Heterogeneous return from Agricultural Innovation Adoption: The Role of the price effect

I. Bonjean;

KULeuven, BioEconomics, Belgium

Corresponding author email: isabelle.bonjean@kuleuven.be

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In conditions of poor soil fertility and increasing importance of global value chain, agricultural extension projects have been one of the main channel to increase farmer's production and income. In this literature, prices received by farmers for agricultural goods are usually assumed to be homogeneous. We dispute this over-simplification: prices and production levels in developing countries are often jointly determined. The analysis relies on a successful extension program in the Peruvian highlands, where the main income source is the dairy sector characterized by a highly segmented market. We propose a simple theoretical model to explore how the discontinuity in price induces non-linear return to investment and diverging incentives. The econometric analysis confirms the model's propositions: producers that were not included in the formal market at baseline, but close to it, have more intensively innovated. This investment leads to a higher price increase than other producers. The effects are shown to resist to falsification tests, mechanisms are discussed and positive externalities are found within communities. Hence we show that innovation in the context of a segmented market leads to heterogeneous impacts and non-trivial income effects. Contrarily to the expected disequalizing effects of innovation adoption, it induces scope for unexpected social mobility.

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Abstract

In conditions of poor soil fertility and increasing importance of global value chain, agricultural extension projects have been one of the main channel to increase farmer's production and income. In this literature, prices received by farmers for agricultural goods are usually assumed to be homogeneous. We dispute this over-simplification: prices and production levels in developing countries are often jointly determined. The analysis relies on a successful extension program in the Peruvian highlands, where the main income source is the dairy sector characterized by a highly segmented market. We propose a simple theoretical model to explore how the discontinuity in price induces non-linear return to investment and varying incentives. The econometric analysis confirms the model's propositions: producers that were not included in the formal market at baseline, but close to it, have more intensively innovated. This investment leads to a higher price increase than other producers. The effects are shown to resist to falsification tests, mechanisms are discussed and positive externalities are found within communities. Hence we show that innovation in the context of a segmented market leads to heterogeneous impacts and non-trivial income effects. Contrarily to the expected disequalizing effects of innovation adoption, it induces scope for unexpected social mobility.

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. In conditions of acute land pressure and/or poor soil fertility, an increase in farmer's production will not be possible unless technical progress takes place on a large scale. However, transforming technological advances in agricultural improvement has always relied strongly on the efficiency in transferring knowledge and inputs to farmers. Indeed, since farmers' perceptions of the return to these technologies 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.). To overcome this market imperfection, agricultural extension services have been one of the most common forms of knowledge diffusion.

During the recent years, extension programmes gained renewed interest due to major changes in agricultural markets, likely to reinforce the long-lasting and deepening poverty gap. Indeed, there exists a fear that increasingly stringent food quality and safety norms on agri-food supply chains will result in the exclusion of small farmers (Key and Runsten, 1999 ; Okello et al., 2007). Though some studies provide evidence that small farmers can participate in and benefit from high-value chains (Maertens and Swinnen, 2009; Minten et al., 2009), the concern induced NGO and peasants organizations to call for best practices and technology diffusion from the public and the private sectors. Numerous projects aimed at diffusing agricultural technologies were implemented, 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. The empirical literature shows that a wide variety of factors may influence technology 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; Munshi, 2048; Adegbola and Gardebroek, 2007); in other cases credit constraints (Croppenstedt et al., 2003; Barrett et al., 2004; Gine and Klonner, 2005; Minten et al., 2007; Miyata and Sawada, 2007), consumption risks (Dercon and Christiaensen, 2008; Gine and Yang, 2009; Foster and Rosenzweig, 2009), poor learning effects due to low density of social networks (Foster and Rosenzweig, 1995; Munshi, 2004; Bandiera and Rasul, 2006; Conley and Udry, 2010), 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 approachs are used to measure the causal impact of each of theses constraints. A flurry of such experimental studies is currently undertaken under the Agricultural Technology Adoption Initiative (ATAI) of the Gates Foundation, aiming at testing the impact of various types of interventions.

Within this most recent research wave, a portion is also trying to assess the return to these innovations. 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, measuring the extent of innovation adoption and diffusion should be done provided a positive return to the adoption exists. Some more recent studies seek to measure the return to specific innovations (mainly fertilizers use) using random allocation of the treatment (Duflo et al, 2009 ; Suri, 2011, Beaman et al, 2013). Yet, we identified two research questions of the highest relevance in areas with marginalised and highly unequal population (which are often the target of extension program) that remain understudied. The first one is the variation of the returns along the income distribution and the effect of innovations on poverty alleviation and inequalities. Second, no attention has been given yet to the market structure farmers face though this characteristic determine farmer's return to innovation, their income and welfare. This article tends to fill both gaps.

We use detailed information about a successful community extension programme implemented in the Peruvian highlands by the NGO "Practical Action" (PA) between 2002-2007 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. The price that a farmer obtains for his production has received little attention in this portion of the economic literature. In particular, researchers usually assume that prices are common to all farmers. However, this assumption is known to be far from reality regarding small farmers market conditions. Market in developing countries are of the most imperfect and information provision is highly inequal. Transaction costs are reckoned to be high. An interesting example lies in Fafchamps and Vargas Hill's paper (2005) where authors support that usually in poor countries farmers have the choice between selling their production at the farmgate or traveling 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 decision and its effect 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 guarantee 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 Holly Wang et al, 2014, for a recent literature review).

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 assessing the opportunities of social mobility and understanding innovation adoption. 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 and an indirect effect operating through a higher unit price for all milk sold. Interestingly, heterogeneity in the return to innovation would also induce variation in the innovation adoption behavior due to different incentives to do so, leading to non-trivial income effects.

Results confirm these expectations. During the time of the programme, 21% of the milk producers shifted beyond the MPC's threshold[1]: this proportion corresponds to almost 50% of the households who produced initially less than this quantity. For those "*shifters*" the average price received for their milk production increased relatively more than for the other producers, whatever their relative position to the threshold. It bears emphasis that the *shifters* were on average located significantly closer to the threshold than those who remained at lower levels of production. Still, although closer to the threshold, shifters increased their produced quantity more than the rest of the population on an average. The higher production increase might 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[2]. Finally, at baseline, shifters had significantly bigger cow herd than producers who remained below the threshold and they increased it significantly more.

Variation in the innovation adoption incentive and return is measured in two ways: the position relatively to the threshold and the distance to it. The focus is on the evolution of quantity produced and unitary price during the programme. First, we develop a simple model to analyse the incentive to innovation adoption according to the household initial production level. It shows that initially smaller producers will innovate provided it enables them to reach the threshold. Moreover, with convex cost of effort, bunching at the threshold will also be observed. Data provide the stylized facts supporting the propositions of the model. Then, the econometric analysis reveal that herders who produced a quantity below the threshold required by milk processing companies but were relatively close to it, benefitted 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 disentangle for the different groups according to their level of innovativeness.

The paper is organized as follows. The theoretical model is developped in the next section. The third section contains the empirical results: data are described then the first and second channels of return to innovation adoption are analysed. Finally, social mobility is discussed in section 4. The last section concludes.

2 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

[1] 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)

[2] 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).

total production is 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 and there is no externality from others innovation adoption. 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 fact that those parameters will influence the share of producers that will stick to the threshold are the following. 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. These characteristics were approximated by the continuity of x in the theoretical model.

3 Econometric Analysis

3.1 Data about the sample of households

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.

3.2 The first channel of social mobility : the incentive to innovate

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. We regress the number of innovations adopted at endline on the initial level of production (Table not included in this shorter version). We gradually increase the threshold chosen from 4 to 10 liters 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, 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)[3]. 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 is translated into a positive correlation between the initial distance to the threshold and the increase in milk output between both periods (Table not included in this shorter version). We also test this 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 then 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.

3.3 The second channel of social mobility : the price effect

The objective of this section is to identify the second channel of social mobility, that is 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 through 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. Indeed, the most obvious alternative channel would be a reduction in the transaction costs borne by big processing companies, translated into a reduction of the minimum production requirement. In this situation, producers on the left side of the threshold but sufficiently close to it would benefit from a price increase, independently of their own innovativeness or production increase. 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 threshold, with household and time fixed effects and clusterizing 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. This to say that, 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 in order to let potential heterogeneous effects appear. The strategy used here is similar to an intention-to-treat strategy.

The equation estimated is the following one:

$$\begin{aligned} price_{ict} = \alpha &+ \beta_0 DrySeason_{ict} + \beta_1(Time_t \times Below10liters_{ict_0}) \\ &+ \Gamma_1(Time_t \times HouseholdControls_{ict_0}) + \Gamma_2(Time_t \times CommunityControls_{ct_0}) \\ &+ \Gamma_3(HouseholdControls_{ict}) + \Gamma_4(CommunityControls_{ct}) \\ &+ \delta_i + \lambda_t + \epsilon_{ict} \end{aligned} \tag{7}$$

[3]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

where *price*$_{ict}$ is the household unit price, measured in both periods, for the rainy and the dry seasons[4], hence the term *DrySeason*$_{ict}$ accounts for the systematic permanent differences between both seasons[5]. The model used is OLS with household and time fixed effects. Standard errors are clustered at the community level[6]. 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.

The first set of results is reported in table 1. 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 difference for producers at lower initial level of production. However, if we allow for a different trend in communities directly served by big processing companies, differentiated effects emerge. This can be seen when we either reduce the sample to the communities served by MPCs (column 3 and 4) or when we allow a different time effect in both types of communities through a triple interaction (column 5 and 6). 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 of below-threshold producers, it appears that this positive effect on prices is higher for producers that produced at most 2 liters from the threshold, while the coefficient is on average divided by two for producers at a higher distance (column 4 and 6). Finally, in the last two columns, results resist to the introduction of controls at the household and community levels.

The next step is to proceed to falsification tests (results not shown in this shorter version) in order to ensure that the positive price effect found for households below the threshold is indeed located around the production level of 10 liters a day, required by big processing companies. To do so, we show that results resist to a smaller window around the threshold. Moreover no price effect is 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 (results not shown in this shorter version).

Then we dig into the understanding of the mechanisms driving the effect of the innovation adoption on prices received by farmers. First, the price increase ought to be tested against other channels than a shift to the most profitable share of the segmented market. To do so, we show (Table 2) that the introduction of the quantity variable quicks out the significance of the coefficient associated to each category of production level except the one just below the threshold (i.e. the 8-10 liters category). It reflects the fact that the price effect for groups of producers whose production at baseline was inferior to 8 liters 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 benefit from a price increase even if they do not outweigh the average production increase of the population. Second, one would like to identify what is the channel through which producers at lower levels of production increase their quantity. Then let us look at the origin of the production increase : it can be either the result of an input increase, that is the cow herd size, or an increase in the productivity per herd unit, that is the average number of liters milked per cow per day. Both channels are tested by replacing the variable of milk quantity by its cow herd 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 category of 6-8 liters a day while this is never the case for the lower category. Hence producers belonging to the 6-8 category and whose production increased such that they benefitted from the price effect, did so through both a capital and a productivity increase, though the effect appears to be stronger for the cow herd size (observe the reduction in the size of the coefficient associated to the category at stake).

Finally, we show that positive externalities exist within communities. Indeed according to column

[4]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.

[5]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.

[6]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.

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 benefitted 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 liters a day, controlling for clusters standard errors correlation, is positive and highly significant[7]. 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[8]. To test for the existence of such an effect, in the sixth column of Table 2, the share of producers producing more than 10 liters 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 category of producers initially producing less than 6 liters a day which can be seen as an evidence that the remaining effect for this category was due to positive externalities from more productive households[9]

Hence, strong evidence is provided that all producers might have benefitted from a production increase, but the indirect price channel exists in MPCs area for initially poorer households only, i.e. below the threshold, creating a second opportunity of economic mobility for this category of producers.

4 Social mobility

Furthermore, one would like to confirm those findings by investigating the mobility of the different categories of producers, along the income distribution. In particular, if they benefitted relatively more than their pairs, *"shifters"* would be expected to be *upwardly mobile*. The matrix of mobility (not reported in this version) reflect that 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%.[10]

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 farmgate. Moreover, shifters are over-represented in MPCs communities : 56% of them lives in a community where MPCs collect milk at the farmgate while those communities represent 46% of the total population.

Finally, we may want to look at the inequality evolution between both periods, between the different groups. 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 (results not included in this short version). Within producers initially below the threshold, the income share of those who

[7]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).

[8]Insights of the existence of such positive externalities already showed up in the previous descriptive statistics. Indeed, 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 (results not shown in this shorter version). 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.

[9]In the longer version of the paper, we discuss the role played by Extension Agents and their role in shifting producers up to the threshold

[10]In the complete version of the paper, we show that, in line with the story of Fafchamps and Vargas Hill (2005), 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.

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.

5 Conclusion

In this paper 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 of quantity and price following the intervention. We propose a simple model to explore how the discontinuity in the price received for each production unit affects the incentive to innovate. Then the implications of the model are tested on the data and it is shown that the price effects plays a critical role for initially poorer households. Evidence shows that, unlike their richer pairs, initially poorer households benefit from two channels of return to the programme: a quantity and a price channel. This creates scope for mobility along the income distribution. We show that producers initially closer to the threshold have higher incentive to invest in innovation because of their higher probability of shifting beyond the threshold, hence higher expected return to the investment. There also exist positive externalities on the price received by producers who remained below the threshold, generated by a critical mass of above-the-threshold producers living in their community.

Evidence suggests that the quantity effect 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 thanks to access to better-paying purchasing companies. 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. If the efficiency of information transmission is not orthogonal to households' wealth such that poor people would underinvest in innovations because they underestimate the returns, what is observed here is a lower-bound to the potential of the programme.

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 findings stress the importance of considering and understanding the price mechanism, when assessing the return to innovation adoption.

TABLES

Table 1: Evolution of the milk price between baseline and endline according to categories of production levels at baseline

	Unit Milk Price							
	(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 10 liters	1.6005		3.7125***		-0.2891		3.4769***	
	(1.2727)		(0.7422)		(2.0309)		(0.5211)	
time × 8-10 liters		1.6187		6.1875***		-1.8710		5.0610***
		(2.0065)		(0.7795)		(1.5921)		(1.4346)
time × 6-8 liters		1.0102		2.7467*		-0.4607		3.1378**
		(1.1194)		(1.3579)		(1.4186)		(1.0086)
time × below 6 liters		2.3578		3.1151**		-0.7107		3.1102***
		(1.8207)		(1.0381)		(2.8664)		(0.5923)
time × below 15 liters					3.0140			
					(1.8836)			
time × MPCs						4.3887*		
						(2.1940)		
time × 8-10 liters × MPCs						8.1466***		
						(1.7122)		
time × 6-8 liters × MPCs						3.2955*		
						(1.8196)		
time × below 6 liters × 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 2: Evolution of the milk price between baseline and endline: mechanisms

	Unit Milk Price							
	(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 × 8-10 liters	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 × 6-8 liters	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 6 liters	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 10 liters	0.0282							
	(0.0198)							
cow number		-0.1766		-0.0281		-0.2406		
		(0.3173)		(0.2678)		(0.2255)		
cow number × below 10 liters		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 10 liters			-0.2614	-0.3342		-0.3370		
			(0.2868)	(0.2339)		(0.3020)		
time × EA number					0.7822			
					(0.7835)			
proportion cty >10 liters						-5.6849		
						(6.4364)		
proportion cty >10 liters × below 10 liters						4.6526		
						(4.4998)		
time × below 10 liters							-3.1597***	
							(0.7513)	
time × EA presence							0.2862	0.2862
							(4.0864)	(4.0996)
time × EA presence × below 10 liters							3.1373*	
							(1.7594)	
time × MPCs							4.2407**	4.2406**
							(1.4891)	(1.4939)
time × MPCs × below 10 liters							3.8231**	
							(1.7507)	
time × EA presence × 8-10 liters								3.6301
								(2.2115)
time × EA presence × 6-8 liters								2.8804
								(2.0249)
time × EA presence × below 6 liters								2.2137
								(4.7473)
time × 8-10 liters × MPCs								6.3844***
								(2.1622)
time × 6-8 liters × MPCs								2.7769
								(1.8764)
time × below 6 liters × 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
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

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