in Thomas et al. (2003), who investigated the impact of an iron-supplementation program, our voucher-based approach is too costly to be easily scaled up. In a non-experimental setting, complete outsourcing of milk testing to an independent laboratory would be more efficient than establishing a parallel structure for B-sample analyses.

Study Area, Sample and Randomization

Almost 70 percent of the domestically produced milk in Vietnam stems from the region around HCMC. The study area is located in Long An and Tien Giang, two provinces south of

HCMC where Vinamilk has contracted 402 dairy farmers. The milk supply is channeled through four MCCs.

At MCC level, differences with respect to average dairy output (quantity, quality) can be observed (Table A1 in the Appendix). Three out of the four collection centers (MCCs B, C and D) are spatially clustered, so it is unlikely that agro-ecological factors cause the performance differential. As farmers can choose freely which MCC to supply their milk to, we suppose that selection based on unobservables may cause the farmer population of one MCC to systematically differ from farmers at other MCCs. For example, dairy producers do not only choose an MCC based on the distance to their farm but also based on soft factors such as trust towards the management of the MCC. Beside the three clustered MCCs, there is also one more isolated collection center (MCC A) where farmers do not have the option to choose between different Vinamilk MCCs. However, a competitor of Vinamilk sources raw milk in the area of MCC A. Hence, farmers could entirely switch to the competing dairy processor, if they were unhappy with Vinamilk, the contract or the collection center management. We reckon that farmers who deliver to Vinamilk despite having an alternative may be systematically different from Vinamilk farmers without such an outside option. Such possible differences are accounted for in our analysis through MCC dummies.

Given the limited number of MCCs and significant mean differences in observable characteristics, a randomization of treatment status over MCCs—even though easier to manage—might have confounded our results. Hence, we randomized over the entire population of 402 dairy farmers. In May 2009, all farmers attended a public lottery in which 102 farmers were randomly assigned to the treatment group. Another 100 farmers were randomly assigned to the control group, continuing to produce under the original, incomplete contract without enforcement. Farmers were informed that due to a budget constraint and for the sake of a clear evaluation of the *project* (the term experiment was avoided when communicating with farmers due to its negative connotation) only a limited number of slots would be available in the treatment group. Owing to the complexity of the treatment design, the implementation had to be delayed several times. The intervention eventually started in May 2010 when the first batch of B-samples was obtained. It was continued for a period of 12 months.

Data

We collected detailed information for all farmers participating in the experiment. Through two rounds of structured household surveys we generated a data set comprising socio-economic details on dairy production, income from agricultural and non-agricultural activities, household expenditure and assets owned. Additionally, questions measuring social capital, trust, time and risk preferences were included in the questionnaire. The first round of interviews, the baseline survey, took place in May 2009 before the experiment started. In May/June 2011, all farmers were revisited for the follow-up survey when the experiment was completed.

The household data were complemented with farm-level output data for each producer in the sample provided by the processing company. Vinamilk provided these data for the period from May 2008 to May 2011, covering 24 months prior to the intervention and the time period of the intervention. On the one hand, it can be assumed that these data are of higher quality than self-reported recall data on output obtained through household surveys, as this weekly reported information—disaggregated by milk quantity and three quality parameters—is the basis for farmers' payment. On the other hand, the dairy company may have an incentive to strategically release information, i.e. provide manipulated data to mask underreporting of milk quality and price in case farmers were cheated before the intervention. We carefully address this issue in the discussion section when we assess the internal validity of the results.

Identification Strategy and Econometric Estimation

The impact of third-party quality verification is assessed in three dimensions: (a) input use in dairy production, (b) output generation in dairy production, and (c) welfare of the farming household.

While (a) is measured by the amount of purchased fodder (concentrate) used per cow and day reported by farmers, (b) is captured by three variables, the total amount of milk fat and total solid produced during the twelve months when the experiment was ongoing and revenues from dairy farming for the same time period. Data on these output variables are provided by the dairy company. For (c) we use total annual household consumption expenditures on food (own produced food items were valued at the market price), other consumer goods and durables obtained through the household survey.

We seek to identify two types of treatment effects. First, the average treatment effect on the treated (ATT) which is estimated according to

$$\text{ATT} = \mathrm{E}(y_1 - y_0 | v = 1), \tag{11}$$

where ATT is the difference of y_1, the average outcome of the treated, and y_0, the counterfactual outcome of the untreated, conditioned on the treatment status $v = 1$, which means being treated. Given the random assignment of *v*, the control group constitutes an adequate counterfactual of the treatment group.

Second, we are interested in the ATT conditional on specific baseline covariates *x*. To estimate this heterogeneous treatment effect, we condition ATT on *x* according to

$$\text{ATT}(x) = \mathrm{E}(y_1 - y_0 | x, v = 1). \quad (12)$$

To estimate ATT and ATT(*x*) econometrically, we specify OLS models

$$y = \propto + \beta v + \gamma x + \delta v x + \varepsilon, \quad (13)$$

where the dependent variable *y* is one of the outcome variables measured at the end of the experiment.

For each outcome variable we use three distinct specifications. In the first specification, which aims at identifying ATT, we only include the treatment dummy *v*. To estimate ATT(*x*), the model is augmented by adding a vector of variables indicating baseline characteristics at time t_0. This allows for testing whether the relationship between baseline characteristics and outcome variables is different conditional on treatment status. One specification for ATT(*x*) includes the covariate *baseline trust*, which is a dummy variable taking the value 1 if farmers agreed with the statement "Vinamilk is a trustworthy business partner" and 0 otherwise.[1] We suppose that initial trust levels may affect the impact intensity of the voucher. For example, farmers already trustful in the baseline may be less affected by an intervention that aims at ruling out potential opportunistic behavior from Vinamilk. The other specification for ATT(*x*) includes dummies indicating the farmers' delivery to milk collection centers (MCC *B*, *MCC C* and *MCC D; MCC A* was chosen as benchmark). These dummies capture the effect of unobserved characteristics that make farmers select a specific MCC.

Randomization

Prior to the impact analysis we verified that treatment and control groups are similar statistically with respect to the large number of observables available from the baseline survey, including the outcome variables (Table 1). The only statistically significant (at 10 percent error rate) differences are for the variables capturing road infrastructure and time preferences[2], indicating that treatment farmers are located slightly closer to paved roads and are less patient than their peers in the control group. Given the random assignment of the treatment status, the observed differences are not systematic, e.g. better infrastructure did not make a household more likely to be assigned to the treatment group.[3]

Attrition

Between the baseline survey in May 2009 and the implementation of the treatment in May 2010 a number of milk farmers ceased production or switched from Vinamilk to the competing dairy processor. The number of households in the treatment and control group decreased from 100 and 102 to 94 and 91, respectively. Those producers dropping out of the sample have significantly (at 10 percent level) smaller baseline heard sizes, are less productive and have lower revenues from milk. The attrition rate is balanced between treatment and control groups.

Compliance

As pointed out above the intervention did not require high compliance rates (primary enforcement), i.e. voucher being executed by a large number or farmers, in order to be effective. However, from treatment farmers' perspective a minimum compliance in the treatment group is (psychologically) desirable to credibly build up the threat to the dairy processor of being effectively monitored.

We find that only seven farmers (out of 93) have actually requested independent verification of milk testing results despite it is easy, cheap and safe. It is worthwhile mentioning that those farmers who have executed vouchers on average had larger herd sizes with more productive dairy cows. A possible explanation could be that these larger farmers had a higher interest in verifying the milk testing results, because even little underreporting of quality by the processor would lead to substantial losses due to larger quantities involved. We have systematically evaluated the voucher treatment in the follow-up survey to identify reasons for low take-up rates; selected results are presented in figure 1. The majority of farmers who have not executed vouchers agreed that third-party quality assessment was useful, easy to request, and that the independent laboratory is trustworthy. Some 50 percent of all treated farmers stated to not have executed a voucher because they were satisfied with the milk quality results provided by Vinamilk. A significant proportion indicated that they would feel uneasy to secretly check up on Vinamilk.

It should be stressed again that due to the fact that indirect threat is sufficient for the voucher treatment to be effective the low execution rate of vouchers does not pose a problem to the subsequent impact analysis; hence, all individuals assigned to the treatment group (expect for drop-outs) can be regarded as treated.

Estimation Results

At first we investigate how treatment affects self-reported fodder usage (concentrate fed per cow and day in kg). Results are presented in table 2, columns (1) to (3). We find a highly significant positive treatment effect, which is robust across specifications. Farmers in the treatment group on average fed their cows 13 percent more purchased concentrate than their peers in the control group. The coefficients of the additional control variables, baseline trust towards the dairy company and the affiliation to a specific collection center, are mostly insignificant. As we do not find a significant effect for the interaction terms, it seems that the level and significance of the treatment effect is homogenous with respect to the treatment group; the effect of the intervention does not differ for farmers who were trustful towards Vinamilk in the baseline or those affiliated to MCC B, C or D.

Beside the amount of purchased concentrate, which makes up the largest share of total input costs, we also analyzed the treatment effect with respect to labor, veterinary services and artificial insemination. However, for these inputs we did not find significant differences between treatment and control groups.

The regression results for dairy output are also presented in table 2. Without controlling for other covariates, the ATT for absolute milk fat and solid produced is positive but insignificant. But once we control for baseline trust and collection center affiliation, we find significantly positive treatment effects for both output measures (columns 5 and 9). Apparently, the increased production intensity (higher use of concentrate) has translated into higher output quantity.

Looking at quality, the relative composition of milk remained constant, as a comparison of fat content and total solid per kg of milk before and after treatment shows. We also ran regressions using average fat and solid content per kg of milk as dependent variables, without finding significant treatment effects (results not presented here). Above we proposed three ways how farm-level dairy output could be increased. These results suggest that farmers mainly realized the second option, namely increasing milk quantity (in kg) while keeping quality (milk fat and total solid content per kg) constant. A possible explanation for the observed increase in milk quantity instead of quality can be found in the physiology of dairy cows. To produce large quantities of milk, the dairy cow requires a nutritious and balanced fodder ration, especially with respect to protein and energy. If the ration is unbalanced, for example if it contains too little protein relative to energy, milk yield will drop (Roth, Schwarz and Stangl 2011). The concentrate purchased by farmers in Vietnam is rich in protein. It is therefore plausible that an increase in concentrate use, as observed among treated farmers, contributes to relaxing a protein constraint in the fodder ration.

Higher output leads to more revenues from dairy production, as shown in table 3. The positive and significant (at 10 percent error rate) coefficient of the treatment dummy in column (3), in which baseline characteristics are controlled for, points to a heterogeneous treatment effect, especially with respect to milk collection center affiliation. As milk quality was not affected by the treatment (and thus the average price received remained unchanged), the increment in revenue can entirely be attributed to increased production quantity.

Finally, we look into the intervention's impact on total household consumption expenditures, a commonly used measure of living standard and welfare. We do not find a significant ATT (Table 3, columns 4 to 6). This is not very surprising, because households tend to adjust their consumption expenditures only slowly, that is, an increase in revenue or profit may not immediately be reflected in changed consumption behavior. To measure impacts on consumption expenditure, the duration of the experiment may have simply been too short.

But we observe a welfare increase for those treatment farmers that were more trustful towards the company before the experiment started. This can be inferred from the positive and significant coefficient of the Vinamilk Trust*Voucher interaction term in column (5) of table 3. Interestingly, neither the trust variable itself nor the interaction term was significant in any of the previous models. The results here appear counterintuitive on first sight, as one would expect stronger impacts for farmers that do not trust the company much. Yet, it should be noted that our trust variable may capture trust towards the company in different dimensions, also beyond quality reporting. The statement “Vinamilk is a trustworthy business partner” that farmers were asked to rate may also involve expectations regarding the timing of payment or beliefs about the company’s long-term commitment to the contractual relationship. Hence, farmers with lower level of trust may perceive the relationship with Vinamilk as riskier, and thus act more cautiously, for instance by saving additional revenues instead of spending more on consumption. It is possible that their consumption behavior (welfare) would have changed if the experiment had continued for a longer period of time. Against this background it is also plausible to observe positive welfare effects for more trustful farmers in the short run.

Discussion

Our findings confirm the hypothesis that third-party enforcement of contracts mitigates underinvestment and hence are in line with Wu and Roe’s (2007) results from laboratory experiments with college students. Furthermore, our study shows under real-world conditions that higher input levels observed under the enforced contract actually translate into higher output, a result which would be impossible to obtain in the laboratory. The findings also suggest that specific subgroups are affected to varying degrees by the intervention, especially those delivering to particular collection centers. Given data limitations, we are not able to further analyze possible mechanisms that may explain the differences in treatment effects between farmers that deliver to different MCCs. In part, these differences may be due to unobserved factors that determine farmers' self-selection into specific MCCs.

Contamination

As pointed out in Section I, by issuing personalized vouchers to treatment farmers we avoided control farmers getting direct access to third-party quality assessment. However, the random assignment of the treatment status may still have led to positive contamination. Farmers in the control group could have gotten indirect access to the treatment through trust spillovers, e.g., if a control group farmer updated her belief about Vinamilk's type from "unfair" to "fair" after communicating with a neighboring treatment farmer. We evaluated this possibility through specific questions in the follow-up survey. Trust levels[4] significantly increased in both treatment and control farmers (though more for treatment farmers), suggesting the existence of positive spillovers. We follow that the treatment effect we measured actually underestimates the real impact of third-party contract enforcement.

A cleaner design, less susceptible to positive contamination, would have implied to strictly separate treatment and control farmers, to avoid communication between groups. However, choosing the milk collection center as unit of randomization, as one possible way of separating treatment and control farmers, would have been much more costly due to the large number of collection centers needed for proper randomization. With only a small number of

MCCs, as in our case, randomization between MCCs could have led to biased treatment effects due to systematic differences, as discussed above.

Data Provision and Incentive Compatibility

We attribute the entire treatment effect to a behavioral change of treatment farmers, not to a change in Vinamilk's reporting behavior. This is justified but deserves further explanation. If the company had underreported output quality before the independent quality verification was implemented, we would not be able to easily attribute observed effects to changes in either farmer or company behavior. In an extreme case, higher output could be entirely the result of Vinamilk ceasing to underreport quality.

Before we analyze patterns in the data to reveal whether Vinamilk deliberately underreported quality and thus the price of output, we introduce some additional notation. Let t_0 represent the starting point of the intervention, t_{+1} the point when the intervention ended after twelve months and t_{-1} the point twelve months prior to the intervention start. We distinguish between the output (quantity and quality) reported by Vinamilk and the real output obtained using laboratory methods, which for quality is private information in the standard contract. If Vinamilk had exploited the informational advantage, *reported* output levels would have been lower than *true* output levels. If instead Vinamilk played fair, *reported* and *true* output levels would have been identical. This is shown in a stylized way in figure 2 in which *reported* output for the treatment group is represented by a solid line, *true* output by a dashed line.

We have shown that independent verification of quality attributes made farmers produce more milk fat and total solid in the time interval $[t_0, t_{+1}]$ than during interval $[t_{-1}, t_0[$. This was a result of an increase in milk quantity *q* at constant milk quality *θ*. This effect on *q* is graphically represented in the left panel of figure 2 by the positive slope in *reported* average quantity delivered to the company in the interval [t_0, t_{+1}]. It is important to note that the amount of milk delivered has always been observable to both farmers and the company, because milk is weighed under the eyes of the farmers at the MCC. Hence, there has never been information asymmetry with respect to quantity. As a result, *reported* and *true* output must be identical, which is indicated by the coinciding dashed and solid lines.[5] Thus, the observed treatment effect with respect to *q* can unambiguously be attributed to a change in farmers' input use.

While *q* increased, *θ* was not affected by the intervention. For the interval [t_0, t_{+1}], in which quality was verifiable through the independent laboratory, we know with certainty that *reported θ* and *true θ* must be identical. This is graphically depicted in the right panel of figure 2 by the coinciding solid and dashed lines for the interval [t_0, t_{+1}]. If the dairy processor cheated before t_0 and stopped doing so when the third-party testing started, we would have been able to identify a discontinuity (jump) in the *reported* average quality between [t_0, t_{+1}] and [t_{-1}, t_0[. This is not what we actually observe in the data.

However, before we can infer that Vinamilk did not underreport in [t_{-1}, t_0[, we need to rule out a possible alternative explanation for the missing discontinuity: Vinamilk could have stopped cheating farmers as soon as they learned about the nature of our intervention. In this case, Vinamilk would have ceased underreporting at some point before t_0 to avoid providing evidence for cheating. This possibility can be ruled out, because Vinamilk had already started providing production data (quantity and quality) at a very early stage of our cooperation, before we actually discussed the nature of the specific intervention. Hence, we had already received data at a time when Vinamilk could not anticipate that we planned to look into independent quality verification. This precludes that the company provided us with “tailored” data to mask strategic underreporting of quality. The mere fact that they actually agreed to this intervention is also a sign that Vinamilk did not cheat on quality reporting prior to the experiment.

Pareto Improvement in the Supply Chain

Putting the pieces of evidence together, we conclude that the company has not been deliberately underreporting milk quality and price, neither in [t_{-1}, t_0[nor in [t_0, t_{+1}]. This finding has strong implications for the distribution of gains from third-party monitoring. If the company did not behave opportunistically, no information rents actually accrued. Thus, in a situation in which the principal plays “fair” but—due to the architecture of the supply chain—is unable to send a credible signal of his type, third-party verification leads to a Pareto improvement, increasing the welfare of both actors in the supply chain, sellers and buyer. While farmers benefit from unlocked productivity reserves, the processor’s per-unit transaction costs decrease if procuring from farmers who are more productive in a situation of symmetric information.

Generally, for a rational buyer to refrain from cheating, expected benefits from underreporting quality should be lower than expected costs. Such costs could arise from two sources: first, as forgone operational profits from farmers’ suboptimal milk output (as we could show) and second, from the expected damage when cheating is detected. Reputational damage in particular could be severe for Vinamilk, given the company’s size and the fact that it has established several high-profile brands in the national market. But this may not be so obvious for farmers. While company decision makers have more information to assess expected costs of cheating, contracted smallholder farmers may underestimate Vinamilk's risk and damage of being caught. For example, farmers may find it unlikely that Vinamilk would be convicted for fraudulent behavior. Anecdotal evidence suggests that Vinamilk is perceived as a powerful and politically influential player, due to its history as a state-owned company.

From this we cautiously conclude that for Vinamilk it is the dominant strategy to play fair, but that farmers may nevertheless form the belief that the company behaves opportunistically. It remains to be discussed why in this situation the company itself has not established an independent system of quality verification to signal its fair type, even though this could be profitable. One explanation could be that the credibility of any processor-driven initiative to increase transparency may be low. Duflo et al. (2012) showed for industrial pollution in India that—if incentives are not aligned—firms employ auditors who write favorable reports, actually understating pollution caused by the company. The current equilibrium of distrust that we find could probably be broken by a credible intervention from outside, such as by research institutions like in our experiment or by the government. A study by Olken (2007) found top-down monitoring to be relatively effective, even in an environment notorious for corruption. But governments do not necessarily need to undertake controls by themselves. As Yang (2008) has shown for import tax fraud, governments can "hire integrity" from private firms, which is comparable to the independent laboratory in our case. The fact that no such attempt has yet been undertaken by the Vietnamese government may not surprise, given that the local dairy industry is still emerging. Also in other sectors of developing countries, such as health and education, market and policy failures are widespread phenomena (World Bank 2003).

Conclusion

Contracting has become a widely embraced approach to facilitate supply chain relations between selling farmers and buying companies, especially in emerging markets for high-value agricultural products. Smallholders entering contractual relations with buyers of high-value products – such as fruit and vegetables, meat or milk – often become highly specialized and derive a considerable income share from the output sold under contract. However, production contracts remain incomplete if product quality attributes are observable to the buyer but not to the selling farmer. If buyers behave opportunistically and exploit this information asymmetry to increase their profit, output prices for producers are lower than in a situation of symmetric information. Farmers taking this into account may underinvest, i.e. use suboptimal levels of input translating into lower output levels, a non-desirable outcome for both farmers and buyers.

In this study we have shown that third-party contract enforcement can be one way to mitigate the adverse effects of information asymmetry. Conducting a field experiment with dairy farmers in Vietnam we found that the provision of third-party contract enforcement had a positive impact on input use (purchased fodder) and output levels (quantity of milk fat and total solid), ultimately translating into higher revenue and also household welfare for specific subgroups of the sample. Given the design of our intervention we cannot fully avoid positive contamination of the control group, and thus may actually underestimate the treatment effect.

From the available data we infer that the observed treatment effect can be fully attributed to a behavioral change on the side of farmers, instead of a change in the company's reporting strategy. It can also be concluded that in this specific case, the company had not exploited the informational advantage when the contract was yet incomplete. Instead, the company was playing fair but could not credibly signal its type to the farmers due to the specific architecture of the supply chain. Hence, not only the smallholders can benefit from more transparency regarding quality assessment. If more output per farmer is generated, per-unit transaction cost for the buying company goes down. As both sides in the transaction are better off, the contract enforcement leads to a Pareto improvement.

Our results were obtained in an environment that is representative for the fast growing Vietnamese dairy sector. The findings may also be transferable to other agricultural sectors, especially those where competition between buyers is low and information asymmetry exists. If quality attributes determine the output price but testing requires costly equipment, independent monitoring helps to overcome problems associated with information asymmetry, whether this is for fat content in milk, sugar concentration in beets or cane or protein content in grains—in Vietnam and beyond. In situations without a monopsony, contracts may be less biased towards the buyer.

Endnotes

[1] In the baseline survey, interviewees had to rate this statement on a four-point Likert-scale ("very much agree", "agree", "disagree", "very much disagree"; the option "I don't know" was also included). We collapsed the responses into a dummy taking the value 1 if farmers opted for "agree" or "fully agree" and 0 otherwise.

[2] In the baseline survey we revealed through a battery of choices between hypothetical payoffs the discount rates at which farmers accepted to wait for one month to receive a significant lump sum payment. The variable was converted into a dummy which takes the

value 1 if farmers agreed to wait one month if a monthly interest rate of up to 3.5 percent is paid.

[3] As robustness check, both variables were included in the regression equation but their inclusion neither led to significant coefficients for these variables nor to notable changes in the treatment effects.

[4] Trust levels were measured before and after the treatment. The variable is constructed in the same way as baseline trust.

[5] For illustrative purposes, the coinciding solid and dashed lines have been separated in the graphs.

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Table 1: Mean Difference for Baseline Variables in Treatment and Control Groups

	Control -Voucher	**SE**
Basic household characteristics		
Age of HH-head (in yrs)	1.233	1.558
Education HH head (in yrs of schooling)	0.556	0.442
Number of HH member	0.073	0.183
Total land size (in m²)	893	783
Distance to paved road (in km)	-0.270*	0.122
If agree to postpone at interest rate <= 3.5% (1=y)	-0.183**	0.069
Dairy enterprise		
Delivers milk to MCC A (1=y)	0.033	0.063
Delivers milk to MCC B (1=y)	-0.098	0.064
Delivers milk to MCC C (1=y)	0.065	0.065
Delivers milk to MCC D (1=y)	-0.000	0.065
Daily concentrate per cow (in kg)	1.626	1.826
Absolute milk fat (in kg)	-53.519	59.996
Absolute total solid (in kg)	-173.342	194.658
Annual revenue from dairy (in USD)	-432.499	550.234
Household expenditure		
Annual HH-expenditure (in USD)	36.410	111.463

Note: Asterisk (*), double asterisk (**), and triple asterisk (***) indicate significance level of 0.1, 0.05, and 0.01, respectively. HH means household. MCC means milk collection center.

Table 2: Estimation Results for Input Use and Output Produced

	Input			Output					
	Daily concentrate per cow (in kg)			Absolute milk fat (in kg)			Absolute total solid (in kg)		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**
Voucher treatment (1=y)	0.826***	0.869**	0.973*	71.31	119.1	289.7**	227.6	387.8	913.9**
	[0.266]	[0.364]	[0.512]	[70.19]	[95.14]	[136.9]	[221.6]	[300.4]	[433.4]
Trust towards Vinamilk (1=y)		-0.0202			157.6			505.5	
		[0.391]			[102.2]			[322.6]	
Vinamilk Trust * Voucher		-0.0334			-82.03			-279.7	
		[0.542]			[141.3]			[446.1]	
MCC B (1=y)			-0.935*			212.8			683.3
			[0.504]			[134.5]			[425.7]
MCC C (1=y)			-0.847			29.50			105.6
			[0.541]			[151.7]			[480.1]
MCC D (1=y)			0.136			110.3			367.7
			[0.541]			[144.9]			[458.6]
MCC B * Voucher			0.271			-154.8			-522.8
			[0.701]			[193.4]			[611.9]
MCC C * Voucher			-1.059			-271.9			-829.2
			[0.709]			[198.5]			[628.3]
MCC D * Voucher			0.0875			-363.7*			-1,139*
			[0.720]			[197.0]			[623.5]
Constant	6.905***	6.915***	7.375***	515.2***	443.2***	415.2***	1,630***	1,399***	1,304***
	[0.194]	[0.268]	[0.393]	[51.05]	[69.06]	[101.1]	[161.2]	[218.0]	[320.1]
Observations[1]	164	162	164	172	170	172	172	170	172
R-squared	0.056	0.060	0.221	0.006	0.025	0.071	0.006	0.026	0.066

Note: Asterisk (*), double asterisk (**), and triple asterisk (***) indicate significance level of 0.1, 0.05, and 0.01, respectively. Standard errors in brackets. MCC means milk collection center.

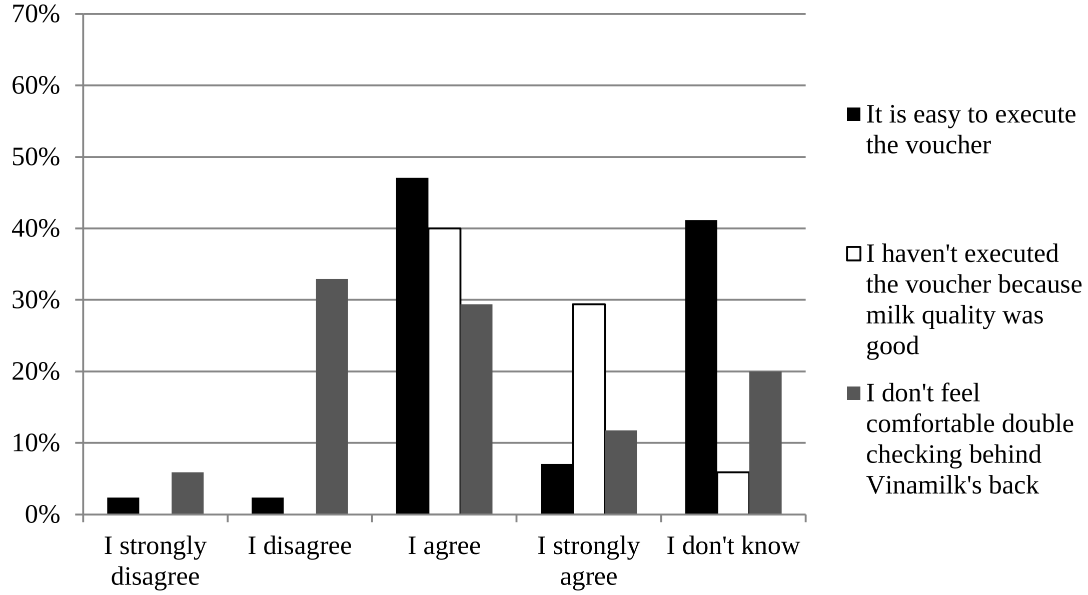
[1] The number of observation varies because of randomly missing values for specific dependent or independent variables.

Table 3: Estimation Results for Revenue and Household Welfare

	Revenue Annual from dairy (in USD)			Welfare Annual HH expenditure (in USD)		
	(1)	(2)	(3)	(4)	(5)	(6)
Voucher treatment (1=y)	812.8	1,446	3,164*	82.95	-733.6	153.5
	[845.3]	[1,146]	[1,659]	[451.9]	[607.9]	[931.4]
Trust towards Vinamilk (1=y)		1,940			-661.5	
		[1,231]			[647.9]	
Vinamilk Trust * Voucher		-1,119			1,731*	
		[1,702]			[911.2]	
MCC B (1=y)			3,173*			-63.94
			[1,629]			[907.6]
MCC C (1=y)			874.4			-344.6
			[1,837]			[972.8]
MCC D (1=y)			1,931			-778.6
			[1,755]			[940.5]
MCC B * Voucher			-1,825			-1,185
			[2,342]			[1,310]
MCC C * Voucher			-2,704			658.8
			[2,404]			[1,300]
MCC D * Voucher			-3,859			-17.20
			[2,386]			[1,294]
Constant	6,118***	5,232***	4,474***	4,106***	4,400***	4,401***
	[614.8]	[831.8]	[1,225]	[323.0]	[431.9]	[687.9]
Observations[1]	172	170	172	184	182	184
R-squared	0.005	0.025	0.060	0.000	0.021	0.026

Note: Asterisk (*), double asterisk (**), and triple asterisk (***) indicate significance level of 0.1, 0.05, and 0.01, respectively. Standard errors in brackets. HH means household. MCC means milk collection center.
[1] The number of observation varies because of randomly missing values for specific dependent or independent variables.

Panel (a)



Panel (b)

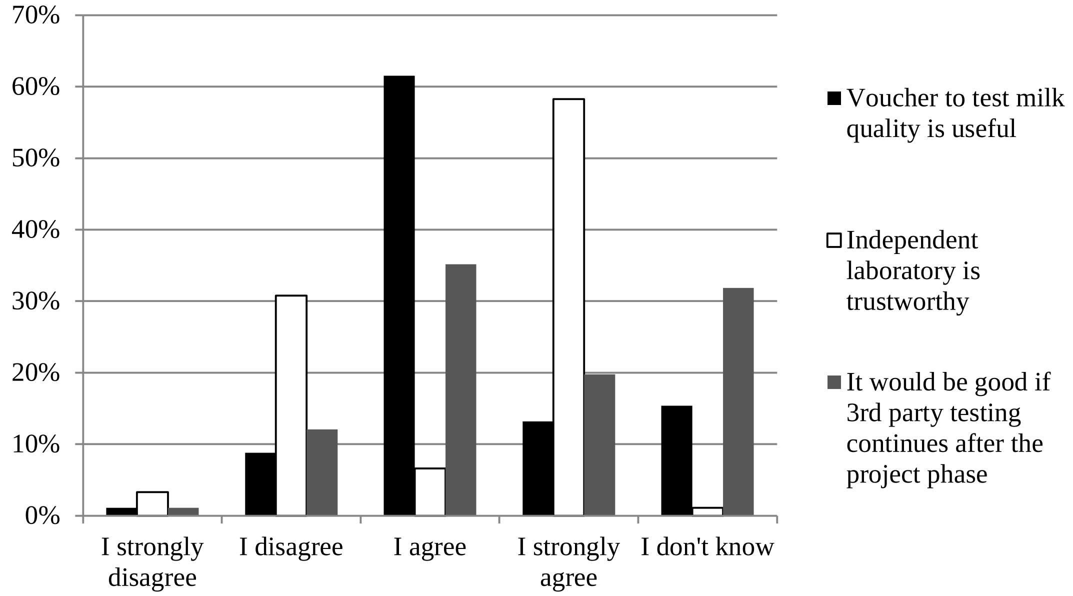


Figure 1: Farmers who have not executed a voucher evaluate the treatment (n=86)

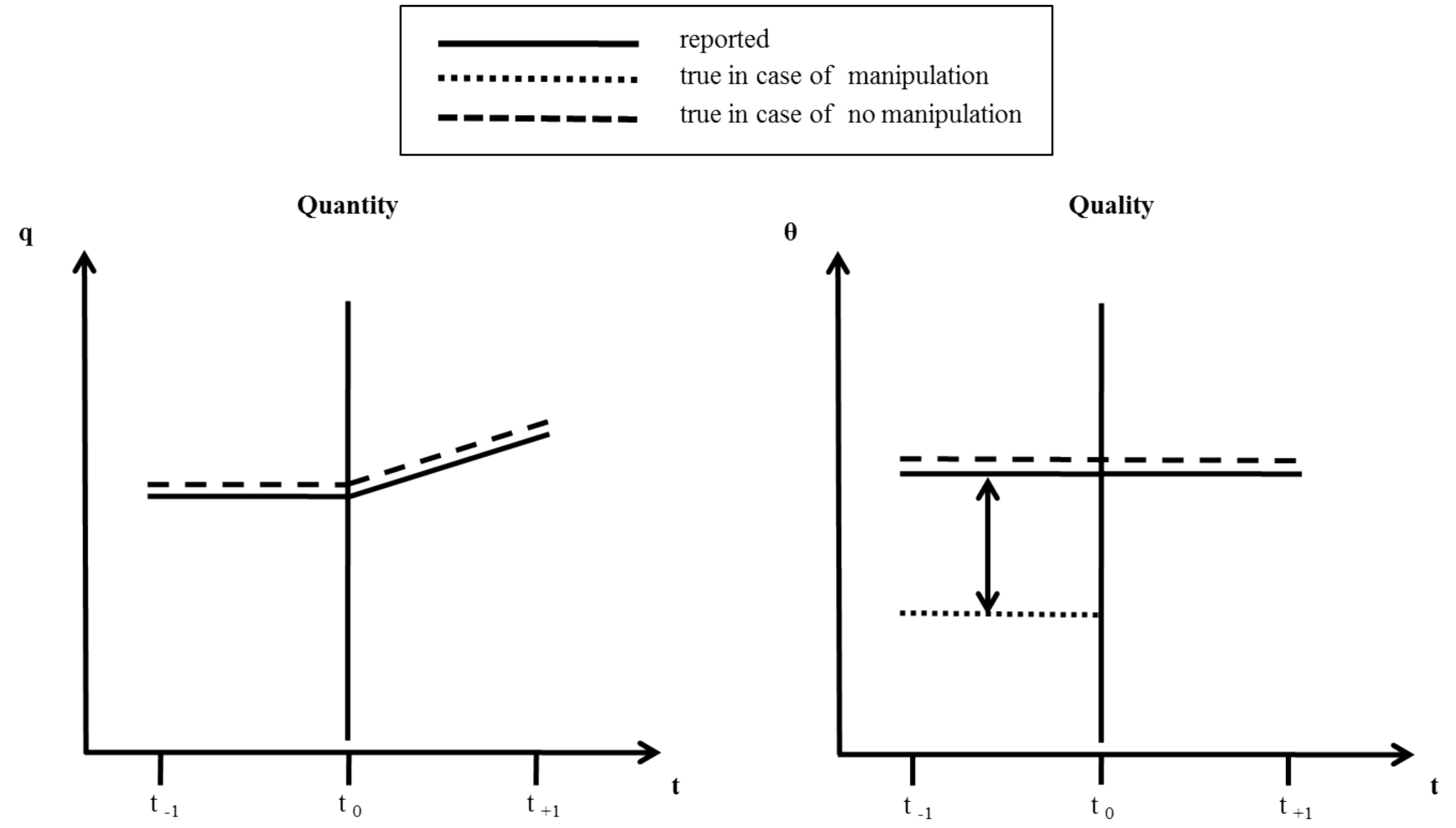


Figure 2: Stylized development of output levels (treatment group)

Appendix

A1: Summary Statistics of Selected Variables and Pair-wise Comparisons by Milk Collection Center (MCC)

	Mean (SD in parentheses)			
	MCC A (n=113)	**MCC B n=(103)**	**MCC C (n=86)**	**MCC D n=(83)**
HH-characteristics				
No. of HH member	4.513	4.641	4.244	4.341
	[1.536]	[1.514]	[1.255]	[1.399]
Age of HH-head	45.46	44.66	47.61	47.38
	[11.53]	[9.161]	[11.74]	[11.39]
Total HH income (VND)	74,192,179	82,514,741	67,618,558	73,970,047
	[49,567,765]	[69,491,153]	[58,362,681]	[53,442,489]
Dairy income (VND)	45,968,059	53,551,420	44,313,419	52,171,927
	[35,675,422]	[55,525,486]	[53,633,181]	[47,796,603]
Dairy production				
Herd size (heads)	7.611	8.194	7.744	6.398
	[5.417]	[5.369]	[4.587]	[3.751]
Productivity per Cow (kg)	4,051.6	4,925.9*	4,477.3	n.a.
	[2,888.4]	[2,229.7]	[2,472.7]	
Average milk price (VND)	6,850.0	6,730.9**	6,542.4***	6,671.4*
	[275.6]	[294.7]	[416.7]	[772.3]
Total solid (%)	12.63	12.50	12.35***	12.61
	[0.520]	[0.496]	[0.427]	[0.641]
Milk fat (%)	3.980	3.907*	3.862**	4.074
	[0.280]	[0.245]	[0.221]	[0.482]
Milk hygiene score	3.572	3.642	3.686**	3.578
	[0.368]	[0.205]	[0.162]	[0.465]

Note: Mean differences are tested for MCC B – MCC A, MCC C – MCC A and MCC D – MCC C. Asterisk (*), double asterisk (**), and triple asterisk (***) indicate significance level of 0.1, 0.05, and 0.01, respectively