The Impact of Third-Party Enforcement of Contracts in Agricultural Markets – Evidence from a Field Experiment in Vietnam

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Abstract

Asymmetry of information is a fundamental problem in economics. Agricultural production contracts remain incomplete if quality attributes measured by the buying company are unobservable for selling farmers. Opportunistic buyers would report lower than actual quality, negatively affecting farmers' compensation given it is directly linked to specific quality attributes. When farmers factor in the buyer's opportunistic behavior, underinvestment may occur. Using the example of the Vietnamese dairy industry, a twelve months lasting field experiment is conducted in which contracts are enforced for randomly selected dairy farmers by providing them with the opportunity to verify milk testing results reported by the buying dairy processor. Farm-level output data is complemented with information from two rounds of extensive household surveys conducted before and at the end of the intervention. Employing a multivariate regression framework, we find a 10 percent higher use of inputs for treatment farmers compared to their peers in the control group, also resulting in significantly higher dairy output; for specific subgroups we find that welfare levels mildly increase. Various robustness checks are carried out. We suggest that there is scope for public support of third-party contract enforcement in agricultural markets with yet incomplete contracts to increase farm productivity and welfare of smallholders—a finding of significance far beyond the Vietnamese dairy sector.

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, this can lead to the complete breakdown of markets. 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 affect transactions with metaphorical fruit such as lemons but also markets for actual agricultural produce, for example if special technology is required to assess non-tangible 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 private 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 mitigate the negative effect information asymmetry in the supply chain, third-party quality measurement and verification in yet incomplete contracts is one solution (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 (Miguel and Kremer, 2004; Skoufias, 2005; 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).

Applying this tool 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 small-scale dairy farmers being 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; the 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 where the buying company did not behave opportunistically, but failed to signal its type, being fair, to the selling farmers. We suggest that there is scope for public support of third-party enforcement in agricultural markets with incomplete contracts to make markets more efficient and increase farm productivity to the benefit of smallholders and processors.

The remainder of this paper is organized as follows: In the subsequent paragraph an introduction to the Vietnamese dairy industry, the supply chain architecture and the standard contract employed is given. In the following section 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, the results are presented and conceptual and methodological challenges with respect to the internal and external validity of the results are addressed. 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 Asian countries, milk is becoming an increasingly popular food item leading to high growth rates in the industry. For example, only two decades ago the consumption levels of milk and dairy products were almost zero due to cultural practices, low incomes an 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 more than quadrupled between 2001 and 2009 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 a major share of the 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 the 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 the farm, complemented with purchased fodder, most importantly concentrate. Farmers usually supply 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 processor.

The raw milk is channeled through milk collection centers (MCC) which are located in the vicinity of the dairy farms. Roughly 100 farmers are suppliers of an average MCC which is 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 to Vinamilk's dairies in the greater HCMC area; the MCCs also process the weekly payments to farmers.

The standard production contract between Vinamilk and dairy farmers is a country-wide implemented, written agreement determining how much milk of what quality is purchased at which price. The milk price p 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 I and a random shock ν (e.g. animal diseases, changing fodder quality) according to

$$\theta = f(I, \nu)\ . \tag{2}$$

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. As individual milk testing is prohibitively costly and collective action fails, it is unfeasible for smallholders to overcome the asymmetry of information regarding milk quality by systematically cross-checking the results provided by the processor.

2.3 A simple model of underinvestment

In this paragraph, using a simple model adopted from 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:

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

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

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

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

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

where

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

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

In this situation, θ is known to both participants in the transaction which implies that information about product quality is incomplete but symmetric[1].

In contrast to the benchmark situation lined out above, we will now derive how the change in optimal input in an environment in which the buying company has private information about θ leads to underinvestment and 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 which according to (1) would affect the output price. Individual dairy producer *i* taking into account the information asymmetry forms the belief to what degree the milk company underreports which is represented in the equation

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

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

[1] Given equation (2) in the benchmark situation, an archetypal information asymmetry exists between principal (dairy company) and agent (farmer) as milk quality is a function of input levels and a random variable. While the value of the random variable is unknown to both participants in the transaction, the input level *I* chosen is private information of the agent. However, the information asymmetry regarding *I* still exists in an environment in which θ is private information of the principal, but in terms of its effect is overlaid by the pimacy of the information asymmetry with respect to θ. In other words, the information asymmetry regarding θ is added to the benchmark model, ceteris paribus.

$\gamma_i < 0$ the corresponding percentage share of the price is deduced while $\lambda_i < 0$ is a lump sum deduction at any given price level. 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 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.

If expected output prices are higher due to third-party contract enforcement, how can farmers practically boost dairy output? Generally, dairy farmers 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 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 produced can be realized 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 are meant to be executed whenever eligible farmers challenge 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. This process could not be observed by Vinamilk, i.e. the dairy company did not know when an individual farmer 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. The voucher mechanism enabled us to implement a structure to systematically overcome the information asymmetry on milk quality attributes at relatively low cost, compared to validating the results of each and every sample analyzed by Vinamilk. All costs 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 as it is too costly.

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 a service hotline.

To assure that farmers regard 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 using 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 minimize 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 avoided. Hence, we handed out personalized, vouchers tagged with a unique identification number. Vouchers passed on to other farmers (also outside the treatment group) automatically lost their validity.

A scenario in which control farmers sell their milk through treatment farmers to benefit indirectly from the independent milk quality verification mechanism and resulting higher expected milk prices would seriously 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, 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 *i*'s decision to execute a voucher (direct verification) to build a threat to Vinamilk. It is sufficient if farmer 1 forms the belief that farmers 2 or 3 may request an analysis (indirect verification); if 1 believes that farmer 2 or 3 execute a voucher in a given week, this—from farmer 1's point of view—would create sufficient of a threat to the dairy processor to be checked up on, ruling out underreporting, i.e. cheating. Ultimately, this implies that all farmers in the treatment group can be regarded as treated, regardless the compliance with respect to direct verification.

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 409 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 (Appendix I). We attribute this to selection effects, rather than geographically induced agro-ecological or infrastructural differences. As three out of the four collection centers in the study area (MCC B, C and D) are geographically 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 speculate 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 between multiple 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 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 two types of 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 Appendix I). 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—there would be only a limited number of slots 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 several times. The intervention started in May 2010 when the first B-samples were 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 June 2011, all farmers were revisited for the follow-up survey when the experiment was completed after 12 months. The household data is complemented rich farm-level output data for each farmer in the sample data provided by the dairy processor. On the one hand, it can be assumed that the data is of higher quality than self-reported recall data on output obtained through household surveys, as this weekly reported data—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 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 3.5 when discussing the internal validity of the results.

3. Analytical approach and Results

3.1 Identification strategy and econometric estimation

The impact of third-party quality assessment and verification enforcement is measured for outcome variables outcome variables y in three distinct domains, (a) input use in dairy production, (b) output generation in dairy production, and (c) overall welfare of the farming household. Given the random assignment of treatment and control status, the control group constitutes an adequate counterfactual of the treatment group.

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

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

where ATT is the difference of y_1, the outcome of the treated, and y_0, the counterfactual outcome of the untreated conditioned on the treatment status $w = 1$ which means being treated.

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

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

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

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

where the dependent variable y is an outcome variable, measured at the time t_{+1} after the experiment. Outcome is measured in the three dimensions specified above. 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 t which takes the value 1 if an individual was assigned to the treatment group and 0 otherwise. To measure ATT(x) the simple model is augmented by adding a vector X of dummy variables indicating baseline characteristics at time t_0 such as initial trust towards the dairy company and the affiliation to specific MCCs. Vector X is also interacted with the treatment dummy t which allows for testing whether the relationship between specific baseline characteristics and outcome variables is different conditional on treatment status.

For the analysis of heterogeneous treatment effects we have chosen two types of baseline covariates: First, the variable *baseline trust* is a dummy which takes the value 1 if farmers agreed with the statement that "Vinamilk is a trustworthy business partner" and 0 otherwise.[2] We speculate 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.

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) are believed to capture the

[2] In the baseline survey interviewees had to rate this statement on a four-stage Lickert-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.

effect of unobservable characteristics that make farmers select a specific MCC to supply their milk to (see also Section 2.5).

3.2 Randomization results

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 variable capturing road infrastructure and a time preference proxy[3], indicating that treatment farmers 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. being located closer to a paved road did not make this household more likely to be assigned to the treatment group.

3.3 Attrition

In the study area typical structural change could be observed. 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 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 90, respectively.

3.4 Compliance

As pointed out in Section 2.4 the intervention does not require high compliance rates (primary enforcement), i.e. voucher being executed by a large number or farmers, in order to be effective.

[3] 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 an interest rate of up to 1 % per month is paid.

However, from treatment farmers' perspective a minimum compliance is 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 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 of large farmers. 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 Figures 1a and 1b. The majority of farmers who have not executed vouchers agreed that third-party quality assessment was useful, found it was 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. 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 verification 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, we regard each individual assigned to the treatment group (expect for drop-outs) as treated.

3.5 The impact of the treatment

a) 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. 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 use of purchased concentrate which makes up the largest share of total input costs, we also analyzed the treatment effect with respect to other inputs such as labor or veterinary services and artificial insemination. However, we do not find significant differences between treatment and control group.

b) Output

The regression results for dairy output are 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 12-months-period of the experiment. Apparently the increased production intensity (use of purchased concentrate) has translated into a higher output of valuable milk fat and total solid. In Section 2.3 we had proposed three ways how on 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 at constant 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 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 nitrogen-balance is negative depressing the milk yield (Roth, Schwarz and Stangl, 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 N-balance was not binding anymore. As a result this would have effectively alleviated the constraining effect of low N-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 slightly (but statistically not significant) increase of the average herd size in the treatment group.

The rise in output leads to higher revenues from dairy production which is also presented in Table 2. 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.

c) Welfare

Finally, looking at the impact of the intervention with respect to total household-expenditure we observe a positive impact of the treatment on those farmers who were trustful towards the company before the experiment started and deliver milk to collection center A (Table 2). This is indicated by a negative (but not significant) coefficient of the treatment dummy and the positively significant coefficient of the interaction term of the treatment-and baseline-trust-dummy, controlling for affiliation to collection centers B, C and D. The relatively limited impact on expenditures can be explained by the stickiness of expenditures as welfare measure and the short time horizon of the intervention and thus observation.

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 the higher input levels 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 welfare increased for a subgroup of farmers. 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 speculate that selection on unobservables (e.g. identification with an MCC or dairy processor) into specific MCCs may explain the discrepancy of impact.

3.6 Internal validity

a) Contamination

The completely random assignment of farmers to treatment or control group may have lead to positive contamination, i.e. 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 updates his belief about Vinamilk's type from "unfair" to "fair" after communicating with a neighboring treatment farmer. The ex-post evaluation through specific questions in the follow-up survey indeed suggests that positive contamination might have occurred, since the trust levels[4] significantly increased in both treatment and control group (though more for treatment farmers). As a result the overall treatment effect we measured actually underestimates the real impact of the 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. This could have been achieved only if the treatment status had been assigned across milk collection centers, not completely random. However, given the large number of collection centers required for proper randomization, this approach would have been extremely challenging, administratively and in terms of the budget constraint.

b) 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 until 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 would entirely be the result of Vinamilk stop underreporting quality, not a real gain in output.

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 which allows us to 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).

[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 3.1.

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 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 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 the milk quantity q at constant milk quality levels θ. The positive effect on q is graphically represented in Figure 2 by the jump in *reported* average quantity delivered to the company at t_0. 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. 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. 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 are identical. This is graphically depicted in Figure 2 by the coinciding solid and dashed lines for the domain [t_0, t_{+1}]. If, however, 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[.

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 our intervention. In this case Vinamilk would already have stopped underreporting at some point before t_0. This alternative explanation can be precluded 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 the intervention involving the 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 rules out that the dairy company provided us with "tailored" data to mask structural underreporting of quality.

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 find 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 it seems that Vinamilk could not send a credible signal to farmers that it is not cheating, simply because there is no independent third-party testing of milk in the Vietnamese dairy sector. Hence, rational agents (dairy farmers) formed the belief that the principal underreports quality, and ultimately lowered their expectations about the output price. 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 also could not accrue information rents (potentially outweighing the losses from farmers' suboptimal milk and hence making cheating the dominant strategy). Thus, in a situation in which the principal is of the type "fair" but is unable to send a credible signal, third-party contract enforcement would not only increase the welfare of the agent but would also be beneficial for the principal. If farmers produce more output in a situation of symmetric information on quality attributes, the per-unit transaction costs for the procuring company would decrease. This 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).

3.7 External validity

When designing and implementing 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.

With respect to the external validity of the findings it should also be noted that our results were obtained in an environment which is highly representative for the fast growing Vietnamese dairy sector and generally comparable to the situation in other emerging economies in Asia. We have cooperated with the leading company in the Vietnamese dairy sector to get access to a representative sample of farmers, producing under a standard contract. We believe that the trend in the findings of this particular study is generally 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-tangible 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 cane or protein content of grains—not only in Vietnam but also elsewhere.

4. Conclusion

Contract farming has become a widely embraced tool 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 emerging markets for high-value agricultural products in developing countries.

Smallholders entering contractual relations with processors of high-value agricultural 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 intangible product quality attributes are observable to the buyer but not to the selling farmer. Economic theory suggests that rational buyers exploit this asymmetry of information; expected output prices are lower than in a situation of symmetric information; producers taking this into account may underinvest, i.e. use suboptimal levels of input. Underinvestment translates into lower output levels, a non-desirable outcome for farmers and contractors. Third-party contract enforcement, though, can be a useful way to mitigate the adverse effects of asymmetry of information as suggested by results from laboratory experiments.

In close collaboration with the leading dairy processor in Vietnam, Vinamilk, we conducted a field experiment involving a representative sample of 202 farmers. One half of the dairy producers were completely randomly assigned to the treatment group in which they were provided with the opportunity to verify testing results reported by the dairy company through an independent laboratory. We collected detailed socio-economic data of the participating households during two rounds of surveys, before and at the end of the experiment. This information was complemented with farm-level output data provided by the dairy company.

Employing a multivariate regression framework 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 also can be concluded that in this specific case, the company had not exploited the informational advantage when the contract was yet incomplete, but was not able to credibly signal its type to the dairy producers due to the specific architecture of the supply chain (opaque in-house testing rather than independent quality assessment). This finding has important implications for the distribution of gains from third-party contract enforcement. As the company had not accrued information rents when independent quality assessment was not yet available, it would gain from third-party contract enforcement; if more output per farmer is generated, transaction costs for the company procuring the milk will decrease. This would also encourage the participation of smallholders in high-value markets.

We conclude from the results which were obtained in a realistic and representative contracting environment that independent milk quality assessment mitigates information asymmetry with respect to milk quality and thus leads to higher expected product prices for farmers. When underreporting of milk prices is effectively ruled out, dairy producers allocate their resources more efficiently leading to higher output. More generally, the findings suggest that in agricultural markets in which quality attributes determine the output price but are costly to measure, public support for independent quality assessment and verification would be a way to increase farm productivity to the benefit of small-scale farmers and under certain circumstances also of the contractor—in Vietnam and beyond.

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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 (m²)	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)
Social capital, trust and believes			
If agree to postpone at interest rate <= 1% (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

Table 2: Results of the impact analysis (OLS-Regressions)

	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)	
	ATT	ATT(x)	ATT	ATT(x)	ATT	ATT(x)	ATT	ATT(x)	ATT	ATT(x)
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

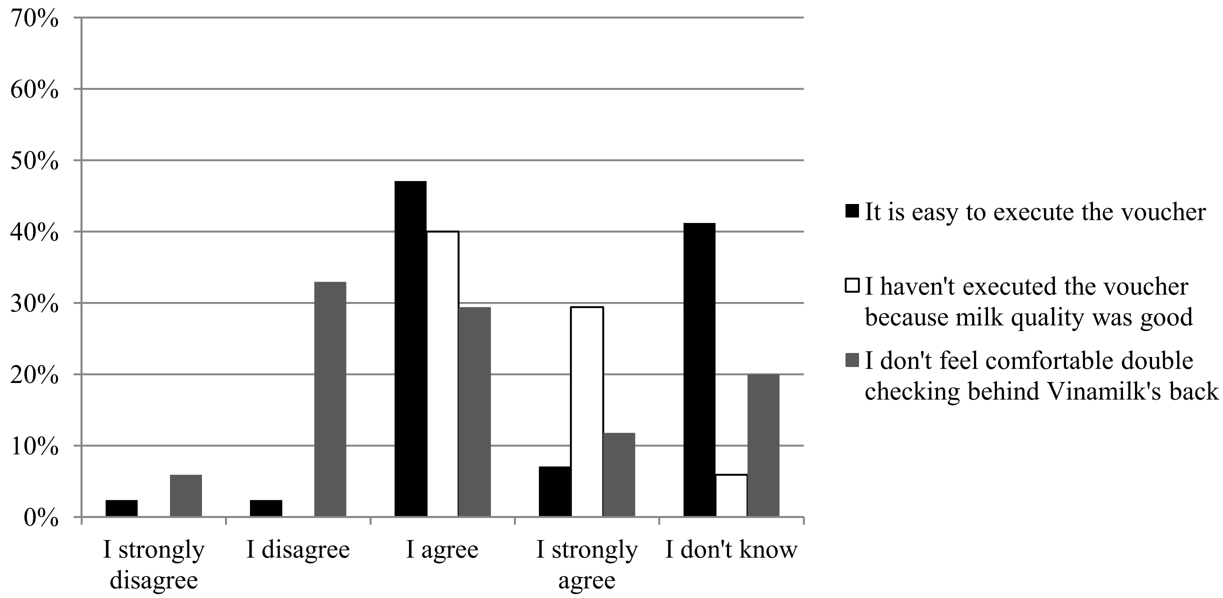

Figure 1a: Farmers who have not executed a voucher evaluate the treatment (n=86)

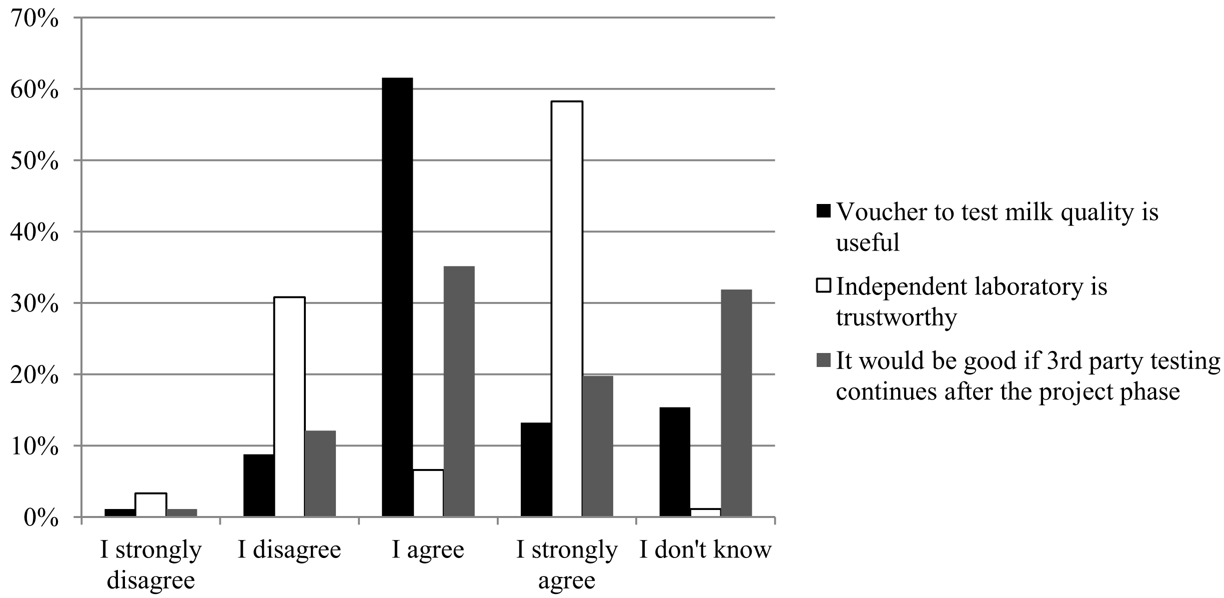

Figure 1b: Farmers who have not executed a voucher evaluate the treatment (n=86)

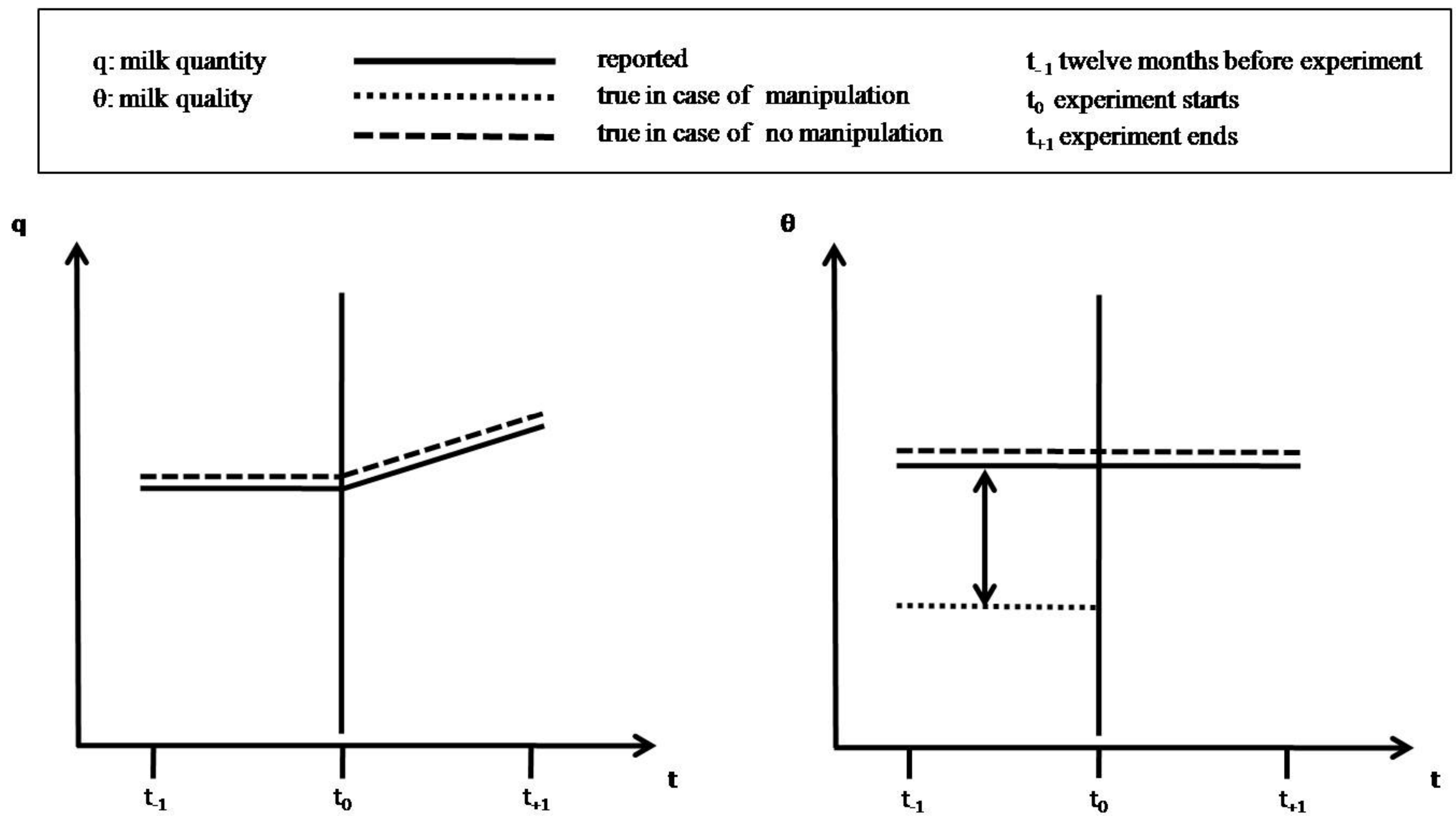

Figure 2: Stylized development of output levels (treatment group) – Data quality

Annex I: Summary statistics of selected variables - pair wise comparisons by milk collection center (MCC)

	Mean (SD in parentheses)				t-tests on differences in means (SE in parentheses)		
	MCC C (n=113)	**MCC B n=(103)**	**MCC C (n=86)**	**MCC D n=(83)**	**MCC B**	**MCC C**	**MCC D**
HH-characteristics							
No. of HH member	4.513	4.641	4.244	4.341	0.128	-0.269	-0.172
	[1.536]	[1.514]	[1.255]	[1.399]	[0.208]	[0.203]	[0.215]
Age of HH-head	45.46	44.66	47.61	47.38	-0.800	2.152	1.918
	[11.53]	[9.161]	[11.74]	[11.39]	[1.426]	[1.668]	[1.665]
Total HH income	74,192,179	82,514,741	67,618,558	73,970,047	8,322,562	-6,573,621	-222,132
(VND)	[49,567,765]	[69,491,153]	[58,362,681]	[53,442,489]	[8,159,607]	[7,683,405]	[7,431,774]
Dairy income	45,968,059	53,551,420	44,313,419	52,171,927	7,583,360	-1,654,641	6,203,868
(VND)	[35,675,422]	[55,525,486]	[53,633,181]	[47,796,603]	[6,305,044]	[6,384,641]	[6,077,842]
Dairy production							
Herd size (heads)	7.611	8.194	7.744	6.398	0.584	0.134	-1.213
	[5.417]	[5.369]	[4.587]	[3.751]	[0.735]	[0.726]	[0.692]
Productivity per	4,051.6	4,925.9	4,477.3	n.a.	874.3*	425.7	n.a.
Cow (kg)	[2,888.4]	[2,229.7]	[2,472.7]		[359.9]	[393.9]	
Avg milk price	6,850.0	6,730.9	6,542.4	6,671.4	-119.2**	-307.7***	-178.6*
(VND)	[275.6]	[294.7]	[416.7]	[772.3]	[39.38]	[49.64]	[79.01]
Total solid (%)	12.63	12.50	12.35	12.61	-0.139	-0.284***	-0.0231
	[0.520]	[0.496]	[0.427]	[0.641]	[0.0704]	[0.0700]	[0.0835]
Milk fat (%)	3.980	3.907	3.862	4.074	-0.0733*	-0.118**	0.0938
	[0.280]	[0.245]	[0.221]	[0.482]	[0.0365]	[0.0371]	[0.0550]
Milk hygiene score	3.572	3.642	3.686	3.578	0.0703	0.115**	0.00616
	[0.368]	[0.205]	[0.162]	[0.465]	[0.0419]	[0.0432]	[0.0598]

*** p<0.01, ** p<0.05, * p<0.10