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

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Abstract

Asymmetry of information is a fundamental problem in agricultural markets. Production contracts remain incomplete if product quality attributes measured by the buying company remain unobservable for the selling farmer. Opportunistic buyers would report lower than actual output quality, negatively affecting farmers' compensation given it is directly linked to quality. When farmers factor in the buyer's opportunistic behavior, underinvestment may occur, negatively affecting farm productivity. Using the example of the Vietnamese dairy industry, a field experiment is conducted in which randomly selected dairy farmers are entitled to independently verify milk testing results. Farm-level output data are complemented with household information from two rounds of comprehensive surveys conducted before and at the end of the intervention. We find a 10 percent higher use of inputs for treatment farmers, also resulting in significantly higher dairy output; welfare levels increase for a specific subgroup of farmers. As the buying company had not underreported output quality despite the existing information asymmetry, third-party enforcement enabled the company to credibly signal its fair type to farmers, leading to a Pareto improvement in the supply chain. While producers benefit directly from higher farm productivity, buying companies are better off due to lower per-unit transaction costs when procuring the farm output.

1. Introduction

Asymmetry of information is a fundamental problem in economics. When information is not freely available but instead costly to obtain for one part in a transaction, markets eventually may break down. Since Akerlof's (1970) seminal paper on the market for used automobiles, 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 labor markets, markets for insurances, 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 does not only important in transactions with metaphorical fruit such as lemons but is also crucial 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 to gather this information 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 attributes than the agent (selling farmer). This implies that agricultural production contracts remain incomplete (Gow and Swinnen, 1998). The information asymmetry between seller and buyer regarding product quality 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. However, rational sellers forming the belief that the buyer cheats would factor in the buyer's opportunistic behavior, lowering their expectations about the product price they receive. Thus, weak contract enforcement can induce sellers to underinvest (Gow et al., 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.

To overcome information asymmetry in the supply chain, more transparency, e.g. through third-party quality measurement and verification in yet incomplete contracts is one 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, the external validity of these type of studies may be limited (Levitt and List, 2007). Hence, over the past decade field experiments (or randomized control trials) in which subjects take decisions in their natural environment have become extensively used. This approach has enabled economists to convincingly isolate and measure the treatment effect of interventions in the field of social welfare, health care and education without compromising real world complexity (Skoufias, 2001; Miguel and Kremer, 2004; Kremer et al., 2005). Only recently, randomized control trials have been carried out in the field of agriculture (Duflo et al., 2008; 2011; Ashraf et al., 2009).

For the first time applying this novel approach to the evolving field of the study of agricultural contracts, we carried out a field experiment using the example of the fast growing Vietnamese dairy industry in which third-party enforcement is yet missing. The dairy sector is characterized by a great number of small-scale dairy farmers who are contracted by a large milk processing company, and hence is an excellent example for emerging markets for high-value agricultural products in developing countries (Reardon et al. 2009; Mergenthaler et al. 2009). 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 small-scale milk producers?

In the framework of this field experiment we closely collaborate with a private-sector dairy company which enables us to access weekly farm-level output data. This information is complemented with data from own extensive 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 expenditures for a specific subgroup of our sample. We are able to attribute observed differences in output to a behavioral change of farmers rather than alterations in the reporting strategy of the buying company. This also implies that in this specific case we observed a situation in which the buying company did not behave opportunistically, but failed to signal its fair type to the selling farmers. Hence, third-party enforcement in agricultural markets with incomplete contracts can lead to a Pareto improvement as both smallholders and processors or wholesalers benefit from increased farm productivity.

The remainder of this paper is organized as follows: In Section 2 an introduction to the Vietnamese dairy industry, the supply chain architecture and details on the standard dairy contract used are presented. Subsequently, the theoretical framework of our intervention is explained, followed by a description of the study area and the intervention. After lining out the identification strategy in Section 3, the results are presented in Section 4. Conceptual and methodological challenges with respect to the internal and external validity of the results are addressed in Section 5. The article closes by giving specific policy recommendations.

2. Experimental design

2.1 Background on 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 of the sector. For example, only two decades ago the consumption levels of milk and dairy products were almost nil due to cultural practices, low incomes and resulting food consumption habits. But with increasing welfare levels, intensifying urbanization tendencies and the spread of Western lifestyle the demand for milk has increased tremendously. Today’s per-capita consumption of milk in Vietnam has reached 15 kg per annum (30 kg in China) which is about 8 percent (16 percent for China) 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 the local demand in Vietnam. 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 still meeting only a fifth of domestic consumption (USDA, 2011).

The leader in the dynamic dairy industry—and cooperation partner in this field experiment—is formerly state-owned *Vinamilk*. This dairy processor collects the major share of milk produced in Vietnam and is a main importer of powdered milk. Currently, Vinamilk 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).

2.2 Supply-chain architecture and the standard contract

In Vietnam, milk is produced mainly on specialized small-scale farms; cross-bred dairy cows are held in stables all year round. A major input is fodder; rations usually consist of forage produced on farms, complemented with purchased fodder, most importantly concentrate. Farmers usually sell the entire milk output to one dairy processor. Formal outside 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 compared to large (monopsonistic) dairy processors.

The raw milk is channeled through milk collection centers (MCC) which are located in the vicinity of the dairy farms. Roughly 100 farmers supply an average MCC which is usually operated by private entrepreneurs working on commission for Vinamilk; some MCCs are collectively owned by farmers. 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 external staff employed 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 standard 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. The output price for milk p received by farmers is a function of milk quality θ which we write as:

$$p = f(\theta)\ . \tag{1}$$

Quality is a composite measure of several parameters, most important total solid and milk fat content which depends on input use x and a random shock s (e.g. animal diseases, changing fodder quality) according to

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

On a daily basis external 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 the requirements set by the dairy company. As milk analyses are carried out in the company's own laboratory and hence 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.

2.3 A simple model of underinvestment

In this subsection, drawing on a model described by Sandmo (1971), we formally derive how the asymmetric information on quality attributes described above leads to lower input use and suboptimal output compared to a situation of symmetric information. First, it assumed that the objective of farmers is to 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

$$T(q) = V(q) + F, \tag{3}$$

where q is the 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:

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

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

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

where the product of p and q is the total revenue (TR). Farmers maximize profits at the level of output where marginal revenue (MR) equals marginal costs (MC) according to

$$MR = MC, \tag{6}$$

where

$$MR = \frac{\partial TR}{\partial q} = p \quad (7)$$

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

In this situation, θ is known to both participants in the transaction which implies that information about product quality is not complete but symmetric.

In contrast to the benchmark situation lined out above, we will now derive how the optimal input changes in an environment in which the buying company has private information about θ, inducing underinvestment by sellers which in turn results in lower output. Exploiting its informational advantage, the dairy processor could report a lower level of quality to the farmer than implied by the results obtained in the laboratory. Hence, according to (1) withholding private information negatively affects the output price while increasing the residual income for the dairy processor. In a situation of asymmetric information a rational dairy producer i forms a specific belief to what degree the milk company underreports. This is represented in the equation

$$p_i^{reported} = \gamma_i p_i^{true} + \lambda_\mathrm{i}, \quad (9)$$

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 $\lambda_\mathrm{i} < 0$ a lump sum is deducted at any given level of p_i^{true}. For those farmer who believe that Vinamilk cheats we follow that

$$p_i^{reported} < p_i^{true}. \quad (10)$$

If farmers maximize expected utility by setting marginal costs equal 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. Hence, if plugged in to 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.

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, or (b) keep the quality constant while increasing the quantity, or (c) simultaneously increase quality and quantity.

On farm-level the goal of improving 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 components (e.g. concentrate) to make the ration more nutritious, provided that the physiological requirements of dairy cows in terms of a balanced ration are still met. 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 which, however, requires capital. 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.

2.4 Design of the intervention and implementation

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

Each 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 and stored there. 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 knows 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 each and every sample analyzed by Vinamilk, the voucher mechanism enabled us to implement a structure 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 treatment farmers delivering milk and Vinamilk staff taking the additional B-samples thoroughly understood the procedure. During a half-day workshop treatment farmers were informed about the independent milk testing works 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 especially 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 reference material imported from Germany. 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. Hence, 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 mechanism and resulting higher expected milk prices would confound the subsequent impact analysis, but is extremely unlikely. If a treatment farmer accepts milk from a fellow control group farmer (or an unknown source) she takes the risk to mix milk of unknown quality with her own milk, jeopardizing the milk quality of the whole batch delivered to the MCC, potentially leading to a lower milk price and a serious 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. (2009) have 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 special with respect to compliance in so far 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 decision to execute a voucher to build a direct threat to Vinamilk. It is sufficient if farmer A forms the belief that farmers B or C may request an analysis; if A believes that B or C execute a voucher in a given week, this—from farmer A's point of view—would create sufficient of an indirect 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 the compliance with respect to direct verification.

At this point also 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 yet unobservable quality attributes. Like in the case of Thomas et al. (2003) who have 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. Successful examples of outsourcing of quality assessment exist in countries such as Germany where independent milk testing has been implemented several decades ago.

2.5 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 representative provinces south of HCMC where Vinamilk has contracted 402 dairy farmers. The milk supply is channeled through four MCCs.

On MCC-level differences with respect to average dairy output (quantity, quality) can be observed (Table A1 in the Appendix). We attribute this to selection effects rather than geographical differences. As three out of the four collection centers in the study area (MCC B, C and D) are spatially clustered, it is unlikely that for example 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 between their farm and the MCC but also based on soft factors such as trust towards the management of the MCC. Besides the three clustered MCCs there is also one more isolated collection center (MCC A) where farmers—in contrast to the MCC cluster—do not have the option to choose 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, e.g. if they are discontent with Vinamilk, the contract or the collection center management. We follow, that on average those farmers who deliberately keep delivering to Vinamilk despite having an outside option for some reason (e.g milk price or identification with Vinamilk as an organization) are systematically different from those Vinamilk farmers without such an outside option. In the subsequent impact analysis we take these selection effects into account.

Given the limited number of MCCs and significant mean differences in observable characteristics between the MCCs, a randomization of treatment status over MCCs—even though easier to manage—would not be useful (for a comparison of selected outcome variables, see Table A1). Hence, in May 2009 the entire population of 402 dairy farmers attended a public lottery in which 102 farmers were completely randomly assigned to the treatment group. Another 100 farmers were completely 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. Especially the latter justification was needed to maintain control group farmers motivated to participate in the follow-up survey. Due 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.

2.6 Data

We collected detailed information for all farmers participating in the experiment. Through two rounds of structured household surveys we generated a panel data set comprising socio-economic data 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 rich farm-level output data for each farmer in the sample for data provided by the dairy processor, covering the period from May 2008 to May 2011 which is 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 Section 5.2 when discussing the internal validity of the results.

3. Analytical approach

3.1 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 first 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 both output variables are provided by the dairy company. For (c) we use total annual household 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

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

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

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

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

To estimate ATT and ATT(x) econometrically, we employ a multivariate regression framework and specify an OLS regression model according to

$$y = \propto + \beta v + \gamma \boldsymbol{X} + \delta v \boldsymbol{X} + \varepsilon, \tag{13}$$

where the dependent variable y is an outcome variable measured at the end of the experiment.

For each outcome variable under investigation we specify two distinct regression models. In the first specification which aims at identifying ATT we include the treatment dummy *v* which takes the value 1 if an individual was assigned to the treatment group and 0 otherwise. To measure ATT(x) the model is augmented by adding a vector X of dummy variables indicating baseline characteristics at time t_0. which allows for testing whether the relationship between specific baseline characteristics and outcome variables is different conditional on treatment status. We have chosen two types of baseline covariates: First, the variable *baseline trust* which is a dummy variable taking the value 1 if farmers agreed with the statement that “Vinamilk is a trustworthy business partner” and 0 otherwise.[1] We suppose that initial trust levels may affect the

[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.

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.

Second, the dummy variables indicating the affiliation to a specific milk collection center (MCC *B*, *MCC C* and *MCC D; MCC A* was chosen as benchmark) capture the effect of unobservable characteristics that make farmers select a specific MCC to deliver their milk (see also Section 2.5).

3.2 Randomization

Prior to the impact analysis we have verified that both treatment and control group are similar statistically with respect to the large number of observables available from the baseline survey (Table 1). The only statistically significant (at 10 percent error rate) differences we find 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. But given the random assignment of the treatment status, the observed differences are not systematic, e.g. better infrastructure did not make this household more likely to be assigned to the treatment group[3].

3.3 Attrition

Typical agrarian structural change could be observed in the study area, as a number of very small producers ceased dairy production. Among those farmers delivering to MCC A some switched from Vinamilk to the competing dairy processor and thus effectively dropped out of the

[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 variable which takes the value 1 if farmers agreed to wait one month if a monthly interest rate of up to 3.5 % 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 (results are not presented here).

sample. Overall, between baseline and follow-up survey the number of households in the treatment and control group had decreased from 100 and 102 to 93 and 91, respectively.

3.4 Compliance

As pointed out in Section 2.4 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 for this observation could be that these large farmers had a higher interest in verifying the milk testing results provided by the processor as even little underreporting of milk quality and thus milk prices would lead to substantial losses due to the higher production volume. 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 trusted the independent laboratory. Roughly 50 percent of all treatment farmers stated to not have executed a voucher because they were content with the milk quality results provided by Vinamilk while the experiment was ongoing. Half of the farmers indicated 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 individual assigned to the treatment group (expect for drop-outs) can be regarded as treated.

4. Estimation results

4.1 Input

First we investigate how the treatment affects self-reported fodder usage (concentrate fed per cow and day in kg). Results are presented in Table 2, columns (1) and (2). We find a highly significant positive treatment effect which is robust across both 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 insignificant across all specifications. 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.

Besides 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 do not find significant differences between treatment and control group.

4.2 Output

The regression results for dairy output are also presented in Table 2. If baseline trust and collection center affiliation are controlled for, we find a significantly positive treatment effect with respect to the absolute amount of milk fat and total solid produced during the twelve months period of the experiment as can be seen in columns (3) to (6). Apparently the increased production intensity (use of purchased concentrate) had translated into a higher absolute output of valuable milk fat and total solid. In contrast, the relative composition of milk remained constant as suggested by mean comparisons of total solid and fat content before and after the treatment; likewise running the above specified regression models with average total solid and fat content as dependent variables, no significant impact of the treatment was found (results not presented here).

In Section 2.3 we had proposed three ways how farm-level dairy output can be increased. The results suggest that farmers mainly chose the second approach, namely increasing the milk quantity (in kg) while keeping quality (milk fat and total solid content in percent) constant. A possible explanation for the observed increase in milk quantity but unchanged milk quality (fat and total solid content in percent) can be found in the physiology of dairy cows. To produce large quantities of milk, the dairy cow requires a nutritious but also balanced fodder ration, especially with respect to protein and energy content of the fodder. If the dairy cow is fed suboptimal levels of one of the two components, the milk yield drops. For example, if the ration contains too little protein relative to energy, the ruminal protein-balance is negative depressing the milk yield (Roth et al., 2011). As the concentrate increasingly purchased by farmers in the treatment group is rich on protein, it is plausible that, for example, a formerly negative protein-balance was not binding anymore. As a result this would have effectively alleviated the constraining effect of low protein-availability and boosted the per-cow milk yield without changing the milk composition with respect to milk fat and total solid content. Besides that, the higher output may be partially attributed to a slight (but statistically not significant) increase of the average herd size in the treatment group.

The increase in output leads to higher revenues from dairy production which is presented in Table 2, columns (7) and (8). The positive and significant (at 10 percent error rate) coefficient of the treatment dummy in the second model in which baseline characteristics are controlled for points to a heterogeneous treatment effect, especially with respect to milk collection center affiliation. The increment in revenue can entirely be attributed to the increased production volume as the milk price remained constant.

4.3 Welfare

Finally, we look into the intervention's impact on total household expenditures, a relatively stable measure of welfare that adjusts rather slowly to moderate positive or negative income shocks. We observe a welfare increase for the subgroup of treatment farmers that was trustful towards the company before the experiment started (high-trust farmers), as presented in Table 6.2, columns (9) and (10). This can be inferred from the positively significant coefficient of the interaction term *Vinamilk Trust*Voucher*. Interestingly the impact evaluation with respect to all other outcome variables of interest has so far not provided any evidence that low-trust farmers are more strongly affected by the treatment than high-trust farmers. The coefficient of the interaction term *Vinamilk Trust*Voucher* has not been statistically significant in any of the prior models. Apparently, even high-trust farmers might had formed the belief that Vinamilk cheated before the intervention started, given the supply chain architecture and the realistic threat of opportunistic behavior.

Further, the specific way we measured trust variable, it could capture trust in more than only one dimension. The statement "Vinamilk is a trustworthy business partner" that had to be rated by survey respondents probably did not only capture the belief about Vinamilk's quality reporting strategy, but also expectations regarding timing of payment or assumptions about Vinamilk's long-term commitment to output price levels provided when the contract was initially signed.

If this is the case, low-trust farmers may perceive the entire relationship with Vinamilk as riskier, and act more cautiously. Given the relatively short time horizon of the intervention and the slowly adjusting welfare measure we use, the time period of observation might have been too short to find an increase in household spending for low-trust farmers. Instead of increasing expenditures to the same degree as their high-trust peers, low-trust farmers may instead have saved more money, building up a safety buffer to prepare for future shocks (which they perceive as being more likely), e.g. Vinamilk lowering the output price for milk.

5. Discussion

Overall our findings confirm the formally derived hypothesis that third-party enforcement of contracts mitigates underinvestment and hence are in line with Wu's and Roe's (2007) findings from laboratory experiments with college students. Furthermore this study shows under real-world conditions that higher input levels observed under the enforced contract actually translate into higher output, a result which would impossible to obtain in the laboratory as the underlying technology and possible supply response would be predetermined by the experimenters. The findings also suggest that on average specific subgroups are affected to varying degrees by the intervention, especially those delivering to particular collection centers. Given the available data we are not able to open the black box of collection center affiliation to identify clear mechanisms behind this particular finding. However, we suppose that selection on unobservables (e.g. identification with an MCC or dairy processor) into specific MCCs may explain the discrepancy of impact.

5.1 Contamination

As pointed out in Section 2.4 we avoided control farmers getting direct access to third-party quality assessment by issuing personalized vouchers to treatment farmers. However, the completely 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: For example, if a control group farmer for some reason updated her belief about Vinamilk's type from "unfair" to "fair" after communicating with a neighboring treatment farmer. We evaluated this through specific questions in the follow-up survey. The results suggest that positive contamination might have occurred, since the trust levels[4] significantly increased in both treatment and control group (though more for treatment farmers). From this we follow that the treatment effect we measured actually underestimates the real impact of third-party contract enforcement. A cleaner design, less susceptive to positive contamination, would have implied to strictly separate treatment and control farmers, to avoid communication between members of the different groups. However, choosing the milk collection center as unit of randomization would have been prohibitively costly in terms of budget requirements and administrative burden due to the large number of collection centers needed for proper randomization.

5.2 Data provision and incentive compatibility

In the results section above, we attributed the entire treatment effect to a behavioral change of treatment farmers, not (partly) to a change in Vinamilk's reporting behavior. If the company had underreported output quality (total solid and fat content) until the point in time the independent quality verification was implemented, we would not be able to disentangle the observed differential in output and attribute it either to farmers or the company. In the most extreme case, higher observed output quality would entirely be the result of Vinamilk stop underreporting quality.

In this section we will become explicit about how we infer from the available data that Vinamilk's type is "fair" with respect to reporting milk testing results and prices, allowing us to

4 Trust levels were measured before and after the treatment. The variable is constructed in the same way as baseline trust, explained in detail in Section 6.3.1.

fully attribute the observed changes in output to farmers. Further we will elaborate what this finding means in the context of the second research question, i.e. if third-party contract enforcement has positive welfare implications (for smallholders).

Before we analyze patterns in the data to reveal if Vinamilk deliberately underreported milk quality and thus the price of output or not, let us first introduce a little bit of notation: We choose t_0 to represent the starting point of the intervention and label t_{+1} the point when the intervention ended after twelve months; t_{-1} marks the point in time, twelve months prior to the intervention. We distinguish between the output (quantity and quality) reported by Vinamilk and the real output obtained using laboratory methods which in case of quality is private information. 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.

In the results section we had shown that independent verification of quality attributes made farmers produce more milk fat and more total solid in the interval [t_0, t_{+1}] than during interval [t_{-1}, t_0[. As already pointed out, this is the result of an increase in milk quantity q at constant milk quality levels θ. The positive net-effect on q is graphically represented in Figure 2 by the non-zero slope in *reported* average quantity delivered to the company in the domain [t_0, t_{+1}]. It is important to note that the amount of milk delivered has always been observable to both selling farmers and the buying company as milk is weighed under the eyes of the farmers at the MCC. Hence, there has never been an asymmetry of information with respect to the milk 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, levels of θ were not affected by the intervention as already pointed out in the Section 4.2. 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 Figure 2 by the coinciding solid and dashed lines for the domain [t_0, t_{+1}].

If the dairy processor cheated before t_0 and stopped behaving opportunistically as soon as the third-party testing was implemented, we would have been able to identify a jump in the *reported* average quality between the intervals [t_0, t_{+1}] and [t_{-1}, t_0[. However, we do not find such a jump.

Before we can infer that Vinamilk did not underreport in [t_{-1},t_0[, we need to rule out an alternative explanation for the pattern found in the data: Vinamilk could have stopped cheating farmers as soon as they learned about the nature of our intervention. In this case Vinamilk would already have stopped underreporting at some point before t_0 to avoid providing evidence for cheating. This alternative explanation can be ruled out as Vinamilk had already provided the first batch of production data (quantity and quality) in a very early stage of our cooperation when exploratory talks were taking place and we had not yet come up with this specific intervention involving verification of milk testing results. Hence, we had received data at a point in time when Vinamilk could not have possibly anticipated what exact type of intervention we were proposing to implement and evaluate. This precludes that the dairy company provided us with "tailored" data to mask strategic underreporting of quality.

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

5.3 A story of moral hazard or signaling?

Putting all these 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 however sheds new and interesting light on the evaluation of the overall effect of mitigating asymmetric information in our specific case. Apparently, we did not identify a situation in which the principal (Vinamilk) was behaving opportunistically (at least in the domain of quality testing), exploiting the advantage of having private information. Instead we infer that Vinamilk could not send a credible signal to farmers that it is not cheating, because of the supply chain architecture: the Vietnamese dairy sector lacks an independent body for milk quality assessment. Hence, rational agents (dairy farmers) formed the belief that the principal underreports quality. As a result they lowered their expectations about the output price, responded to by suboptimal input use, leading to lower output. This is an important finding as it also has implications for the distribution of possible gains from third-party contract enforcement. If the company did not cheat in the first place, it no information rents could be accrued (potentially outweighing the losses from farmers' suboptimal milk output and hence making cheating the dominant strategy). Thus, in a situation in which the principal plays "fair" but is unable to send a credible signal of his type, third-party verification leads to a Pareto improvement, increasing the welfare of both agent and principal. Per-unit transaction costs for the procuring company decrease if farmers produce more output in a situation of symmetric information. This also is also crucial for smallholder participation in emerging high-value markets, as high transaction costs are one reason why processors tend to prefer contracting larger farmers (Birthal et al., 2005).

6. Conclusion

Contract farming has become a widely embraced approach to facilitate supply chain relations between selling farmers and buyers such as processing companies or wholesalers, not only in the developed world but also in developing countries, especially in emerging markets for high-value agricultural products. Smallholders entering contractual relations with buyers of 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 non-visible product quality attributes are observable to the buyer but not to the selling farmer. If buyers behave opportunistically and exploit this asymmetry of information to increase their residual income, output prices for producers are lower than in a situation of symmetric information. Producers taking this into account may underinvest, i.e. use suboptimal levels of input translating into lower output levels, a non-desirable outcome for farmers and buyers.

In this study we have shown that third-party contract enforcement can be a useful way to mitigate the adverse effects of asymmetry of information. Conducting a field experiment with dairy farmers we find that the provision of third-party contract enforcement had a positive impact on input use (mainly purchased fodder) and output levels (quantity of milk fat and total solid), ultimately translating into higher 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 even underestimate the treatment effect.

From the available data we infer that the observed treatment effect can be fully attributed to a behavioral change of farmers, instead of a change in the reporting strategy of the company. 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 dairy producers due to the specific architecture of the supply chain. Hence, it is not only the smallholders benefitting from more transparency regarding quality assessment. If more output per farmer is generated, per-unit transaction cost for the buying firm goes down. As both sides in the transaction are better off, the contract enforcement leads to a Pareto improvement.

Cooperating with the leading company in the Vietnamese dairy sector we accessed a representative sample of farmers, producing under a standard contract. Hence, our results were obtained in an environment which is highly representative for the fast growing Vietnamese dairy sector. The trends in the findings of this particular study are also transferable to other agricultural sectors. Of course, the initial trustfulness of the relation between farmer and a contracting company may vary from case to case. However, if non-visible quality attributes determine the output price but testing requires sophisticated and costly laboratory equipment, independent testing will help to overcome the detrimental information asymmetry, be it for fat content of milk, sugar concentration in beets or cane as well as protein content of grains—in Vietnam and beyond. Hence, we suggest that public support to establish infrastructure required for independent quality assessment and verification would be one way to increase farm productivity to the benefit of all stakeholders in agricultural supply chains of developing countries.

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Table 1: Selected baseline variables for treatment and control group

	Mean (SD in parentheses)		**Control - Voucher** (SE in parentheses)
	Control (n=91)	**Voucher** n=(93)	
Basic household characteristics			
Age of HH-head (yrs)	44.67	45.90	1.233
	[9.863]	[11.01]	[1.558]
Education HH head (yrs of schooling)	8.400	8.956	0.556
	[2.887]	[3.055]	[0.442]
Number of HH member	4.400	4.473	0.0725
	[1.216]	[1.250]	[0.183]
Total land size (m^2)	6,614	7,507	893
	[4,955]	[5,577]	[783]
Distance to paved road (km)	0.577	0.308	-0.270*
	[1.001]	[0.622]	[0.122]
If agree to postpone at interest rate <= 3.5% (1=y)	0.422	0.239	-0.183**
	[0.497]	[0.429]	[0.0687]
Dairy enterprise			
Delivers milk to MCC A (1=y)	0.222	0.255	0.0331
	[0.418]	[0.438]	[0.0632]
Delivers milk to MCC B (1=y)	0.300	0.202	-0.0979
	[0.461]	[0.404]	[0.0638]
Delivers milk to MCC C (1=y)	0.222	0.287	0.0650
	[0.418]	[0.455]	[0.0645]
Delivers milk to MCC D (1=y)	0.256	0.255	-0.0002
	[0.439]	[0.438]	[0.0647]
Household income and expenditure			
Total income (in 1000 VND)	69,913,219	69,013,660	-899,559
	[48,958,820]	[47,638,312]	[7,160,270]
Dairy income (in 1000 VND)	44,200,027	45,871,479	1,671,452
	[35,153,033]	[40,143,973]	[5,711,772]

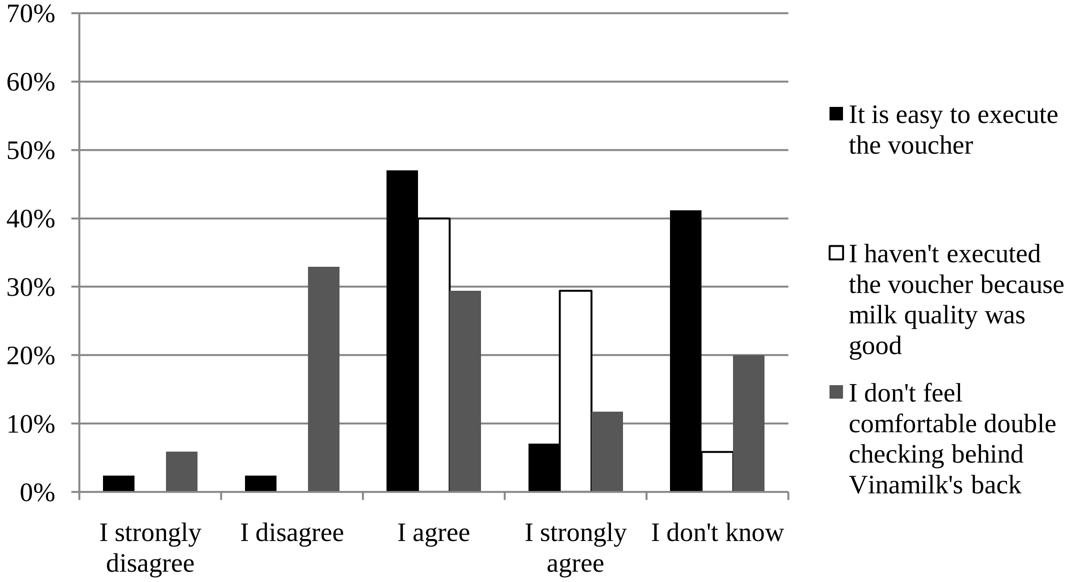
*** p<0.01, ** p<0.05, * p<0.10
Source: Own data

Table 2: Estimation results (OLS-model)

	Input		**Output**				**Revenue**		**Welfare**	
	Daily concentrate per cow (in kg)		Absolute milk fat (in kg)		Absolute total solid (in kg)		Annual from dairy (in USD)		Annual HH-expenditure (in USD)	
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**
Voucher treatment (1=y)	0.913***	1.333**	46.63	357.0**	150.6	1,137**	519.9	4,022*	184.5	-1,300
	[0.280]	[0.631]	[76.80]	[179.6]	[242.4]	[568.8]	[923.7]	[2,183]	[517.5]	[1,262]
Trust towards Vinamilk (1=y)		-0.0475		178.2		573.8		2,519		-552.8
		[0.374]		[110.6]		[350.3]		[1,862]		[754.8]
Vinamilk Trust * Voucher		-0.722		-135.4		-439.4		46.51		2,164**
		[0.538]		[154.6]		[489.6]		[2,068]		[1,072]
Collection Center B (1=y)		-0.834		146.4		482.4		2,279		-577.0
		[0.542]		[153.2]		[485.2]		[2,068]		[1,074]
Collection Center C (1=y)		-0.746		-51.68		-142.3		-1,321		-1,246
		[0.577]		[170.2]		[538.9]		[2,619]		[1,152]
Collection Center D (1=y)		0.304		122.7		414.5		-2,455		-1,145
		[0.591]		[170.2]		[538.9]		[2,711]		[1,180]
Collection Center B * Voucher		0.528		-108.8		-385.5		-5,054*		-1,027
		[0.760]		[215.5]		[682.4]		[2,701]		[1,515]
Collection Center C * Voucher		-1.298*		-252.7		-771.0		2,233*		1,967
		[0.775]		[223.1]		[706.4]		[1,345]		[1,537]
Collection Center D * Voucher		0.165		-458.1**		-1,443**		-1,639		599.6
		[0.778]		[222.3]		[703.8]		[1,879]		[1,552]
Constant	6.864***	7.295***	572.7***	419.0***	1,811***	1,303***	6,819***	4,333**	4,120***	5,134***
	[0.202]	[0.483]	[56.59]	[137.5]	[178.7]	[435.4]	[680.7]	[1,671]	[375.2]	[963.1]
Observations[1]	150	148	151	149	151	149	151	149	156	154
R-squared	0.067	0.257	0.002	0.109	0.003	0.104	0.002	0.090	0.001	0.062

Standard errors in brackets; *** p<0.01, ** p<0.05, * p<0.10; [1] The number of observation varies because of randomly missing values for specific dependent or independent variables Source: Own data

Panel (a)



Panel (b)

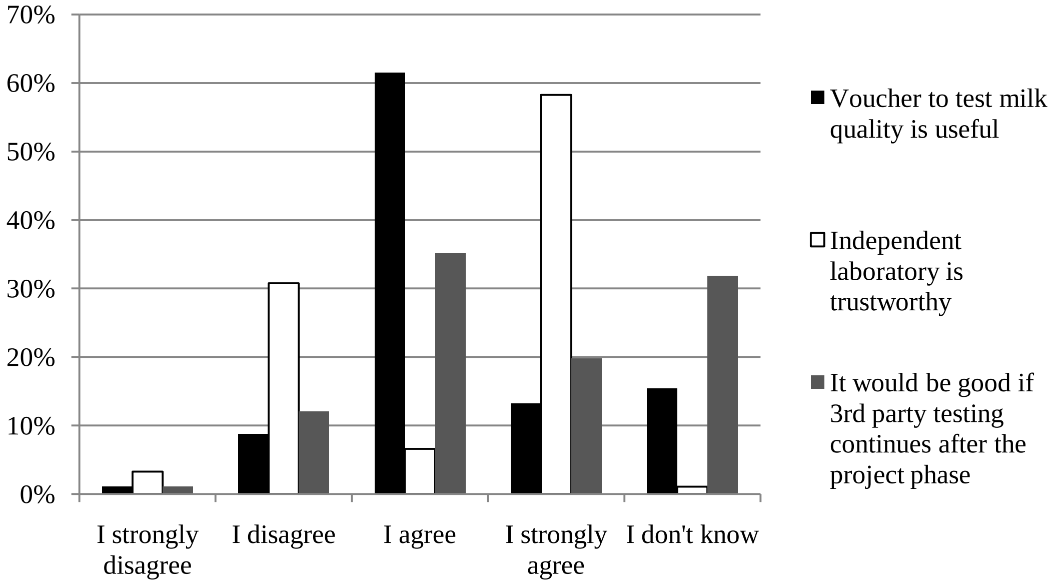


Figure 1: Farmers who have not executed a voucher evaluate the treatment (n=86)

Source: Own data

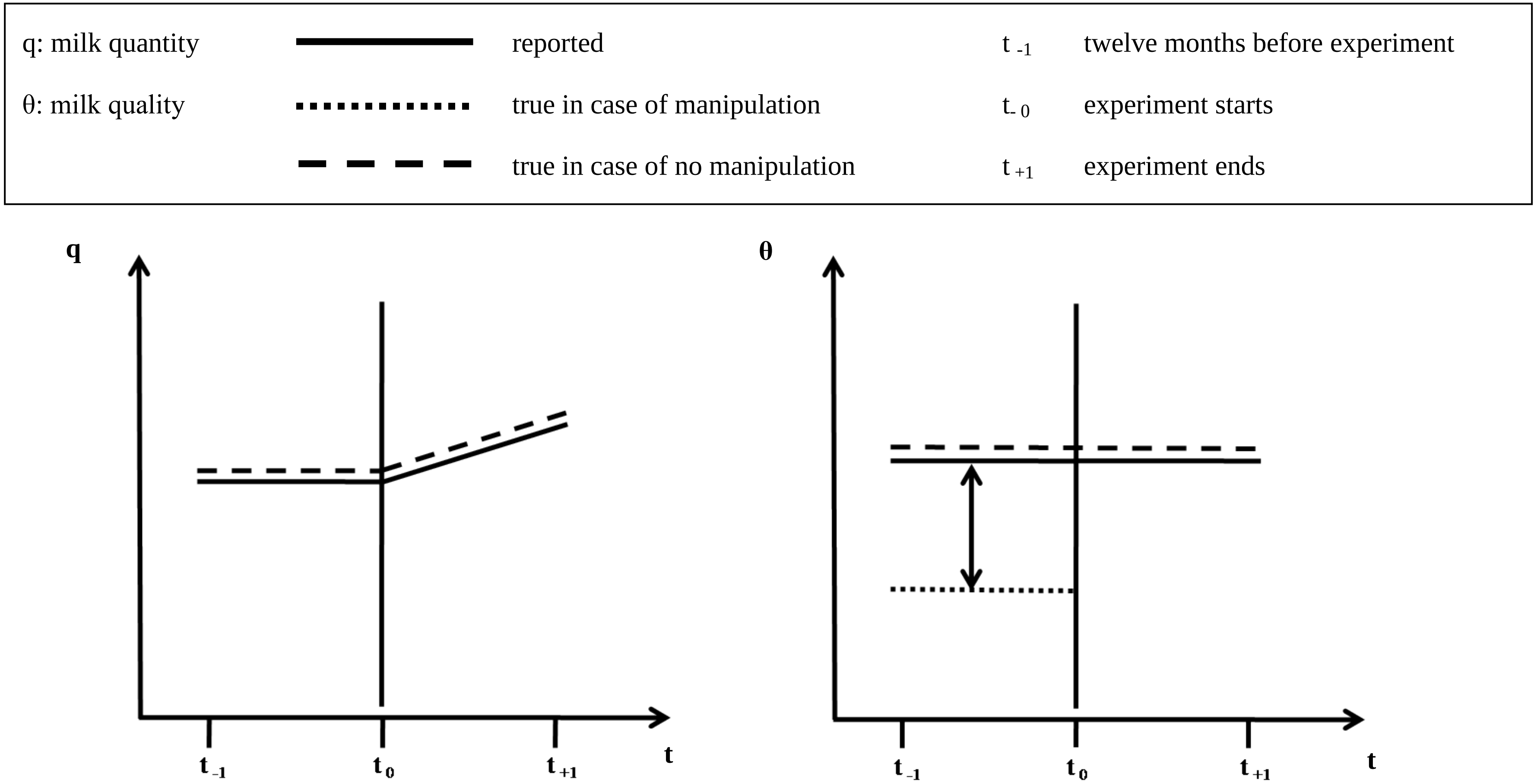


Figure 2: Stylized development of output levels (treatment group)

Source: Own data

Appendix

A 1: 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]

Mean differences are tested for MCC B – MCC A, MCC C – MCC A and MCC D – MCC C. Asterisks indicate statistically significant mean differences. Levels for mean differences: *** p<0.01, ** p<0.05, * p<0.10.