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Abstract

It is now commonly accepted that poverty alleviation and the development of agricultural value chains in developing countries requires farmers to technically innovate. However numerous constrains to innovation adoption have been identified. In this literature, the price received for each unit of output is usually assumed to be homogeneous among all households. We dispute this over-simplification: because of transaction costs, contract farming and other market imperfections, prices and quantities in developing economies are often positively jointly determined. We develop a simple model to discuss how market segmentation induces non-trivial effects on incentive to innovate. Then we test it on farm-level panel data from an extension project in the Peruvian highlands, where the main income source is the production of raw milk and fresh cheese sold on a highly segmented market. Data confirms the propositions derived from the model: producers that were not included in the formal market at baseline but close to it, have more intensively innovated. The indirect consequence of this investment is a higher price increase than the rest of the population, creating heterogeneous effects of the program, social mobility opportunities and a reduction in inequality. The evidences stress how considering the effects of market structures in developing countries leads to a new understanding of the process of agricultural innovation adoption.

Key Words: Innovation Adoption, Extension Agents, Market Imperfection, Contract Farming, Inequality, Social Mobility

JEL classification: Q13, Q16, O12, O17

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1 Introduction

In most developing countries, agriculture represents the main income generating activity for the major share of the population. The limited alternative income sources confer to this sector a key role regarding poverty alleviation. Because of acute land pressure and/or poor soil fertility, technical progress is a necessary condition for an increase in farmer's production. This requirement has been accentuated by the developments of agri-food markets since the beginning of the 21st century. The most remarkable trend is the reinforced importance of food supply chains which are highly organised and transform and deliver big volumes to growing cities and export markets (Reardon et al, 2003, Reardon and Timmer, 2005). Numerous studies have shown average positive effects of these on farmers' welfare and income (Key and Runsten, 1999, Barrett, 2008, Barrett et al., 2011, Bellemare, 2011). Yet evidence of inclusiveness of smallholders exist but are still scarce (Maertens and Swinnen, 2009; Minten et al., 2009; Briones, 2015) while the majority of the studies finds relatively small farmers still have difficulties participating and benefiting from agri-food supply chains (Barrett et al, 2011). More importantly, some studies even question the high variability of the return for reasons that might not only lie in the size of the farm (Narayanan, 2014).

The improvement of agricultural performance has relied strongly on the efficiency in transferring knowledge and inputs to farmers, often by means of agricultural extension services. Indeed, since farmers' perception of the return to agricultural innovations might be biased, in absence of perfect market for technical information, they might deviate from the social optimum in terms of resource allocation and technology choice (Birkhaeuser et al, 1991; Evenson and Westphal, 1995). Projects aiming at diffusing agricultural technologies are numerous, creating scope for a growing literature on the measurement of innovation diffusion and impact. The portion of this literature that is dealing with the constraints to innovation adoption and diffusion is abundant and shows that a wide variety of factors may influence agricultural innovation adoption in developing areas. Whereas in some cases information problems and lack of education act as a significant barrier (Foster and Rosenzweig, 1996; Weir and Knight, 2000; Dimara and Skuras, 2003; Adegbola and Gardebroek, 2007); in other cases credit constraints (Croppenstedt et al., 2003; Barrett et al., 2004; Minten et al., 2007; Miyata and Sawada, 2007), consumption risks (Dercon and Christiaensen, 2008; Gine and Yang, 2009), poor learning effects due to low density of social networks (Foster and Rosenzweig, 1996; Munshi, 2004; Conley and Udry, 2008), problems of access to, and timely delivery of modern inputs, as well as all the constraints associated with poor infrastructure (Suri, 2009; Moser and Barrett, 2006) turn out to be the most decisive hurdles (see Foster and Rosenzweig, 2010, for a recent survey that puts emphasis on learning effects, and on risk, credit and scale constraints). More recently, experimental approaches are also used to measure the causal impact of each of theses constraints (see for example the Agricultural Technology Adoption Initiative (ATAI) of the Gates Foundation).

Another wave of the most recent research is also trying to assess the return to these innovations (Qaim and de Janvry, 2003; Duflo et al, 2008). Indeed, as Foster and Rosenzweig (2010) emphasized: "Under-adoption is defined as a situation in which there are substantial unrealized gains to the use of a new technology or expansion of input use". Hence, assessing constrains to innovation adoption and diffusion should be done provided a positive return to the adoption exists. More concretely, a lower take-up among poor people does not necessarily mean that a financial constraint is binding unless the existence of a positive return to the technology has been proven for this share of the population. Studies discussing the return to innovation adoption are not numerous. Moreover, most of those studies are unable not only to fully trace the specific impact of technical change proper, but also to disentangle the role of the various factors or mechanisms at play. In particular no attention is given to the market structures farmers face. While it is now reckoned that agricultural supply chains are at the same time drivers of development but may also not be inclusive, this is a serious caveat. In particular the price that a farmer obtains for his production has received little attention and it is usually assume that the same price applies to all farmers. This assumption is known to be far from reality regarding small farmers market conditions. Market in developing countries are ones of the most imperfect and information provision is highly unequal, so that often prices and quantities are jointly determined. An interesting example is Fafchamps and Vargas Hill's research on the coffee market in Uganda (2005) where authors argue that usually in poor countries farmers have the choice between selling their production at the farmgate or travelling to the market where they get a higher price but have to endorse high transaction costs. The former may be the only alternative for poor farmers whose production is not sufficiently high to bear fixed travelling costs, creating a poverty trap for smaller producers. As the authors themselves point out, it is very surprising that this type of decisions and its effects on output prices and farmers' welfare, has not received more attention given the long-standing literature in transaction costs. Furthermore, the flourishing literature on contract farming where the farmers is often guaranteed an advantageous well-defined price structure also gives insights that prices and quantity are highly correlated on agricultural market in developing countries given that small-holders are often documented as being excluded from this type of contracts (see Bijman, 2008 and Holly Wang et al, 2014, for recent literature reviews).

This article tends to fill this gap in the following way. We use detailed information about a successful community extension programme implemented in the Peruvian highlands to understand innovation effects on the distribution of income in the context of a highly segmented market, i.e. where production levels and output price are not orthogonal. In our study area, the segmented market is found on the main agricultural product: raw milk. Indeed, milk processing companies (MPCs), that offer better prices than their competitors, refuse to sign a contract with herders who do not reach a minimum threshold of production. This feature plays a key role in understanding innovation adoption and assessing the opportunities of social mobility. Indeed, given the discontinuous relationship between prices and quantities, one would expect heterogeneous effects of an extension programme aimed at increasing milk quantities, across different levels of production. Households already producing the minimum threshold required by companies are more likely to be already selling their production to this type of buyers, providing them with higher prices. Hence, for those large cattle herders, the major channel of return to an extension programme is through a quantity increase while prices would be stable. However, for households initially located below the production threshold, a quantity increase following an extension programme might push them above the minimum threshold and thereby give them the opportunity to benefit from higher prices. Therefore, unlike initially bigger producers, poorer ones would benefit from a double channel of return: the direct effect of the extension programme on their production volumes and an indirect effect operating through a higher price per litre of milk sold. This heterogeneity in the return to innovation would also induce variation in the innovation adoption behaviour due to different incentives to do so.

Results confirm these expectations. First, we develop a simple model to analyse how the segmented market shapes incentives to innovation adoption. It shows that initially smaller producers will innovate provided it enables them to reach the threshold to enter the high value market. Moreover, with convex cost of effort, bunching at the threshold will also be observed. Data provides the stylized facts supporting the propositions of the model. Then, the econometric analysis reveals that herders who produced a quantity below the threshold required by milk processing companies benefited, on average, from a second channel of return through a price increase. Different identification strategies and tests are offered to assess the effects and the underlying channels. Finally, social mobility is disentangled for the different groups according to their level of innovativeness.

The paper is organized as follows. The next section presents the survey area and the extension programme. Section 3 describes how the segmented structure of the market influences the decision to innovate. Then the theoretical model is developed in the fourth section. The fifth section deals with data and descriptive statistics along with the description of the empirical framework. The empirical results are in section 6 and finally social mobility is discussed in section 7. The last section concludes.

2 The survey area, the programme, and the context of the study

The study area covers the two districts of La Encanada and Hualgayoq, which both belong to the province of Cajamarca, itself located in the northern sierra of Peru. Situated between 3,200 and 4,000 meters, the populations of these districts are among the most elevated communities in the whole country, hence their extreme isolation. The ecosystem of this region of the Andine Cordillera is classified as *paramos*, whose climate characteristics differ depending on the specific location. In the Northern Peru, this type of region is characterized by a rainy and a dry season which both suffer from high variation of temperature during the day and extreme climatic conditions. Moreover, at these high altitudes, soils are poor and agricultural productivity is not only low but also subject to strong variations due to the risk of natural plant burning. Given the above characteristics of the physical environment, the dominant activity from which local inhabitants draw their livelihood is cow herding for milk and cheese production.

In order to increase animal productivity through better health practices (vaccination campaigns), the central government of Peru has initiated a programme known as SENASA (*Servicio Nacional de Sanidad Agraria*) delivering subsidised veterinary services to local herders. This programme yielded disappointing results, apparently for reasons that include low presence of government extension officers on the ground and deep distrust among local inhabitants. It is about at the same time that a Peruvian NGO "Practical Action" (henceforth called PA), stepped in with the same idea of upgrading technical practices among milk herders of the highlands. Drawing lessons from the failure of SENASA as well as from the weaknesses of its own first attempt at extension work, the management staff decided to adopt a market-based participatory approach grounded in the following principles. First, the NGO offered to 20 communities of the selected area to participate in a project of agricultural extension. None of the communities refused. Second, each community had to supply a list of potential candidates to be trained as extension agents. This list could contain permanent residents only, who had to be selected through a democratic election process during a community assembly. A total of 69 candidates were offered to the NGO. Third, from this list, PA selected 42 people to be trained as extension agents, called *promotores*. Besides satisfying a number of criteria decided by PA (minimum age, minimum education, probity, etc.), the trainees had to commit themselves to returning to their native community in order to carry out their extension activities on a business basis. Moreover the objective of the NGO was to group extension agents in three associations. Those associations would have to meet once a month and give the opportunity to its members to share new knowledge and experience but also their concerns and problems regarding their new activity. Each association was provided with a fund allowing it to start buying a stock of inputs. For the sake of sustainability, the NGO selected the extension agents such that they would match with the other members of the association. The output of this selection process left 25% of the communities without any extension agent, representing 23.1% of the population[1]. The rest of the communities received between 1 and 6 extension agents. Note that the length of the list of candidates offered by each community did not vary by more than one candidate. Moreover, a simple check of the EA's geographical breakdown within the project area dismisses the fear of spatial correlation of the number of extension agents between communities. [2]

In this context, the role of an extension agent is multiple. First, extension agents supply the knowledge and inputs for the adoption of new innovations related to the improvement of pasture quality and cattle's health. They also train their community about good practices regarding the management of the cow herd and the production of milk. Those training sessions were usually given once a month, during the community assembly. Note that each man, aged between 18 and 65 years old and belonging to the community, have to attend the community assembly so that the training given at this occasion is likely to help reinforce the community dynamism and cohesion[3]. Finally, they may also act as a signal of innovativeness with regard to buyers of raw products, in such a way that EA could help attracting new intermediaries. An essential yet unintended feature of the programme is that the services of *promotores* are typically not confined to their community of residence. Indeed, extension agents moved to neighbouring communities in order to supply services. Contamination thus happened. Yet, contamination could happen only for the individualized services, and not the community training, since the

[1] The objective of the NGO was to train other waves of extension agents but they finally end up training another type of agents, that will be discussed later one.

[2] Started in July 2002, the base training programme ended in September 2003. Afterwards, training continued in the form of occasional one-day follow-up sessions that were organised upon request from one of the associations of promotores, or a subgroup of them. The extension support programme of PA in the region stopped in June 2007.

[3] In particular, we know that with the help of the NGO, extension agents achieved the reinforcement of major portions of the irrigation system at the community level.

assembly communities are restricted to community members only (Piccoli, 2008). Moreover, the *promotores* survey reveals that extension agents moved for one innovation in particular, the vaccination of cattle, which is the most profitable.

3 The milk market : segmentation on a fixed threshold

Households draw the major share of their income from milk production. In our sample, this share corresponds to 85% of the household income on average. Milk can be sold under two forms: either fresh or after having been transformed into fresh cheese called quesillo. Fresh cheese is sold to intermediaries on one of the three weekly market located in the area. The price for this product varies highly during the year but is weekly fixed on each market place and there is not formal market. Therefore, we will not consider this type of producers who corresponds to 38% of the population. The price received for fresh cheese is lower than the one received for the equivalent unit of fresh milk, the latter being a higher quality product which is more difficult to produce and sell given it is perishable. Indeed fresh cheese can be preserved during a week while milk has to be sold the next day after cow milking at the latest. Hence, households producing fresh cheese are usually poorer and more isolated. Moreover, producers are fully specialized: they sell fresh cheese only if they don't have access to the milk market.

There exist three channels to sell fresh milk. First, it can be sold to one of the two companies collecting it in the area: Nestle or Gloria[4]. Alternatively, milk may be sold to small rural undertakings located in the communities. Finally, the producer can go through an intermediary producer who would then sell the raw milk to one of the two former types of buyers. According to Boucher and Guegan (2004) who did an extensive survey in the area, in order to get a contract with one of the two multinationals, the producer must comply with a minimum production: *"The enterprise requires 10 litres daily... hence the small producers are excluded"*[5]. Hence if they cannot reach this minimum quantity, households sell to one of the two other types of buyers who usually pay a lower price than Nestle and Gloria. Built on our sample of households, Table 1 confirms that households producing less that 10 litres per day receive on average a lower price per litre of milk than the more productive households, whether the baseline and the endline are merged (column 1) or taken separately (column 2 and 3). Moreover, above the threshold, no significant positive correlation is found between the price received and the quantities sold[6].

During the time of the programme, 21% of the milk producers shifted beyond the threshold of 10 litres[7]: this proportion

[4]Note that Gloria entered the area in 2004, that is two years after the beginning of the programme.

[5]Own translation from Boucher and Guegan (2004) "Queserias Rurales en Cajamarca", p.73, line 6

[6]It is worth adding that both companies are the only ones who can measure the actual quality of the milk, that is the fat content, since doing so is very costly. Hence, the actual quality cannot be observed below the production threshold (10 litres per day). The fat content is measured when the contract is settled and is rewarded by a small premium above the minimum price fixed by milk processing companies. Then spot controls are performed randomly by both enterprises during the year.

[7]Note that this proportion corresponds roughly to the increase in the market size of both Gloria and Nestle, in the study area, between the baseline and the endline (Boucher and Guegan, 2004)

corresponds to almost 50% of the households who produced initially less than this quantity. For those "*shifters*" the average price received for each litre of milk increased relatively more than for the other producers. It bears emphasis that the "*shifters*" were on average located significantly closer to the threshold than those who remained at lower levels of production. Interestingly, in the communities hosting at least one extension agent, "*shifters*" were on average located at a higher distance from the threshold than in the remaining communities, indicating that extension agents might have had a positive discriminatory effect favouring producers with relatively low initial volumes. Still, although closer to the threshold, shifters increased their produced quantity more than the rest of the population on an average. Note that this group of producers might be very heterogeneous hence we will spent time in the next section to disentangle the different types of their profiles. The higher production increase is likely to result from a greater innovativeness given that "*shifters*" innovated more than the rest of the population and they invested especially in innovations impacting the quantity produced instead of the quality[8] (see Table **??** in Appendix). Finally, at baseline, shifters had significantly bigger cow herd than producers who remained below the threshold and they increased it significantly more (see results of Table **??** in Appendix).

Finally, the averages of prices and quantities at baseline and endline are reported in Table 2. The following remarks are worth mentioning. First, the key evidences of the existence of a segmented market are present. Indeed, producers above the threshold produced more than the remaining categories at baseline while "shifters" increased significantly more their produced quantities than the remaining producers. Moreover, both categories of producers below the threshold at baseline received similar prices, significantly lower than the "above" category. At endline "shifters" reached the same level of prices as the "above" category and "still below" remained at significantly lower levels on average. Interestingly, the difference of the average price at baseline between producers below and above the threshold is three times that of endline. This might be a first evidence of the existence of positive externalities generated by a critical mass of above-the-threshold producers in a given community.

4 Modeling innovation adoption in the context of segmented markets

We develop a simple model to explore the incentive given by the price reward in the decision to innovate. The individual utility function is a profit function that depends positively on production and negatively on effort, assumed to be strictly proportional to the increase in quantity (no scale economies). If we assume a linear budget set with constant marginal cost, individual production levels q are distributed according to a smooth density function $h(q)$. In period zero i.e. baseline, when there is no innovation possibility, the heterogeneity in q is due to difference in preferences, ability or endowment, all of them being captured by heterogeneity in the utility function $u(\pi; q)$.

Suppose producers sell their production on a segmented market with p_l, the unit price received if total production is

[8] Note that producers belonging to the *"shifters"* category were significantly less prone to adopt innovations involving the use of improved food for cows (innovations 8 to 11).

lower than a fixed $\bar{Q}$ and $p_h = p_l + a$ with $a > 0$, otherwise.

Now suppose the possibility to innovate is introduced. We assume there is no liquidity constraint to the adoption of a new innovation. When innovations are supplied, the household can increase its initial production q_i by x_i, for a fixed unit cost c such that $\frac{c}{p_h} < x_i < \frac{c}{p_l}$, for each i. This means that it is profitable to increase output by x_i yet only if the producer can obtain price p_h. Therefore, if then q is the quantity produced at baseline and Q is this quantity at endline, we have the three following cases :

Case I : if $\bar{Q} > Q_i \geq q_i \Rightarrow$ no innovation
Case II : if $Q_i \geq q_i \geq \bar{Q} - x_i \Rightarrow$ innovation adoption
Case III : if $Q_i \geq q_i \geq \bar{Q} \Rightarrow$ innovation adoption

Case II corresponds to the shifters' decision choice while cases I and III correspond respectively to a situation in which producer remain below the threshold $\bar{Q}$ and a situation in which producer were initially above this threshold. We assume that producers will not disinvest that is, producers initially above the threshold remain so in the second period.

Now, assuming a convex cost of effort associated to innovation, cx^2, the net benefit in second period from the innovation investment in first period, for a given producer i:

$$\Pi_i = (p_2 - p_1)q_i + p_2 x_i - c x_i^2 \tag{1}$$

where p_1 is the unit price received in the first period and p_2 the price received in second period, and

$$p_1 = p_2 = p_l \text{ if } \bar{Q} > Q_i \geq q_i$$
$$p_1 = p_l < p_2 = p_h \text{ if } Q_i \geq \bar{Q} > q_i$$
$$p_1 = p_2 = p_h \text{ if } Q_i \geq q_i \geq \bar{Q}$$

If $q_i < \bar{Q}$, it will not be optimal for the producer to reach $\bar{Q}$ if he is better off remaining below the threshold than "shifting", that is if:

$$p_h \bar{Q} - c(\bar{Q} - q_i)^2 < p_l Q_i - c(Q - q_i)^2 \tag{2}$$

where $Q_i < \bar{Q}$

If we define $Q_i = \bar{Q} - \beta_i$ with $\beta_i > 0$ then (2) is equivalent to :

$$(p_h - p_l)\bar{Q} + p_l\beta_i + c(\beta_i^2 - 2\bar{Q}\beta_i + 2q\beta_i) < 0 \tag{3}$$

Proposition 1 *Producers will reach the threshold if $(\bar{Q} - q_i)$ is low enough, that is, if they are initially located at a distance close enough to $\bar{Q}$. If $(\bar{Q} - q_i)$ is high enough, we cannot rule out the possibility that there exists a x_i such that $p_l = 2cx_i$ and $x_i < \bar{Q} - q_i$.*

Proof. : given $(p_h - p_l)\bar{Q}$ and $p_l\beta_i$ are strictly positif then the condition (3) is impossible to satisfy if $\frac{\beta}{2} \geq \bar{Q} - q_i$

■

The next question is : assuming that $x_i \geq \bar{Q} - q_i$, will producers "bunch" at $\bar{Q}$?

The problem is then :

$$\max_{Q} \Pi_i^b = p_h Q_i - c(Q_i - q_i)^2 \tag{4}$$

and the interior solution to (2.4) is :

$$Q_i - q_i = \frac{p_h}{2c} \tag{5}$$

Bunching will arise if there exists a corner solution to this problem, that is if and only if :

$$\left.\frac{d(\Pi_i^b)}{dQ_i}\right|_{Q_i = \bar{Q}} < 0 \iff \frac{p_h}{Q_i - q_i} < 2c \tag{6}$$

Proposition 2 *With convex cost of effort, bunching will arise if c is high enough or p_h low enough or $(\bar{Q} - q_i)$ large enough.*

The intuitions behind the effects of the parameters on the share of producers that will stick to the threshold are the followings. First, if the unit cost c is high, the total x that can be supported is small, hence the share of producers that will not find profitable to go beyond the threshold will be high. Second, if p_h is low, the price reward of shifting above the threshold is low, so is the x that can be covered, hence the lower share of producers that will afford to go beyond the threshold. Third, when $(\bar{Q} - q_i)$ increases, the threshold is reached at a very high cost, hence the probability that the producer is facing a high marginal cost at $\bar{Q}$, such that it will not be profitable to go beyond this level of production. The generalizability of proposition 2 is limited to effort functions characterized by convex cost.

We will then proceed to the empirical investigation of the implications of this model in our case study. Note that in this context, a big set of innovations are available, among which many are divisible. This characteristic was approximated by the continuity of x in the theoretical model.

5 Data, Descriptive Statistics and Empirical Framework

5.1 Data

In the 20 communities covered by the *promotores* programme, all residents have been informed about the PA initiative through their participation in local popular assemblies (*the asemblea de ronda*) which also elected the programme trainees. According to the NGO's record, this corresponds to a population of 2021 households. From this population, a random sample of 423 household heads has been drawn by the NGO staff so as to include a proportion of (about) one-fifth of each community. Key characteristics of these potential innovation adopters have been collected just before the project, in year 2002. This information was completed by a second wave of surveys done in 2007, after the project, and collected by an independent survey enterprise with the help of local extension agents. The baseline and the endline databases were collected at the beginning of the rainy season (mid-November) and contain the same set of information on assets (cow herd and other animals, land pasture, irrigation infrastructure, etc), income sources (dairy products, handicraft, vegetables, etc) and prices and quantity for each income source. For both latter measures, households were also asked to provide information for the dry season. Descriptive statistics are reported in Table **??** and **??** in the Appendix.

5.2 Stylized facts on innovation adoption

In this section, we check if the propositions derived from the model find support in our data.

First, following proposition 1, we expect to observe in our data that producers initially located at lower levels of production innovate less, due to their lower expected return to the investment following the lower probability to reach the threshold for a given innovation. In Table 3, we regress the number of innovations adopted at endline on the initial level of production. We gradually increase the threshold from 4 to 10 litres per day. It appears that producers with lower levels of initial production innovate systematically less than the rest of the population : this is reflected in the negative coefficient associated to each dummy standing for a given level of below-threshold initial production and in the decrease in the correlation obtained as this level is raised (Table 3), though at a negative speed, as expected. The same pattern is observed on the decision to adopt a particular innovation, each innovation being taken separately (result not shown)[9].

Second, if bunching arises, we expect to observe among shifters, a positive correlation between the distance to the threshold and innovation intensity, that is, producers initially closer to the threshold would innovate less. They would do so such that their investment will enable them to reach exactly the threshold. This pattern would be translated into a positive correlation between the initial distance to the threshold and the increase in milk output between both periods. This correlation is reported in Table 4, on the variation of quantity sold in rainy season between both periods, with household fixed effects. We also test the effect by excluding producers below a given production level and look at the correlation between the distance to the threshold and the increase in quantity. The same pattern emerges.

Overall, in terms of social mobility, both patterns would be translated into intensive social mobility for producers initially located below the threshold and a quasi-static situation for producers at initial production levels higher than the threshold.

5.3 Empirical framework

The objective of this section is to identify the existence of different price effects according to the producer' initial position to the threshold. The approach used consists in a non-randomized difference-in-differences where the threshold and, latter on, the distance to it, are used to identify heterogenous price increase between baseline and endline years. This method controls for systematic differences between groups that are constant over time. However, it is likely that producers self-select relatively to the threshold so that their initial position is not randomly assigned. In other words, it might be that producers have particular characteristics that are not orthogonal to the their position to the threshold and might explain differences in the evolution of the price received for each unit of milk. The regressions will therefore include controls for the time effect of observed differences at baseline, at the household and community levels. Relevant characteristics varying with time will also be controlled for. Finally, the existence of alternative mechanisms will be discussed. The biggest threat to the interpretation of the findings in terms of innovative behavior would be if there exist market changes or community developments that would benefit more the producers at lower levels of production. To check for this effect will be done by controlling for different market and community variables varying with time and insuring that the household channel suggested is indeed the main one.

Our analysis of incentives to innovate and the resulting quantity increase identified the distance to the threshold as one of the deterministic characteristics. In this section, we use a corresponding reduced form specification to analyze the price evolution during the intervention. Our strategy is the following one. First, we simply regress the price received for each unit of milk at baseline and endline on a dummy taking value one if the household was initially located below the

[9]It is worth pointing that controlling for market incentive or community characteristics - which includes the EA's supply of innovation - through the introduction of a dummy for MPCs presence or community fixed effects, does not affect the results

threshold, with household and time fixed effects and clustering data at the community level. That is, we use the threshold to compare the average increase in price between both groups of producers, whatever their position relatively to the threshold at endline. Then we disaggregate this group of producers below the threshold between three categories according to their initial distance to the threshold: the category called "upper" refers to producers just below the threshold, the category "medium" is for producers producing between 6 and 8 litres at baseline and the last category called "lower" is for producers who initially produced less than 6 litres. Hence instead of using the continuous measure of distance to the threshold, we allow for a non linear effect of the initial position below the threshold.

The equation estimated is the following one:

$$\begin{aligned} price_{ict} = \alpha + \beta_0 DrySeason_{ict} + \beta_1(Time_t \times Below10litres_{ict_0}) \\ + \Gamma_1(Time_t \times HouseholdControls_{ict_0}) + \Gamma_2(Time_t \times CommunityControls_{ct_0}) \\ + \Gamma_3(HouseholdControls_{ict}) + \Gamma_4(CommunityControls_{ct}) \\ + \delta_i + \lambda_t + \epsilon_{ict} \end{aligned} \tag{7}$$

where $price_{ict}$ is the household unit price, measured in both periods, for the rainy and the dry seasons[10], hence the term $DrySeason_{ict}$ accounts for the systematic permanent differences between both seasons[11]. The model used is OLS with household and time fixed effects. Standard errors are clustered at the community level[12]. In this equation, the coefficient we are interested in is β_1: the effect of the baseline position to the threshold, taking value 1 for household initially below the threshold.

6 Empirical Results

The first set of results is reported in table 5. The first two columns contain the output of the regression 7 for the entire sample of producers. Prices increased massively between both periods but overall we do not observe any significant differences for producers at lower initial levels of production. However, if we allow for a different trend in communities directly served by big processing companies, different effects emerge. We do so by either reducing the sample to the communities served by MPCs (column 3 and 4) or by allowing a different time effect in both types of communities through a triple interaction (column 5 and 6)[13]. The advantage of the second specification is that it avoids the loss of power due to sample reduction. In both specifications, a significant higher average time effect emerges for producers initially below the threshold but only in communities where trucks of big processing companies can pass i.e. MPCs. When we disaggregate the group

[10]That's why, the number of observations reported in each table is four times the number of households considered, that is two measures for both periods.

[11]Then the differences in the price effects between both seasons were tested by running the same regressions on the rainy and on the dry seasons, separately. Results can be found Appendix in Table **??** to **??**.

[12]Given the small number of clusters, each regression will then be bootstrapped to control for biased due to the "Moulton Factor" (Angrist and Pischke, 2009 ; Moulton, 1986). Results are robust to this test.

[13]Descriptive statistics and mean difference between MPCs and non MPCs communities are reported in Table **??** and **??** in Appendix.

of below-threshold producers, it appears that the positive effect on prices is higher for producers that produced at most 2 litres from the threshold (the "upper" category), while the coefficient is on average divided by two for producers at a higher distance (column 4 and 6). Note that there is no significant difference between the coefficient associated to the medium category and the herders at lower production levels at baseline. The coefficient associated to each category corresponds to the share of producers who passed the threshold between both periods times the average price gain of shifting beyond the threshold. With the distance to the threshold, the former term increases while the latter one decreases. Moreover, with convex costs of innovation, our model predicts that the share of producers who will decide not to pass the threshold will increase more rapidly than the price gain associated to the shift to the formal market[14]. This is coherent with the relative size of the coefficient associated to categories of distance : the average total effect on price decreases with the distance to the threshold. Finally, in the last two columns, results resist to the introduction of controls at the household and community levels. At the household level, those controls are the pasture size and a dummy for the irrigation technology used by the household[15], in both periods. Note that the irrigation control is justified by the fact that an important share of the irrigation system was modernised thanks to the EA initiative, hence the quality of the household irrigation technology is not entirely the consequence of his own innovative behaviour. Then at community level, the set of variables includes the time effect of community controls at baseline and characteristics of the communities evolving with time. The former includes the number and the quality of roads linking the community to others ones and the distance to the closest fresh cheese market at baseline. The latter covariate is the presence of small rural enterprises in the community (in each period).

The next step is to proceed to falsification tests in order to ensure that the positive price effect found for households below the threshold is indeed located around the production level of 10 litres a day, required by big processing companies. To do so, results must resist to a smaller window around the threshold. Moreover no price effect should be found when we replace the actual threshold by a fake one or when we consider the upper share of the distribution already producing the quantity corresponding to the actual cut-off. Table 6 offers the three following falsification tests. First, in the first two columns, the regression of column 7-8 of Table 5 (i.e. with controls) is run on the sample of observations restricted to the window of 4 to 16 litres per day, that is, 6 litres below and above the threshold, at baseline. Results resist to the reduction in the number of observations, though they are less significant. This provides evidence that the discontinuity in the price received is indeed located around the threshold of 10 litres per day. Second, we test the existence of different fake thresholds. To do so, we apply the same econometric model by replacing the threshold of 10 litres by different thresholds above the true one. We first look at the coefficients associated to the price increase for producers below those fake thresholds, on the entire sample. The coefficients associated to the threshold dummies appear to be less significant and smaller than the one associated to the threshold of 10 litres. Then we reduce the sample of observations to producers above the threshold of 10 litres only. We verify that the coefficients associated to the various fake thresholds are never significant. Results are reported in Table 6 for the fake threshold of 15 litres (column 3 and 4). The combination of both results is another confirmation that

[14] This is the case if the quantity increase is a linear function of the innovation investment.

[15] Four dummies corresponding to each technology : natural irrigation, water conveyed by a central canal, access to a secondary channel infrastructure and irrigation through sprinkling). The reference category is the first technology.

the price effect is located around the true threshold of 10 litres and not beyond. Indeed, the significant and lower effect found for the entire population (column 3) reflects a dilution mechanism born of the fact that we mix up producers located below the threshold with producers initially at higher levels of production (10-15 for the fake threshold of 15 litres reported in Table 6). This effect completely disappears if we reduce the sample to the producers above the threshold (column 4). Finally, the last two columns of Table 6 provide evidence that there is almost no correlation between the increase in quantity produced and the price increase for producers whose production was at baseline at least 10 litres a day. It is also worth pointing that an equivalent increase in quantity sold has a higher price effect below than above the threshold, which is another evidence that the price effect is the result of the segmentation of the market (results not shown).

Finally, we can now try to better understand the mechanisms involved. First, the price increase ought to be tested against other channels than a shift to the most profitable share of the segmented market. Second, one would like to identify what is the channel through which producers at lower levels of production increase their quantity.

The very first interesting test to be done is the introduction of the milk quantity as a control in the specification of Table 7, when the group of producers below the threshold is disaggregated according to the distance to the threshold. Indeed, if the channel of the price increase is the quantity produced, this variable should cancel out the effect associated to categories of producers initially below the threshold. However, we expect heterogeneous effects between categories. Indeed, this is the result of the theoretical part suggested: with convex cost of effort, it is increasingly difficult to shift beyond the threshold as the distance to it increases. Hence, we expect the price effect associated to the categories further away from the threshold to be driven by groups of producers that are more homogeneous in term of production increase than the category close to the threshold. Given the nature of the relationship between price and quantity, we allow for a different effect for producers initially below and above the threshold. Results confirm the heterogeneous effect according to the distance to the threshold (column 1 of Table 6). Indeed the introduction of the quantity variable cancels out the significance of the coefficient associated to each category of production level except the one just below the threshold (i.e. the "below threshold_upper" category). It reflects the fact that the price effect for groups of producers whose production at baseline was inferior to 8 litres per day is the result of a quantity increase and that it exists mainly for the producers in this groups whose production increased massively. To the contrary, producers close to the threshold can access the formal market even if they do not outweigh the average production increase of the population.

Then let us look at the origin of the production increase : it can be either the result of an input increase, that is the size of the cowherd, or an increase in the productivity per cow (the average number of litres milked per cow per day). Both channels are tested in Table 6 by replacing the variable of milk quantity by its cowherd size counterpart in column 2 and by the average productivity of the cows owned by the household, in column 3 (column 4 contains both). As for the quantity counterpart, we allow for a different effect for producers initially below and above the threshold. It appears that both variables completely clean up the price effect associated to the medium category of producers while this is never the case for the lower category. Hence producers belonging to the medium category and whose production increased such that they benefited from the price effect, did so through both a capital and a productivity increase, though the effect appears to be stronger for the cowherd size (observe the reduction in the size of the coefficient associated to the category at stake). Finally, it appears that the EA played a role in the higher price increase for this category of producers given that controlling for the number of EA living in the household's community leads to the same results as the introduction of the herd size or the cow productivity (column 5 of Table 6).

Regarding producers belonging to the lower category, the origin of the price effect is still not clear. According to column 1, the price increase is explained by an increase in the quantity of milk sold however this is not entirely due to an increase in production capacities (according to column 2 to 4). Interestingly, it seems that a big share of those producers did not shift above the production threshold yet increased their price to the same level as their more productive neighbours, hence benefited from a new contract with one of the two MPC. It is especially the case in communities where a bigger share of the population shifted beyond the threshold. Moreover, the correlation between the price received at endline by producers still below the threshold and the proportion of their community neighbours who produce more than 10 litres a day (controlling for clusters standard errors correlation) is positive and highly significant[16]. This is a first evidence of positive externalities generated by a critical mass of above-the-threshold producers. In other words, the processing company would look at aggregate rather than individualized quantities to decide whether to buy the milk[17]. To test for the existence of such an effect, in the sixth column of Table 6, the share of producers producing more than 10 litres is controlled for. Again, we allow for a different effect for producers initially below and above the threshold. The introduction of the time effect of this community characteristic appears to completely clean the price effect of the lower category of producers which can be seen as an evidence that the remaining effect for this category was due to positive externalities from more productive households.

A question remains on the role played by the EA in the innovation process. Descriptive statistics revealed that shifters in EA communities are on average located at a higher distance from the threshold relatively to communities where no EA resides (see Table **??** in Appendix). That is, bigger effects for producers below the threshold are found in communities where EA lives relatively to communities supplied by non resident EA. This is confirmed by column 7 and 8 of Table 6. Note that in MPCs area, all communities are serviced by at least one resident EA. That's why we would like to disentangle the effect of the EA programme and the effect associated to the higher incentive to innovation in the MPCs area. To do so, in column 7, the entire sample is considered and two interaction terms are introduced : the time effect for producers initially below

[16]The same results are obtained from a regression on the MPCs' population, either of the price at endline or of the evolution of price between both periods, on the proportion of producers above the threshold, controlling for the individual quantity to produced or the individual's category (those controls are necessary because the higher the proportion of producers above the threshold, the higher the probability that the individual himself will be above this threshold).

[17]Insights of the existence of such positive externalities already showed up in the previous descriptive statistics. Indeed, in Table 2, the higher standard deviation of milk prices at endline for the category of "still below" relatively to the two remaining categories was another evidence of heterogeneous effects between producers which we now know are in fact happening between communities. Comparing those averages between communities according to their share of shifters gave us another evidence of the existence of positive externalities : in communities with more than 90% of producers above the threshold, there is no significant difference between the price received on average by producers still below the threshold and those who shifted while in the remaining communities the difference between both groups is highly significant.

the threshold in the community where at least one EA lives and the time effect for this same group of producers in the community serviced by MPC. It appears that both interaction terms are positive and significant though the one associated to the effect in EA communities is lower and significant only at 10%. When we investigate those effects between the 4 categories of producers considered before (above versus the 3 categories of producers below the threshold according to their distance to it), the effects are similar (column 8). Indeed, the coefficient associated to the time effect for the categories of producers below the threshold is always higher in the MPCs communities but the sum of the effects for producers living in EA communities that are also serviced by MPCs is always positive and significant (as confirmed by a Wald Test of the joint significance).

7 Social mobility

The question remains as whether the combined effects on revenue induced mobility along the income distribution. In particular, *"shifters"* are expected to be *upwardly mobile*. The matrix of mobility is reported in Table 8. The columns refer to the quantiles at baseline while the rows contain the quantiles at the endline. Each cell reports the percentage of households belonging to the quantile of the column who moved to the quantile mentioned in the row. Hence, the total of each column is 100%. In complete absence of mobility, the downward diagonal would be characterized by a succession of 100 while the remaining cells would report zero's only. This is very far from what is observed in Table 8. Indeed, as expected the percentages contained in the extreme cells of the diagonal are higher than 50, reflecting few mobility of the extremely poor and extremely rich households. However when progressing to the center of the downward diagonal, the percentages decreased. Hence economic mobility is at play. In particular, 31% of the households moved upward by at least one quantile. In this group of *"upwardly mobile"* producers, the *"shifters"* are highly represented since they count for 52% of this category (remember that they account for 20% of the total population) while the proportion of them who increased by at least one quantile is 70%.

Now, it would be interesting to investigate the difference in social mobility between MPCs and non MPCs area. Indeed, the econometric analysis revealed that the positive price effect exists only in the community served by big companies, when the threshold of 10 litres is tested. However, one would expect that a different threshold applies for households that are located further away from the collection road of big companies, that is a $Q + \gamma$, γ refereeing to the transaction cost borne by the producer to reach the collection road. The mechanism behind this would be in line with the story of Fafchamps and Vargas Hill (2005) that is, if the household does not belong to a community directly served by MPCs but produced at least the minimum production required by big processing companies, he will have to bear himself the transportation cost to bring his production to the collection point. While testing the existence of a different threshold in the non MPCs area, a positive price effect emerges for the households initially producing less than 13-14 litres, on average (see Table in Appendix). To obtain this result, we need to control for community variables related to market opportunities (to give same size producers the same opportunities whatever the characteristics of their communities - openness, etc). If we do not control for them, no threshold emerges significantly, suggesting that there are different thresholds between communities according to their characteristics. In line with this finding, it also appears that the higher the distance to the geographical entry point of MPCs to the surveyed area (i.e. the main road leading to the city of Cajamarca), the weaker the link between the price and the quantity produced. In the relatively remote communities, there is even no correlation between price and quantity and prices are in general much lower. We also observe that in those areas, the level of innovativeness is in general lower. Moreover, among households producing initially less than 10 litres a day, we find that the level of innovation adoption is smaller in the communities that are not directly serviced by big companies.

Therefore, we expect higher rates of social mobility in communities with good access to the milk market. This is precisely what we find : social mobility is higher in area serviced by MPCs than in area where MPCs are not collecting milk at the farm gate. Moreover, shifters are over-represented in MPCs communities : 56% of them lives in a community where MPCs collect milk at the farm gate while those communities represent 46% of the total population. In addition to that, 68% of the producers who moved by at least one quantile lives in MPCs communities. The second dimension along which we expect to find different trends between communities is the intensity of the EA programme. Indeed, as expected, we also observe more mobility in area with more resident EA. Moreover, shifters are over-represented in those communities, that also host a higher share of the upwardly mobile population.

Finally, we may want to look at the inequality evolution between both periods, between the different groups[18]. To start with, two observations are worth mentioning. First, the overall inequality increased during the time of programme: the general entropy and Atkinson indices and the percentile ratios p90/p10 show a deepening of inequality (Table 9). Second, the income share of the MPCs area increased slightly while the total income share of EA versus non EA areas displays stability. Focusing on the MPCs area only, the trend is different from the overall one: a reduction of inequality is observed as reported in Table 9. In line with the findings of this paper, the inequality reduction in those communities appears to have happened through a reduction of inequality between the categories of producers defined by their initial position relatively to the threshold. Indeed, we observe a strong reduction of inequality between both groups above and below the threshold while inequality within those groups of producers remained stable, reflecting an overlap of both groups income during the time of the programme. Interestingly, the income share of the "above" category relatively to its "below" counterpart has reduced substantially : at baseline the group above the threshold held 82% of the total income while at endline this percentage fell to 70 (see Table 10). Within producers initially below the threshold, the income share of those who shifted has increased tremendously, going from 56 to 81%. Finally, we look at inequality between the groups of "shifters" and "above" and the potential of the programme to reduce it. Inequalities are still very high between those groups, yet the income share of "shifters" doubled from 13 to 26%. Hence, this is another evidence that the price catalyst had the power to reduce inequalities between the producers already on the formal market and the newly included.

[18] In order to stick to the income of interest here, we will only consider the portion of income that is drawn from milk production. This portion corresponds to an average of 85% of the household income.

8 Conclusion

For years, innovations adoption has been largely promoted among primary producers of agricultural supply chains. Because the main objective of a farmer in adopting innovations is to increase her agricultural revenue, the design and promotion of agricultural innovations should not be done without considering the market characteristics on which farmers sell their products. Markets in developing countries are known to be highly imperfect and characterized by high transaction costs, putting smaller farmers at a disadvantage. We use detailed information about a successful community extension programme implemented in the Peruvian highlands to understand innovation incentive and effects on the distribution of income when prices and quantities are jointly determined. The focus is on the evolution following the intervention. The existence of a discontinuity in prices induces heterogeneous incentives to innovation adoption. Indeed the higher the effort required to access the formal market, being more rewarding, the lower the likelihood of a positive return to innovation adoption and hence the lower the incentive to innovate. For farmers who manage to put the necessary effort, the reward is doubled as they not only benefit from a higher volume but also from higher prices, pushing them upward the income distribution. Evidence suggests that the increase in volume is mainly driven by an increase in the cattle herd that is likely to have happened through the decrease in the cow mortality, supported by qualitative evidence. On the other hand, the price mechanism is an indirect effect that arose through the quantity channel insofar. Indeed, herders who succeeded in increasing their milk sales above a given threshold could benefit from a perceptible price increase. The proportion of the population who could benefit from such a channel is high since 50% of the initially smaller producers passed this threshold during the time of the programme. Those producers were more innovative than the remaining ones and moved upward the sample income distribution.

Yet we showed that two factors had the ability to counterbalance the disadvantage of really small farmers. First positive externalities at the community level exist whereby processing companies would look at aggregate volumes and hence also integrate smaller farmers in highly performing communities. Second extension agents had the ability to support their own neighbours in such a way that these innovated more than similar farmers living in communities where no extension agents reside. Overall inequality reduced in communities serviced by milk processing companies.

The welfare implications of the programme and its interaction with the segmented market will depend on the absorption capacities of the formal market. If milk processing companies cannot increase their production capacities at low cost, they would be tempted of reallocating their demand towards geographical areas where transaction costs are low. This might affect producers who are already included in the formal market but who are suffering from higher transaction costs because they live farther away from the collection roads or they are surrounded by small producers.

In a nutshell, we showed that the combined effects of agricultural extension and segmented market had the potential to partially counterbalance the natural disequalizing path dependence effect of wealth, in the context of very isolated communities, characterized by strong social ties and drawing their income from a highly imperfect market. The evidence stress how considering the effects of market structures in developing countries leads to a new understanding of the process of agricultural innovation adoption.

TABLES

Table 1: Correlation between the price per litre of milk and the position relative to the threshold set by MPCs

	milk price in rainy season		
	both periods	baseline	endline
	(1)	(2)	(3)
below threshold (dummy)	-5.1191***	-6.4050***	-6.2223***
	(1.3295)	(1.8928)	(1.5451)
N	462	229	233
r2	0.0410	0.0711	0.0880

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

Table 2: Differences in mean price and quantity between the three categories of producers, in MPC's area

	category 1 *"above"*	category 2 *"shifters"*	category 3 *"still below"*	Diff(1 - 2)	Diff(1 - 3)	Diff(2 - 3)
price at baseline	0.560	0.435	0.430	0.125***	0.130***	0.005***
	(0.004)	(0.018)	(0.024)			
price at endline	0.694	0.693	0.650	0.001	0.043***	0.042***
	(0.002)	(0.002)	(0.014)			
Δ price	0.133	0.258	0.220	-0.125***	-0.087***	0.038
	(0.004)	(0.018)	(0.021)			
price increase	0.258	0.296	0.356	-0.038**	-0.098***	-0.060***
	(0.011)	(0.012)	(0.025)			
quantity at baseline	128.162	48.0344	45.231	80.127***	82.931***	2.803**
	(3.783)	(0.852)	(1.061)			
quantity at endline	187.121	121.655	58.692	65.466***	128.429***	62.962***
	(5.744)	(3.232)	(0.613)			
Δ quantity	58.960	86.625	18.900	-27.665***	40.060***	67.725***
	(4.615)	(4.025)	(1.985)			
quantity increase	0.529	1.641	0.332	-1.112***	0.196***	1.309***
	(0.031)	(0.090)	(0.032)			
Share of the milk producers	57.1%	30.3%	12.6%			

standard deviation in parenthesis ; quantities = total production sold per week
"above" = households who already produced 10 litres per day, at baseline.
"shifters" = households who did not reached the minimum threshold required on the high value market at baseline but passed it during the time of project.
"below" = producers who remained at low levels of production, that is below 10 litres of milk per day.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3: Number of innovations adopted at endline by a household as a function of its production level at baseline

	Innovation Number Endline						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
x :	4 litres	5 litres	6 litres	7 litres	8 litres	9 litres	10 litres
below x litres	-1.7213**	-1.7188**	-1.5904**	-1.2867***	-0.9076**	-0.8902**	-0.8943**
	(0.7350)	(0.7281)	(0.6132)	(0.4370)	(0.4047)	(0.4070)	(0.4013)
innovation number baseline	0.0544	0.0564	0.0444	0.0157	0.0429	0.0424	0.0416
	(0.2129)	(0.2122)	(0.2145)	(0.2276)	(0.2317)	(0.2294)	(0.2248)
N	236	236	236	236	236	236	236
r2	0.0964	0.0976	0.0946	0.0743	0.0405	0.0406	0.0410

Standard errors in parentheses ; OLS with standard errors clustered at village level
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4: Variation of Quantity between both periods, among shifters and in rainy season (household FE)

	Milk Quantity in Rainy Season	
	(1)	(2)
production threshold used to define "shifters" :	10 litres	12 litres
time	47.2615***	56.7334***
	(10.6931)	(7.0822)
time × distance to threshold	1.5977***	0.8323**
	(0.5242)	(0.3213)
N	133	145
r2	0.8054	0.8224

Standard errors in parentheses ; OLS with household fixed effects and standard errors clustered at village level

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

Table 5: OLS results for the heterogeneous evolution of the price of milk

	Price per litre of milk							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Entire sample		MPCs area		Entire sample		MPCs area - with controls	
time	9.8319***	9.8319***	11.9375***	11.9375***	8.7074***	7.4607***	1.5407	1.1513
	(1.3721)	(1.3736)	(0.6358)	(0.6371)	(1.8870)	(2.1168)	(8.6672)	(9.0358)
time × below threshold	1.6005		3.7125***		-0.2891		3.4769***	
	(1.2727)		(0.7422)		(2.0309)		(0.5211)	
time × below threshold_upper		1.6187		6.1875***		-1.8710		5.0610***
		(2.0065)		(0.7795)		(1.5921)		(1.4346)
time × below threshold_medium		1.0102		2.7467*		-0.4607		3.1378**
		(1.1194)		(1.3579)		(1.4186)		(1.0086)
time × below threshold_lower		2.3578		3.1151**		-0.7107		3.1102***
		(1.8207)		(1.0381)		(2.8664)		(0.5923)
time × below 15 litres					3.0140			
					(1.8836)			
time × MPCs						4.3887*		
						(2.1940)		
time × below threshold_upper × MPCs						8.1466***		
						(1.7122)		
time × below threshold_medium × MPCs						3.2955*		
						(1.8196)		
time × below threshold_lower × MPCs						3.9139		
						(3.0646)		
Controls								
irrigation type 1							1.9042	1.6389
							(1.3939)	(1.3579)
irrigation type 2							-0.0752	-0.3900
							(2.8250)	(2.8858)
irrigation type 3							-4.9254	-5.1207
							(8.4218)	(8.3870)
pasture area							-0.1606***	-0.1289***
							(0.0192)	(0.0239)
time × road number							7.3164	7.2243
							(5.7564)	(5.8073)
time × road quality							-4.6068	-4.3126
							(3.2664)	(3.2870)
time × proximity to fresh cheese mkt							1.0903	1.0512
							(1.0197)	(1.0241)
time × new rural microenterprise							0.7972	0.9701
							(3.4986)	(3.4499)
dry season	3.3103	3.3103	-0.3760	-0.3760	3.3204	3.3240	-0.3647	-0.3643
	(2.4469)	(2.4495)	(1.3518)	(1.3546)	(2.4472)	(2.4486)	(1.3550)	(1.3590)
N	949	949	494	494	949	949	494	494
r2	0.3233	0.3237	0.6421	0.6452	0.3262	0.3563	0.6571	0.6581

Standard errors in parentheses ; OLS with household fixed effects and standard errors clustered at village level

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

Table 6: Falsification tests on the heterogeneous effects for the price of milk

	Price per litre of milk					
	(1)	(2)	(3)	(4)	(5)	(6)
	reduced window: 6-14 litres		fake threshold: 15 litres		sample >10 litres	sample >15 litres
time	-12.8283***	-14.4989***	0.5954	20.7009**		
	(2.7058)	(3.5199)	(8.0982)	(6.4362)		
time × below threshold	2.8052**					
	(0.9200)					
time × below threshold_upper		4.2209*				
		(2.0862)				
time × below threshold_medium		2.7609*				
		(1.1895)				
time × below threshold_lower		2.2292***				
		(0.5379)				
time × below 15 litres			3.1961***	1.1323		
			(0.5848)	(1.1369)		
milk quantities					-0.0133*	-0.0186
					(0.0059)	(0.0104)
Controls						
irrigation type 1	2.1825	1.8387	1.2307	1.5138	1.6651	5.8384**
	(1.6702)	(1.6786)	(1.2481)	(1.3745)	(1.4174)	(2.2141)
irrigation type 2	0.3976	0.1288	-1.4780	0.7047	1.5504	9.9806
	(2.3297)	(2.5439)	(2.3801)	(3.9780)	(4.1845)	(6.4283)
irrigation type 3	-20.7679***	-21.0700***	-6.7323	1.0161	2.2254	14.4677*
	(1.1502)	(0.9429)	(7.9389)	(6.5837)	(7.2659)	(6.9159)
pasture area	-0.1032	-0.0680	-0.1613***	-0.2500	-0.4103**	-0.4100*
	(0.0962)	(0.0861)	(0.0350)	(0.1722)	(0.1286)	(0.1734)
time × road number	18.1922***	18.4816***	7.6298	0.1280	5.4506	3.3860**
	(0.4961)	(0.7235)	(5.5507)	(3.7873)	(2.9721)	(1.3228)
time × road quality	-10.6079***	-10.3459***	-4.7039	-2.6150	-2.0069	-1.6108
	(1.1072)	(1.2767)	(3.1032)	(2.3038)	(2.6963)	(1.0614)
time × proximity to fresh cheese mkt	1.3386	1.5905	1.3789	-2.7716***	1.7890	2.6813*
	(0.7511)	(0.8130)	(0.7732)	(0.5992)	(2.3087)	(1.2229)
time × new rural microenterprise	5.1575***	5.1219**	-0.1428	3.9341	0.6198	0.9100
	(1.2354)	(1.3590)	(3.2897)	(3.5426)	(5.3518)	(3.1508)
dry season	-0.4269	-0.4272	-0.3528	-0.6657	-1.0852	-1.1154
	(1.5261)	(1.5309)	(1.3579)	(1.1789)	(1.1353)	(0.9665)
N	319	319	494	258	236	145
r2	0.7835	0.7847	0.6555	0.6930	0.6968	0.7290

Standard errors in parentheses ; OLS with household fixed effects and standard errors clustered at village level
Results are very similar without controls at the household and community levels
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 7: Mechanisms discussion for the evolution of the price of milk

	Price per litre of milk							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
time	12.3187***	12.0615***	13.6425***	13.6502***	10.0890***	15.4791***	7.3225*	7.3224*
	(0.8115)	(0.6512)	(0.9559)	(0.9620)	(2.1754)	(1.4109)	(3.8545)	(3.8670)
time × below threshold_upper	4.8717***	5.9028***	6.0942***	5.8408***	5.6243***	4.5260		-3.7388***
	(1.2892)	(0.8380)	(1.2662)	(1.2637)	(1.3850)	(3.4855)		(0.7910)
time × below threshold_medium	1.5112	2.4536	2.6847	2.4128	2.3722	0.9736		-2.8224**
	(1.5727)	(1.3779)	(1.8047)	(1.8106)	(1.6413)	(3.4840)		(1.2109)
time × below threshold_lower	1.5728	2.8107**	3.5888**	3.3433**	2.8641**	1.9630		-2.3224
	(1.1316)	(1.1406)	(1.1570)	(1.2531)	(0.9280)	(2.3613)		(3.2126)
milk quantities	-0.0072							
	(0.0084)							
milk quantities × below threshold	0.0282							
	(0.0198)							
cow number		-0.1766		-0.0281		-0.2406		
		(0.3173)		(0.2678)		(0.2255)		
cow number × below threshold		0.3909		0.5772		0.7909		
		(0.5021)		(0.4887)		(0.5494)		
cow productivity			-0.4173***	-0.4143**		-0.4349***		
			(0.1146)	(0.1240)		(0.1236)		
cow productivity × below threshold			-0.2614	-0.3342		-0.3370		
			(0.2868)	(0.2339)		(0.3020)		
time × EA number					0.7822			
					(0.7835)			
proportion cty >threshold						-5.6849		
						(6.4364)		
proportion cty >threshold × below threshold						4.6526		
						(4.4998)		
time × below threshold							-3.1597***	
							(0.7513)	
time × EA presence							0.2862	0.2862
							(4.0864)	(4.0996)
time × EA presence × below threshold							3.1373*	
							(1.7594)	
time × MPCs							4.2407**	4.2406**
							(1.4891)	(1.4939)
time × MPCs × below threshold							3.8231**	
							(1.7507)	
time × EA presence × below threshold_upper								3.6301
								(2.2115)
time × EA presence × below threshold_medium								2.8804
								(2.0249)
time × EA presence × below threshold_lower								2.2137
								(4.7473)
time × below threshold_upper × MPCs								6.3844***
								(2.1622)
time × below threshold_medium × MPCs								2.7769
								(1.8764)
time × below threshold_lower × MPCs								3.3120
								(3.6727)
dry season	-0.2584	-0.3726	-0.3724	-0.3719	-0.3687	-0.4538	3.3270	3.3278
	(1.4824)	(1.3569)	(1.3525)	(1.3560)	(1.3588)	(1.3128)	(2.4467)	(2.4547)
N	494	494	494	494	494	474	949	949
r2	0.6472	0.6454	0.6507	0.6512	0.6479	0.6560	0.3562	0.3576

Standard errors in parentheses ; OLS with household fixed effects and standard errors clustered at village level

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

Table 8: Matrix of mobility between quantiles between 2002 and 2007

		2002				
		quantile 1	**quantile 2**	**quantile 3**	**quantile 4**	**quantile 5**
2007	**quantile 1**	50.00	20.93	16.67	2.33	9.76
	quantile 2	21.43	37.21	14.29	18.60	9.76
	quantile 3	21.43	32.56	33.33	6.98	4.88
	quantile 4	7.14	6.98	33.33	44.19	9.76
	quantile 5	0.00	2.33	2.38	27.91	65.85
	Total	100.00	100.00	100.00	100.00	100.00

cells contain the percentage of households belonging to this quantile in 2002 (column) who moved to the quantile of the row in 2007

Table 9: Inequality Indices

	A(0.5)	A(1)	A(2)	GE(-1)	GE(0)	GE(1)	GE(2)	Gini
Entire Population:								
baseline	0.094	0.177	0.313	0.228	0.195	0.198	0.240	0.346
endline	0.102	0.199	0.368	0.291	0.221	0.209	0.243	0.357
MPCs only:								
baseline	0.090	0.172	0.302	0.217	0.188	0.189	0.219	0.341
endline	0.073	0.143	0.274	0.188	0.154	0.148	0.168	0.299

A=Atkinson index and GE=Generalized entropy index

Table 10: Inequality Indices between Subgroups, MPCs only

	A(0.5)	A(1)	A(2)	GE(-1)	GE(0)	GE(1)	GE(2)
Baseline:							
between	0.051	0.099	0.180	0.147	0.119	0.101	0.090
within	0.042	0.081	0.148	0.069	0.069	0.087	0.128
Endline:							
between	0.019	0.037	0.071	0.043	0.040	0.038	0.037
within	0.055	0.109	0.219	0.145	0.113	0.110	0.131

A=Atkinson index and GE=Generalized entropy index

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