Two-Sided Wealth Constraints and Innovation Adoption Under a Grassroots Market-Based Extension System*

by

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1. Introduction

2.1 A short survey of the literature

As the present food crisis demonstrates, one key factor impeding growth of food production in poor countries is the lack of yield increase. In fact, almost all the increase in the world's cereal output in 2008 came from rich countries, and much of this was a result of increased acreage, a possibility almost foreclosed in developing countries (FAO, 2009). On the other hand, since poverty in the latter tends to be concentrated in rural areas, and non-agricultural opportunities in rural, urban, and peri-urban areas are limited, poverty alleviation necessitates a significant increase in the incomes drawn from land-related activities. In conditions of acute land pressure and/or poor soil fertility, such an increase will not be possible unless technical progress takes place on a large scale. For yields to be boosted in poor countries, appropriate technologies must be made available for use by smallholders, and the latter must have the willingness and ability to adopt them. Unfortunately, too often these two conditions remain unsatisfied, especially in remote and backward areas. The problem does not necessarily arise from a short supply of technical innovations. Thus, for example, despite the release of nearly 1700 improved wheat varieties in developing countries during the period 1988-2002, only a relatively small number have been adopted on a substantial scale by farmers (Dixon et al., 2006, p. 489). A large majority of them remain on the shelves of big international organizations, such as the Institutes belonging to the CGIAR (Consultative Group for International Agricultural Research).

One possible obstacle on the way to adoption is the lack of response of technical innovations to farmers' needs, a problem that is remediable through participative approaches to innovative research, such as participatory plant breeding or landrace selection (see, e.g., Bellon et al., 2003; Pixley et al., 2007). However, the availability of technical innovations well adapted to the needs and incomes of poor villagers is a necessary but not sufficient condition for their effective dissemination among poor rural strata. Indeed, lack of information and on-the-ground demonstration of the advantages of the new technologies, lack of training and skills among potential users, deficient distribution of the modern inputs that they require (seeds, pesticides, herbicides, and fertilisers), and pervasive credit and insurance market imperfections constitute well-known inhibitors of technical progress in poor rural areas.

Numerous applied studies using the econometric technique have been conducted to assess the adoption behaviour of farmers and to identify the key determinants of technology

adoption. However, data have been generally collected on whether a given technology has been adopted or not, without additional information on whether some individuals are constrained in information awareness or in accessing the technology or the wherewithal to acquire it (Shiferaw et al., 2008, p. 3). In particular, as is evident from a pioneer survey article by Feder et al. (1985) as well as from more recent but partial surveys on technology adoption (see, e.g., Rigby and Caceres, 2001), most of these studies assume full information of potential adopters. This characteristic is reflected in the choice of single-stage adoption-decision models in which the dependent variable is a univariate binary response (adoption versus non-adoption). Since there is a lot of empirical evidence suggesting that producers may not be well informed about (or trained for) new technologies and their potential (see, for example, Foster and Rosenzweig, 1995; Bardhan and Udry, 1999: Chap. 12; Dimara and Skuras, 2003; Adegbola and Gardebroek, 2007), zero values for adoption may be generated by observations that are not informed at all or do not possess sufficient information to allow them to enter an evaluation process. In such cases where information acquisition is critical in creating demand for new technologies, the use of simple dichotomous adoption decision models and the resulting failure to control for selectivity bias yield biased estimates and may therefore lead to misleading conclusions.

To overcome that difficulty and achieve more consistent estimates, researchers have recently started to use sample separation and model the adoption-decision process as a multistage (usually a two-stage) decision process. The first stage corresponds to the process of acquisition of the minimum information necessary to evaluate and assess the innovation. It is typically modelled by assuming that everybody has heard of an innovation, so that awareness results from an active and costly process of information collection only (see Saha et al., 1994, for more details).[1] The second stage estimates the determinants of actual adoption conditional upon possession of sufficient information. Stages preliminary to the actual adoption-decision process need not be associated with information acquisition processes only. For example, the first (or the second) stage may concern access to credit because of credit rationing, and it is only in the second (or third) stage, once credit has been acquired, that valuation is assumed to occur. Likewise, the first stage may deal with access to crucial inputs such as seeds or fertilisers, whose distribution may be imperfect due to a variety of reasons (as is done in Coady, 1995; and Shiferaw, et al., 2008). For farmers with positive

[1] The assumption is that a producer is aware of an innovation if the level of acquired information is greater than a certain threshold information level (Dimara and Skuras, 2003, p. 189).

desired demand, the overall demand for improved varieties, for example, is then determined conditional on the ability to access new seeds (and adequate information).

A different methodological approach to understanding the determinants of technology adoption consists of using random experimental designs. Thus, Duflo, Kremer, and Robinson (2007) have shown that offering Kenyan farmers the option of buying fertiliser immediately after the harvest when liquidity constraints are most relaxed has the effect of increasing significantly the proportion of farmers using this modern input (at the full market price, but with free delivery). In this case, the obstacle to fertiliser use lies in savings difficulties rather than in information problems about its potential benefits, or supply constraints impinging on the local availability of crucial inputs.

In general, there is no clear conclusion emerging from the econometric literature on innovation and technology adoption: whereas in some cases information problems act as a significant barrier, in other cases credit constraints, problems of access to modern inputs, or ill-adaptation of technical innovations on offer are the most decisive hurdles. This is actually not surprising given the great variety of contexts and innovations involved. What is most lacking is a general perspective or theory on which obstacles are more likely to be present depending on the characteristics of the product (subsistence or cash crop), the type of innovation (for example, whether it is embedded in modern inputs that involve out-of-pocket expenditures or not), the profiles of potential users (level of poverty, degree of economic specialisation, social status, etc), and the main features of the environment (e.g., risk-influencing factors, extent of market integration, price volatility).

A particularly interesting issue that is overlooked in the existing literature is the possible interdependence between liquidity constraints operating on the supply and demand sides of the innovation market. Indeed, in conditions of absent or imperfect credit markets, suppliers may not only face their own liquidity problems arising from the need to purchase and store inputs in which innovations are embedded, but they may also compound these problems by providing credit to their customers. In these conditions, savings difficulties of the latter are possibly reduced at the cost of increasing those of the former. Such an issue is especially relevant in poor areas where innovations are delivered by grassroots agents.

Another issue that deserves attention, and has been at the heart of discussions and controversies around the effects of the Green Revolution, for example (see, e.g., David and Otsuka, 1994), concerns the impact of agricultural technical progress on rural inequality. Again, the question arises as to which factors are the most important in causing differential rates of adoption by rich and poor producers: in particular, are knowledge or market

imperfection problems the main driver of unequal adoption? To cite a well-known contribution to the subject, Hayami and Ruttan (1971) came to the conclusion that there is a real danger of growing inequality in rural areas, yet "not because of new technology but because of insufficient progress in the development and diffusion of new technology" (p. 345). Lack of financial resources does not appear as a critical problem as long as technical innovations are embedded in divisible factors.

1.2 The contribution and approach of the present study

This paper is an attempt that lies somewhere in between the multistage modelling of the adoption decision process, on the one hand, and the experimental approach, on the other hand. It is indeed based on a quasi-natural experiment that allows us to estimate the impact of liquidity or savings constraints conditional on good information about available techniques. More precisely, our study exploits the occurrence of an exogenous shock under the form of a NGO (Non-Governmental Organisation) intervention aimed at providing information, extension, and input dissemination to potential innovation users in two districts of the Northern Peruvian Highlands. These two districts in which milk herders predominate belong to Cajamarca province which is known as the third poorest one in Peru. An interesting feature of this NGO intervention is that it relies on catalytic agents who come from, and are elected by, the targeted communities themselves.

Two sets of data are available. The first set contains information about the demand side of the market and reports key characteristics of a sample of herders randomly selected from a population of households duly informed about the new available technologies. These data have been collected by the NGO itself five years after the beginning of its intervention (in 2007). In addition to current information, the sample households surveyed were required, through the recall method, to provide answers about the situation prevailing in 2002, just before the NGO's extension agents began their field activities. The second dataset, collected in October-December 2007 in the communities concerned by one of the authors (Isabelle Bonjean), contains unique information about the supply side of the market, and consists of a detailed survey of almost the whole population of extension agents.

Since the cattle herder households surveyed, numbering several hundreds, all belong to a population of about two thousand households who attended a series of information meetings organised in 2002 by the NGO, and are within reach of extension agents trained by the same organisation, differences in wealth appear as a critical factor susceptible of accounting for variations in individual rates of adoption of the technical innovations on offer. Unfortunately,

because we lack information about the incidence of technical change in a control group, we cannot rigorously test for the impact of the NGO's work in the targeted area, even though we know that a dramatic increase in the adoption of technical innovations has occurred in the period subsequent to its intervention. Our empirical strategy consists mainly of exploiting the fact that NGO's extension and dissemination efforts have had the effect of suppressing several important causes of non-adoption of available (and appropriate) technical innovations. Shortage of savings difficulties is thus left as an important residual factor responsible for the observed under-utilisation of technical potentialities.

We are thus unable to identify the characteristics of the rural producers who have chosen to acquire new technical knowledge through the NGO channel, yet we can measure (i) the extent to which adoption of new techniques disseminated by local extension agents depends upon initial wealth or income, and (ii) the effect of adoption on current incomes and wealth. In short, if we cannot assess the total or average impact of the external intervention under concern, we are in a position to estimate its differential impact on poor and rich potential users and, thereby, gauge its influence on income inequality. On the other hand, since extension agents need working capital to buy and store products, we are in a position to test for the presence of a wealth constraint operating on the supply side of the innovation market. This is a unique contribution of our study which is all the more valuable as there exists an interdependence between liquidity constraints confronting providers and users of technical innovations.

What we show is that, in a context where credit markets are absent and support to local rotating funds by the NGO have been quickly discontinued, wealth constraints effectively limit both the scope of activities of extension agents and the adoption of new techniques by potential users. Regarding the latter result, a special feature of our data −the possibility to distinguish neatly between innovations requiring costly inputs from those that do not− is exploited to adduce particularly strong evidence in support of the existence of such a constraint on the side of potential users. Moreover, distinguishing between poor and rich households allows us to highlight the differential impact of the wealth constraint on different income categories. Finally, because we are in a position to measure and therefore control for the producers' intrinsic dynamism in a rather reliable manner, we may rule out interpretations of the wealth effect in terms of not only informational but also innovativeness advantages (rich households are higher adopters because they are better informed or more entrepreneurial). Regarding the supply side of the innovation market, we do not only document the presence of a wealth constraint but also highlight the way in which the

promotores ration their supply of extension services. Another important finding of our study is that inequality has not increased as a result of NGO's dissemination efforts which have been conceived in the participatory mode.

The rest of the paper is structured as follows. Section 2 describes the context of the study, placing emphasis on the role of the NGO intervention in activating the innovation market, and it provides basic information on our datasets, distinguishing between the supply and demand sides of this market. Sections 3, 4, and 5 are devoted to a discussion of the methodology used and the results obtained regarding each of the three key questions addressed in this study. Section 3 thus deals with innovation adoption behaviour and the role of the wealth constraint, in particular. Section 4 looks at the evolution of income inequality and the determinants of final income following the introduction of grassroots extension agents in the surveyed communities. The impact of the indirect, innovation-induced effect of initial wealth is compared to the impact of the direct, path dependence effect. As for Section 5, it attempts to determine the extent to which the activities of the extension agents are limited by savings difficulties. Section 6 concludes.

2. The survey area, the data, and the context of the study

2.1 Participatory extension and data about the supply of technical support services

Our study area covers the two districts of La Encañada 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: it takes between three and eight hours by bus for them to reach the city of Cajamarca, and there is only one bus service per week. 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 (a slim layer of water is deposed on the plants at dawn which gets frozen during the night and causes intense sun reflection in daytime). It is true that during the rainy season there are abundant surface flows of water discharged through numerous rivulets, and these come to form stagnant masses of water in the small plateau where villages are found. However, owing to the non-permeability of the hard soils (known as *paramos*), water accumulated during the rainy season cannot be stored in aquifers for use during the dry season. Furthermore, construction of irrigation channels turns out to be a arduous and costly enterprise. 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 ended in complete failure, 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, Intermediate Technology Development Group (ITDG) −Soluciones Practicas, 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 (more about this will be said later), the management staff of ITDG decided to adopt an approach combining market orientation with participation of local communities.

The basic principles underlying this approach, started in the districts of La Encañada and Hualgayoq, are the following. ITDG sets up a special training programme consisting of intensive courses covering a period of 26 days and run by teachers from both the NGO and the university of Cajamarca. These courses, entirely subsidised by ITDG, must be attended by all the future extension agents. Named *promotores*, the latter are not chosen by ITDG, but are elected by the local assembly of a village community after it has expressed its interest in the programme. The elected candidates must nevertheless satisfy a number of criteria decided by ITDG (minimum age, minimum education, probity, etc.), and they must commit themselves to returning to their native community in order to carry out their extension activities on a business basis.

ITDG agreed to train a maximum of three *promotores* per community, with specialisation in veterinary services for the first one, in agricultural support services for the second one, and in agro-processing and marketing services for the third one. 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 are organised upon request by the association of *promotores*, or a subgroup of them. Participation in these events was optional. The extension support programme of ITDG in the region stopped in June 2007.

As recorded in the files of the NGO, the total number of extension agents trained is 69, coming from 27 different communities and distributed between specialisations as follows: 30 veterinaries (VET), 15 agricultural service providers (AGR), and 24 agro-processing and marketing service providers (APM). A number of these agents (seven of them) have actually

attended two courses. In September 2007, the time at which we started our field survey, we found only 42 *promotores* still operating in the region. Attrition (equal to 39%) is due to two major causes: migration to cities and employment in the giant mine of Yanacocha (close to La Encanada district). Three out of the 42 *promotores* could not be actually interviewed, because they were never present at their house or on their lands (for two of them), or because of almost continuously drunkeness (one case). We are thus left with a group of 39 extension agents living in 19 different communities which are not necessarily their native communities where they have been elected for the purpose of becoming a *promotor*. Moves to another community of residence occurred in the case of seven *promotores*, and always on the occasion of marriage (either the *promotor* went on residing in the community of his wife, or both spouses decided to change community in order to improve their access to land). Both the attrition process and moves between communities have disturbed the intended balance between communities regarding the number and composition of *promotores*. There are communities with no resident extension agent, or communities where some specialisations are not represented, or are over-represented.

However, an essential yet unintended feature of the *promotores* landscape, as we uncovered it in the course of our field survey, is that their services are typically not confined to their community of residence. This holds especially true for the veterinaries: while VET attend to between one and eight communities **(**mean value: 3.0**)**, AGR go to maximum one community in addition to their community of residence, and APM do not operate outside the latter. In the end, each of the 27 communities covered by the ITDG project is attended by at least one *promotor* and by at most five of them. Out of 39 surveyed *promotores*, 32 are completely specialised and 7 have a double specialisation (VET+AGR or VET+APM). Indeed, extension agents who have received basic training in one field may well have accumulated knowledge and acquired expertise in another field through attendance to follow-up training sessions. In total, there are 23 VET, 12 AGR, and 11 APM.

While VET agents deal with all matters involving animal health, particularly vaccination campaigns, deliveries, and treatment of most common illnesses, AGR agents are mainly concerned with improving the quality of pasture lands, and APM agents look after the quality of milking operations and milk products. In fact, APM agents are specialised in cheese production, and their main concern is to ensure the regular supply of raw product of the required quality −the fat content of the milk must be sufficiently high and the milk must be properly conserved.

The information elicited from the *promotores* is of two types: personal characteristics and business data. The former include age, education, field of specialisation, participation in follow-up training sessions, composition of family (by gender and age), land and animal wealth. As for business activities, the data collected provide detailed information about the volume and value of milk (and cheese) sales, the number of customers using their extension services, the price obtained for these services, the terms of the contracts (mode and timing of payment, interest rate on loans, etc.), the communities in which they operate, the nature and history of relationships between them and the clients, the sanctions applied in case of non-payment for services delivered, and their access to any credit source.

2.2 Data about the potential users of technical innovations

Between 2002 and 2007, ITDG organised in each of the 27 communities of the project zone (the districts of La Encanada and Hualgayoq, in Cajamarca province) a series of information meetings where local inhabitants (all milk herders) could learn about the role of the *promotores* in disseminating technical innovations available. According to the NGO's record, 2,021 households have attended at least one of these meetings. From this population of informed producers, a proportional random sample of 426 household heads has been drawn so as to include (about) one-fifth of the participants in each community. The distributions of this sample population according to economic specialisation in 2002 and 2007 are depicted in Table 1.

*Table 1: Distributions of sample population according to economic specialisation in 2002 and 2007**

	2002	2007
Do not sell any amount of milk or (low quality) cheese	40 (9.4%)	31 (7.3%)
Sell only milk	250 (58.7%)	269 (63.1%)
Sell only (low quality) cheese	136 (31.9%)	112 (26.3%)
Sell both milk and (low quality) cheese	0	14 (3.3%)
Total	426 (100.00%)	426 (100.00%)

* At this stage, we do not identify the producers of high-quality cheese. Just bear in mind that all such producers also produce low-quality cheese.

The data available regarding these informed households pertain to both years (2002 and 2007), and are as follows: composition of the household (number of men and women), number of cows, areas of natural and improved pastures, average production per cow (in the dry and the humid seasons), type of irrigation system used, quantities and prices for each type of product sold, income from ancillary activities, and number of technical innovations used. Since the income from ancillary activities is rather exceptional and in any event quite low, the total household income essentially consists of the sale value of milk products. No imputation is made for self-consumption. Information refers to average monthly incomes during the rainy and the dry seasons which are of roughly the same duration. To arrive at a proper measure of the average monthly income over the whole year, a simple arithmetic mean between these two data is thus computed.

As a matter of principle, production of fresh milk for sale is more profitable than production of (low quality) cheese. There are two reasons for this. First, fresh milk carries a higher price, per raw litre produced, thanks to the existence of long-term contracts signed with purchasing companies (Nestlé and Gloria). Second, milk prices are more stable than cheese prices which vary according to spot demand in local markets. If a number of producers specialise in cheese production, it is either because the community to which they belong is not serviced by one of the two above milk-purchasing companies, or because they are too poor to achieve the minimum production for sale (15 litres per day) required by them.

3. Innovation adoption behaviour

3.1 Intensity and pattern of innovation adoption

Eleven different innovations have been actively supported by the *promotores*:

(1) double cow milking per day (instead of one);
(2) hygienic measures to be applied during milking operations;
(3) vaccination of cows according to a fixed calendar;
(4) precocious weaning (to put the new-born calves on an improved diet);
(5) supplementary nutriments (in the form of flasks);
(6) vitamin complex;
(7) special fodder mixes;
(8) improved seeds for pasture cultivation;
(9) multiple ploughing;
(10) use of lime to reduce acidity of the land;
(11) use of organic or chemical fertilisers.

To construct our innovation adoption variable, we have made a simple counting of the above innovations. Since we have no precise way to estimate the relative profitability of each

of these innovations, we rely on an unweighted sum. To the extent that all innovations can be adopted independently, the summing up operation appears legitimate. For year 2007, the minimum value of the variable thus defined is one and its maximum value is eight. There, moreover, emerges a systematic pattern in innovation adoption among the rural producers of Cajamarca province. To see this, we have constructed a double-entry table in which we depict the type of innovations adopted in 2007 as per the number of them that have been actually adopted by each household. Innovation types are shown in the columns while frequencies are displayed in the rows. From cells (6,2) and (5,2), for example, we read that 79 households using innovation 2 in 2007 have adopted a total of 6 innovations, while 59 of them have adopted 5 innovations.

Table 2: Types of innovation most frequently adopted by rural producers (2007)

	Innovation Type											
Nr of innovations adopted	1	2	3	4	5	6	7	8	9	10	11	Total
0	0	0	0	0	0	0	0	0	0	0	0	6
1	0	9	0	0	1	0	0	1	1	0	0	12
2	8	21	0	0	4	0	1	2	6	0	4	23
3	5	27	1	0	4	0	2	18	30	8	13	36
4	11	31	6	2	2	0	1	23	41	27	28	43
5	21	59	5	4	7	2	2	51	65	54	60	66
6	57	79	27	9	23	4	9	79	89	77	81	89
7	48	51	43	5	18	7	15	58	58	54	56	59
8	22	34	26	11	12	13	19	34	34	34	33	34
9	32	32	31	9	14	28	27	32	34	34	33	34
10	19	20	17	15	15	17	17	20	20	20	20	20
11	4	4	4	4	4	4	4	4	4	4	4	4
Nr of adopters*	227 (34)	367 (60)	160 (14)	59 (8)	104 (29)	75 (8)	97 (6)	322 (43)	382 (76)	312 (2)	332 (25)	
Order of importance	6	2	7	11	8	10	9	4	1	5	3	
Rank order of adoption	2	1	7	11	10	9	8	6	3	5	4	

* The figures between brackets indicate the number of adopters in 2002.

Table 2 contains several interesting pieces of information. First, we see that only 6 out of 426 households (1.4%) had not adopted any innovation at all in 2007 (as compared with a proportion of more than 60% in 2002). Second, as indicated in the penultimate row, the most frequently adopted innovations are, by decreasing order of importance, innovations (9), (2), and (11). Third, as indicated in the last row, the innovations that have priority in adoption are, by decreasing order of importance, innovations (2), (1) and (9). These latter figures have been derived by looking at the most frequently adopted innovation when a household adopts successively one, two and three innovations in total. The strong predominance of these three innovations when few innovations are selected suggests that they are the most cost-effective.

Caution is nevertheless warranted inasmuch as wealth constraints may possibly limit adoption of the most profitable innovations if they also turn out to be rather expensive to acquire.

Overall, 2,437 innovations have been adopted, representing an average number of 5.7 innovations per (informed) household. These figures can be compared to the situation in 2002 when the average number hardly reached unity (308/426). In other words, the average number of innovations has been multiplied eight times during the period 2002-2007. The rate of use of innovation potential, computed as the ratio of the aggregate number of innovations adopted by all the sample households to the maximum number of adoptable innovations (11 innovations times 426 households), amounted to 52% (54% if only households possessing at least one cow are taken into account) in 2007, to be compared to hardly 7% in 2002. These summary statistics are presented in Table 3 below.

Table 3: Descriptive statistics about innovation adoption in years 2002 and 2007

	2007	2002
Average number of innovations adopted per household*	5.72 (5.97)	0.72 (0.75)
Modal value	6	0
Maximum value	11	8
Standard deviation	2.34	1.19
Proportion of households without any innovation	1.40%	60.33%
Rate of use of innovation potential*	52.01% (54.30%)	6.57% (6.85%)

* The figures put in brackets refer to the corresponding statistics measured per cow-possessing household.

3.2 Econometric method and results

In order to assess the role of the wealth constraint during the period 2002-2007, we need to decide which variables to use to measure initial wealth and adoption innovation in a meaningful manner. The number of additional innovations adopted by the household during the years 2002-2007, rather than the number of innovations used in 2007, is the most logical way to measure innovation adoption. As for initial wealth, an obvious candidate is the household monetary income in 2002, measured as the gross proceeds from the sale of milk and cheese, and on a per head (and per annum) basis. Indeed, we want to have as good an indicator as possible not only of the welfare of household members, but also of the household savings that may potentially be used as working capital for the purpose of adopting innovations. Being pre-determined, this variable is not susceptible of causing an endogeneity

bias. Moreover, the testing procedure is valid insofar as unlike in the situation in 2002, most innovations used in 2007 require modern inputs that need to be purchased.[2] In the presence of a wealth constraint, we therefore expect the sign of the coefficient of the 2002 income to be positive.

There are, however, two potential problems arising from the use of average per capita monetary income in 2002 as the household initial wealth. First, a careful look at raw data reveals that the relationship between the number of (additional) innovations adopted and the initial monetary income is quite erratic, yet this erratic character disappears once we distinguish between relatively poor and relatively rich households. More precisely, and in agreement with intuition, a positive relationship between innovation adoption and initial wealth seems to exist for the lower end of the initial income distribution but not for the upper end. To avoid choosing an arbitrary definition for deciding where to set the frontier threshold below which a household will be considered poor, we use the following statistical procedure. We specify a dummy with value one for the households whose initial income exceeds a certain threshold value, and we also specify an interaction term that multiplies this dummy with initial (per capita) income. The selection of the threshold is based on the quality of fit of the estimated model. In other words, we consider all possible values of (monetary) income ranging from zero (the minimum) to 14,000 soles (the maximum) with increases of 50 soles at a time to define the threshold and then estimate the model. The model that leads to the highest pseudo R-squared is kept as the reference model. In the model thus selected, the income that best separates rich from poor households turns out to be 700 soles (1 US$ was worth 3.18 soles and 1 Euro 4.00 soles toward the end of 2007), and it coincides more or less with the mean and the 75th percentile of the household income distribution. It is also strikingly close to the average initial income of innovation adopters (701 soles).

The second problem results from the methodology of data collection used to obtain data for the year 2002. It might, indeed, be argued that since the monetary income of 2002 is a recall variable, measurement errors are likely to be present and to lead to an excessively high correlation with incomes in the terminal year. In order to mitigate this problem, we have chosen to identify the common component underlying four different factors measuring the per

[2] Careful examination of data thus reveals that 82% of innovation adopters in 2002 had adopted less than three innovations and the two most frequently adopted innovations −double cow milking and multiple ploughing− have the special characteristics of being relatively time-consuming and toilsome. At the same time, they do not necessitate the purchase of modern inputs and should not therefore be subject to credit or liquidity constraints as are the other innovations, a hypothesis that we will be able to confirm on the basis of our 2007 data.

capita household wealth in year 2002. Besides the initial monetary income, we use the following factors: the size of the cowherd per head, the grazing land area per head, and the area of improved pastures per head, which measures the farm area sowed with seed varieties provided by extension agents.[3] These three variables are obvious measures of the household physical assets. There is the possibility that one of them, the area of improved pastures, reflects the innovativeness of the household as well. By contrast, monetary income is the outcome of the production process.

The advantage of this procedure is that it relies not only on several dimensions of the household wealth or wealth determinants but also on three variables that are recalled with small risks of error because they are measured in a few discrete units (grazing land area, whether improved or not, and cowherd). The Principal Component Analysis (PCA) that we have run has a first component that explains about 50% of total variation. Its correlation with the number of cows per head is 85%, with monetary income per head 75%, with improved grazing land area per head 76%, with grazing land area per head 65%. Given these encouraging results, we will use this first component to measure initial wealth in our econometric analysis. We have also run all the regressions to be presented below with monetary income per head as the initial wealth indicator, and it is noteworthy that all the results obtained with the PCA-based wealth variable continue to hold when monetary income measures initial wealth.

Besides the initial wealth variable, the rich-and-poor dummy (called *Rich_02*, which takes on value one if the household has an initial monetary income per head higher than 700 soles, and zero otherwise), and the interaction term between this dummy and initial wealth, there are a number of additional determinants of innovation adoption that we want to use as controls in our regressions. Foremost among them are the number of innovations used in 2002, and the average productivity of the cowherd (number of litres produced per cow per day, on an average for the whole year) in the same year. These two variables can be legitimately interpreted as indicators of the innovativeness and intrinsic dynamism or skill level of the household. It bears emphasis, indeed, that in 2002 these two indicators were not well correlated with asset variables.

The situation regarding the first of these two variables deserves particular attention. An above-highlighted feature of our 2002 data, the fact that most innovations used in 2002 were costless, explains why variations in household (initial) wealth cannot explain variations in the

[3] The possession of a cowshed may not be used as an indicator of physical wealth since there was only one household owning a cowshed in 2002 (and there were only three in 2007).

number of innovations adopted in 2002. In other words, the initial number of innovations is not endogenous to initial household monetary income. Furthermore, since we find no correlation between these two variables (the correlation coefficient is equal to 0.04, compared to a coefficient of 0.27 between initial wealth and number of innovations adopted in 2007), we can also conclude that the reverse causation mechanism –variations in number of innovations in use in 2002 determine variations in wealth owned in that year– is not at work either.[4]

This interpretation is actually confirmed when we estimate by simple OLS a regression equation in which the initial income is the dependent variable and the initial number of innovations belongs to the list of explanatory variables. Other variables figuring out on the RHS of the equation include asset measures: the grazing land area owned in 2002 by the household, the number of cows per head owned, and the type of irrigation (whether irrigation is natural, uses the water of a central canal, benefits from secondary channel infrastructure, or uses the sprinkling technique). Also present is a dummy variable indicating whether a household produces fresh milk or is completely specialized in cheese production (in 2002, milk producers numbered 250 out of 426 households). The results (not shown) confirm the absence of any significant influence of the number of innovations used in 2002 on the current monetary income of the household. The only variables (for which data are available) that appear to have determined, or to be correlated with, income in the initial year are the field of economic specialisation −milk producers fared significantly better than cheese producers−, and the size of the cowherd per capita −the larger it is the higher the per capita initial income of the household. [5] To sum up, the initial stock of innovations was not correlated with the initial monetary income, even after controlling for the influence of variables measuring the physical assets of the household.

Likewise, the average cow productivity was not well correlated with asset variables, and it is therefore difficult to argue that households which enjoyed comparatively high cow

[4] The average monetary income per head of adopter households (701 soles) did not significantly differ from that of non-adopter households (685 soles) in 2002.

[5] As will be argued in Section 5, relating cowherd size to the number of women in age of working within the household is probably more meaningful than relating the same to the total number of household members. Unfortunately, in the first dataset we do not find the required information about the ages of household members. An alternative measure would be the cowherd size per woman (since we have available the gender composition of the households), yet substituting this indicator for the cowherd size per capita does not affect our results. This is not surprising because the correlation coefficient between number of cows per capita and number of cows per woman exceeds 0.80.

productivity in the initial year benefited from scale economies.[6] This being said, we cannot rule out the possibility that average cow productivity depends on the quality of grazing land areas which could vary from community to community (owing, in particular, to variations in altitude). It will therefore be important to estimate our innovation adoption model with community-based fixed effects in order to be able to construe average cow productivity as a measure of skill or innovativeness.

Note that the type of irrigation used by the household, which presumably influences the household income-earning ability, is introduced as a control variable in our regression. Since it is measured (through qualitative variables) in the year 2002, no endogeneity problem arises.

The next determinant of innovation adoption behaviour that we want to consider may be taken to reflect the innovative predisposition of the household: this determinant is the rate of attendance of the household head to special information and training sessions organized by ITDG during the years 2002-2007. What we measure here is the intensity of the willingness of the household to obtain additional innovation-related information complementing the basic information initially acquired. Toward that purpose, we use a count variable, labelled *training*, which takes on values between zero and five, since a maximum number of five special sessions have been accessible in the surveyed region.

Furthermore, we are in a position to test for the influence on innovation adoption of the volume of activity of extension agents (the *promotores*) considered as a proxy for the density of support services in a particular community. Using the second dataset, we calculate the aggregate monthly income of all extension agents operating in the community where a household resides, a variable labelled *activity_promotores_07*. This income comprises only the proceeds from the sale of extension services by these agents to the exclusion of their incomes derived from their own herding activities. Since the agents operating in a given community may also supply services to other communities, the above variable may not be interpreted as a proper measure of the turnover of extension services in the community concerned (a data that is not available to us). But it can be viewed as a proxy for the overall dynamism of the agents operating in a community. An alternative, probably more crude measure (since the quality of the agents' work varies appreciably), is the sheer number of operating extension agents.

Finally, we test for the presence of Nestlé multinational in the community to which the household belongs. This milk purchasing company directly operates in a number of the

[6] In 2002, the correlation of average cow productivity with grazing area was 2%, 0% with improved pasture area, 18% with cowherd (and 16% with monetary income).

surveyed communities (in 8 out of 27 of them) and, since such a presence has the expected effect of reducing transaction costs, it is presumed to stimulate innovation adoption. Revealingly, the correlation between the direct presence of Nestlé and the average milk purchase price obtained by producers residing in the community concerned is positive (equal to 0.28) and significant. In an alternative specification of the econometric model used, we drop the Nestlé dummy and introduce fixed effects to control for the influence of community-specific characteristics. The descriptive statistics for the above variables as well as all other variables used in this study are reported in Appendix 1.

In the first column of Table 4, we present the results of the estimate of the innovation adoption equation when the Nestlé dummy is introduced but fixed effects are ignored. In the second column, the Nestlé dummy is dropped and community-based fixed effects are introduced. Note that, since the dependent variable −the number of additional innovations adopted between 2002 and 2007 (*diffinnovations*)− is a count variable, the model should ideally be estimated using a Poisson or a Negative Binomial regression. We have done so, yet because the results are not affected for the sake of clarity we only present the results associated to OLS estimations.

Although we miss conventional determinants of innovation adoption such as age and education, interesting results emerge from Table 4. The key result is the strong and robust presence of a wealth constraint, yet only for the poor households: the coefficients of *wealth_02* and the interaction term, which are highly statistically significant, cancel each other. In other words, adoption of innovation is effectively constrained by initial wealth when the household owns comparatively little wealth in the initial period. Note that the separate effect of the dummy identifying rich households ceases to be significant once fixed effects are introduced.

The initial number of innovations (*innovations_02*) influences adoption negatively (the level of significance is again 99 percent): a larger initial stock of innovations leads to a smaller absolute increase in innovations in the subsequent period. The latter finding is a logical consequence of the fact that there is a ceiling on the total number of adoptable innovations. It bears emphasis that the other two variables supposed to reflect the household innovativeness and dynamism, average cow productivity (*cow_productivity_02*) and attendance to special information and training sessions (a count variable named *training*), exert a strongly significant positive influence on innovation adoption, as expected. Since households with higher average cow productivity tend to be located in some communities, the size and level of significance of *cow_productivity_02* are reduced when we control for

geographical fixed effects, yet the coefficient remains positive and statistically significant (at 90% confidence level). On the other hand, it is noteworthy that owing to multicollinearity the value of the coefficient and the significance of *cow_productivity_02* increase (from 90 to 95% confidence level) once the *training* variable is left out. The implication is that the cow productivity variable measures two attributes simultaneously: the household innovativeness or dynamism, and the quality of grazing land endowments, which is location-specific.

Table 4: Determinants of innovation adoption and the impact of the wealth constraint

Dependent variable	*Diffinnovations*	
Explanatory variables		
Rich_02	0.511**	0.140
	(2.15)	(0.56)
Wealth_02	0.573***	0.421***
	(3.45)	(2.70)
(Rich_02)(Wealth_02)*	-0.558***	-0.420**
	(3.22)	(2.53)
Innovations_02	-0.795***	-0.691***
	(8.32)	(6.28)
Cow_productivity_02	0.158***	0.066*
	(4.53)	(1.70)
Training	0.602***	0.657***
	(4.95)	(5.52)
Activity_promotores_07	0.477	1.284*
	(1.20)	(1.93)
Irrigation1	0.096	-0.124
	(0.33)	(0.42)
Irrigation2	-0.378	-0.302
	(0.88)	(0.58)
Irrigation3	-1.327**	-0.199
	(2.28)	(0.41)
Nestlé	1.190***	
	(3.84)	
Constant	3.716***	3.823***
	(15.07)	(6.30)
Geographical Control	NO	YES
R-squared	0.36	0.52
Nr of Observations	424	424

Robust t statistics in parentheses
** significant at 10%; ** significant at 5%; *** significant at 1%*

Consonant with intuition, communities directly serviced by Nestlé, which tend to benefit from higher milk purchase prices (see above), appear to have adopted more additional innovations than other communities during the years 2002-2007 (*Nestlé* is a dummy with value one when Nestlé Company operates in the community where the household resides).

Finally, greater dynamism of extension agents encourages innovative behaviour, an outcome that comes out only when community-based fixed effects are introduced.

The detailed information that we possess about the available technical innovations and their varying characteristics in terms of working capital requirements allow us to design an even more powerful test of the existence of a wealth constraint than the one provided above. We can thus re-estimate the innovation adoption equation by excluding the two innovations that do not require modern inputs for effective use (innovations (1), double cow milking, and (9), multiple ploughing), or by taking only these two innovations into account while measuring the dependent variable in 2007. In the latter case, the dependent variable can therefore take on three values only: zero when neither innovation (1) nor innovation (9) have been adopted (which is the case for 30/426 of the households), one when only one of these innovation has been adopted (183/426), and two when both have been adopted (213/426). These two innovation variables are labelled *diff_costly* and *diff_costless*, respectively, when they appear as dependent variables, and *costly_innov_02* and *costless_innov_02* when they appear as controls on the RHS of the innovation adoption equations.

The results, reported in four distinct columns in Table 5 (estimates are again made without and with fixed effects), bring neat support for the wealth constraint hypothesis. For innovations that do require the purchase of modern inputs, there is a positive, highly significant effect of initial wealth on additional innovations adopted in the period 2002-2007, yet this is again true only for relatively poor households. However, for costless innovations, there is no evidence of the operation of a wealth constraint even for poor households. There are two other findings worth commenting when innovations are decomposed into costly and costless innovations. First, the effect of the *training* variable is affected by the decomposition: there is no impact when innovations are costless while the impact remains positive and highly significant (at 99% confidence level) when they are costly. This result follows from the fact that most of the additional training provided concerns rather sophisticated techniques (of cheese-making, in particular) that happen to be costly innovations.

Table 5: Determinants of innovation adoption distinguishing between costly and costless innovations

Dependent variables	*Diff_costly*		*Diff_costless*	
Explanatory variables				
Rich_02	0.334	0.112	0.187***	0.011

	(1.64)	(0.52)	(2.80)	(0.17)
Wealth_02	0.509***	0.434***	0.051	-0.012
	(3.71)	(3.13)	(1.17)	(0.36)
(Rich_02)(Wealth_02)*	-0.477***	-0.415***	-0.068	-0.003
	(3.30)	(2.83)	(1.50)	(0.07)
Costly_innov_02	-0.638***	-0.599***	-0.071**	0.004
	(6.57)	(5.30)	(2.53)	(0.14)
Costless_innov_02	-0.286*	-0.197	-0.743***	-0.804***
	(1.87)	(1.02)	(14.77)	(12.48)
Training	0.562***	0.603***	0.040	0.043
	(5.29)	(5.67)	(1.44)	(1.64)
Cow_productivity_02	0.116***	0.046	0.041***	0.023***
	(3.93)	(1.40)	(4.71)	(2.63)
Activity_promotores_07	0.449	0.871	0.021	0.330**
	(1.27)	(1.48)	(0.21)	(2.49)
Irrigation1	0.146	-0.140	-0.070	-0.014
	(0.59)	(0.55)	(0.87)	(0.19)
Irrigation2	-0.211	-0.137	-0.152	-0.162
	(0.56)	(0.31)	(1.37)	(1.36)
Irrigation3	-1.136*	-0.251	-0.099	0.181*
	(1.91)	(0.50)	(1.15)	(1.77)
Nestlé	0.780***		0.418***	
	(2.93)		(5.41)	
Constant	2.811***	2.908***	0.931***	1.058***
	(13.62)	(5.39)	(12.74)	(6.52)
Geographical Control	NO	YES	NO	YES
Nr of Observations	424	424	424	424
R-squared	0.31	0.46	0.44	0.60

Robust t statistics in parentheses
** significant at 10%; ** significant at 5%; *** significant at 1%*

Second, while the average productivity of the cowherd continues to have a significant impact on innovation adoption for costless innovations (the effect is now statistically significant at 99% confidence level), the impact vanishes for costly innovations when we control for the effects of location. However, when the training variable is dropped from the regression, the coefficient of the productivity variable for costly innovations becomes significantly positive again in the regression with fixed effects (at the 95% confidence level). The differentiated result regarding *cow_productivity_02* is thus the outcome of what appears as a statistical artefact: the correlation between *training* and *cow_productivity_02* is stronger for costly than for costless innovations. In actual fact, this result itself is easy to interpret: indeed, comparatively innovation-prone individuals tend to participate in training sessions which, as we have pointed out earlier, matter essentially for rather sophisticated innovations that happen to be costly.

4. The impact of enhanced technological supply on income and inequality

4.1 Innovation adoption and income inequality

Results emerging from the preceding section do not allow us to predict clear outcomes regarding the evolution of inequality during the period 2002-2007. On the one hand, there is the wealth constraint itself which is reflected in the positive relationship between initial wealth and innovation adoption. Since this constraint is at work only for the poorer households, this force is normally expected to deepen income or wealth inequality. On the other hand, households which started with more innovations in 2002 adopt a smaller number of additional innovations during the subsequent period. Since the initial stock of innovations is uncorrelated with the initial monetary income and with the PCA score for our initial wealth variable, it is impossible to predict the impact of the negative relationship between innovation adoption and initial innovation stock on income or wealth inequality.

Computing the Gini coefficients for both the initial and terminal years reveals that inequality in household monetary incomes has remained more or less constant, which could be the consequence of reporting biases due to the recall method used to elicit information for initial incomes. Gini coefficients also remain approximately identical (they slightly decline) when the distribution of cowherds (or cowherds per capita), and the distribution of grazing land areas (or grazing land areas per head) are considered. The same conclusion obtains when the initial and final distributions of average productivity of cowherd are compared (here, the value of the Gini coefficient slightly increases). The only dimension along which the inter-household distribution undergoes a dramatic evolution is improved pasture area: the Gini coefficient decreases from about 0.89 to 0.54 when this variable is measured on an aggregate basis, and from 0.91 to 0.58 when it is measured on a per capita basis. It bears emphasis that the proportion of households owning improved pastures has increased from 9.2% (39/426 households) in 2002 to 90.6% (386/426) in 2007.

This is a major outcome of the *promotores* programme, which has undoubtedly worked toward diminishing wealth and income inequality in the area surveyed. Remember, indeed, that the spreading of improved pastures is the result of adoption of several innovations (numbered 8, 10, and 11 in the list presented in subsection 3.1).[7] Innovation 8, in particular,

[7] According to the definition used in the survey, improved pastures are pastures that are not purely natural but have been improved in some way or other (which does not necessarily imply that they have been sown with new seed varieties).

that is, the use of new seed varieties, has been adopted by as many as 322 households (about 80% of the total sample), which suggests that its adoption was not seriously hampered by the initial wealth constraint. A plausible explanation for such a situation lies in the fact that adoption of improved seeds necessitates more labour effort and hard work than cash expenditures. Interestingly, when this innovation is shifted from the category of costly innovations to that of costless ones, and the estimations of the innovation adoption equations are re-run on the basis of the new definition, we find that all the results continue to hold (results not shown).

In the other way around, we know that only a very small number (eleven households) of our sample herders have undertaken the production of high quality cheese, known as Swiss cheese, which suggests that they are highly performing, skilled and entrepreneurial. As pointed out in Section 2, the fat content of the milk produced must be sufficiently high for this production to be possible. That the presence of this small group of producers tends to increase inequality becomes evident when the Gini coefficient for the monetary incomes obtained in 2007 (whose value is 0.5219) is decomposed by source of income. As we can see from Table 6, the contribution to inequality that arises from incomes derived from the sale of high quality cheese products is substantially larger (by about 9%) than the share of these sale proceeds in the aggregate monetary income of all the households. The opposite is true of the incomes originating in the sale of fresh milk and of those obtained from the sale of low quality cheese products. Marginal effects also reflect the negative impact of high quality cheese producers on the distribution of household incomes.

Table 6: Decomposition of the Gini coefficient as per the source of income (monetary incomes for year 2007)

Income source	Shares of each income source in total income	Shares of each income source in total inequality	Marginal effects on inequality
Milk	59.70%	55.30%	-0.044
Low quality cheese	25.67%	23.37%	-0.023
High quality cheese	10.31%	19.03%	+0.087
Others	4.32%	2.30%	-0.020
Total	100.00%	100.00%	

In Table 7, we confirm through descriptive statistics the specific characteristics of producers of high quality cheese. As a matter of fact, when they are compared to households which produce low quality cheese only, and to those which produce milk (and/or low quality cheese to the exclusion of high quality cheese), marked differences are observed along some critical dimensions. In particular, the final income (per head) of high quality cheese producers is considerably higher than that of milk producers which is itself much higher than

that of low quality cheese producers. Members of the first group have adopted more innovations during the years 2002-2007 than members of the other two groups and, above all, they have attended more special training sessions to acquire additional knowledge (about how to make high quality cheese). Note finally that the average productivity of the cowherd is broadly identical between high quality cheese and milk producers yet it is significantly higher than that achieved by low quality cheese producers.

Table 7: Comparison of descriptive statistics distinguishing between three categories of producers

	Producers of high quality cheese (possibly with milk and/or low quality cheese)	Producers of milk (possibly with low quality cheese)	Exclusive producers of low quality cheese
Improved pasture per head	0.41 ha	0.35 ha	0.25 ha
Number of cows per head	0.67	0.83	0.68
Irrigation system (ordinal scale)	0.91	0.90	0.81
Number of new innovations adopted between 2002-2007	6.36	5.35	4.90
Number of additional training sessions attended in 2002-2007	1.18	0.43	0.50
Average cow productivity	9.05	9.19	7.66
Average income per head 07	6,378 soles per head p.a.	1,234 soles per head p.a.	605 soles per head p.a.

4.2 Impact of innovation adoption on final incomes

In the following, we set out to examine the household income data pertaining to year 2007 in order to determine how innovation adoption influences household incomes in this terminal year. In particular, we want to compare the impact of initial wealth as it operates through the innovation adoption channel to its impact exerted outside this channel. The first effect may be referred to as the innovation-induced wealth effect, and the second one as the path dependent effect. Methodologically, the problem is tricky because the innovation variable (*diffinnovations*), even though it is measured as a difference observed in the 2002-2007 period, is potentially vulnerable to an endogeneity problem. We hence instrument it. The instruments that we use are attendance to additional training sessions between 2002 and 2007 (*training*), the initial stock of innovations used by the household, and the relative income of

each household (*relative_income*) with respect to the mean income of its village community. The first variable, a measure of the customer's dynamism, should be correlated to his innovation adoption behaviour. It should be exogenous since the only way of valuing a new training is through the adoption of new innovations: it is useless by itself. The second variable is *a priori* a good instrument as well since the number of innovations used in 2002 can influence household income in 2007 only through the effect of innovation adoption in the intervening period. Bear in mind that initial wealth is uncorrelated to the initial stock of innovations. Finally, the third variable is a measure of household access to extension services: as will be shown later, indeed, well-to-do extension agents target relatively wealthy customers when proposing their services. This variable is again supposed to be exogenous insofar as it corresponds to the relative wealth of the household with respect to the community and not to its absolute wealth which is already accounted for in the specification.

To test for the quality and relevance of these three instruments, we perform the usual statistical tests (i.e. exogeneity, underidentification and weakness) controlling for heteroskedasticity. To check for the exogeneity of the instruments, we calculate the Hansen J-statistic which is 3.98. The value of this statistic is much smaller than the critical value of a Chi square with 2 degrees of freedom (5.99). We hence do not reject the null hypothesis that the instruments are valid. To check for the relevance of the instruments, we calculate the Kleibergen-Paap rk LM statistic which is 44.67. This value is much larger than the critical value of a Chi square with three degrees of freedom which is 7.81. We hence reject the null that the model is underidentified. Finally, to test for the weakness of instruments, we compute the Kleibergen-Paap rk Wald F statistic which is 21.60. This value is larger than the critical value tabulated by Stock and Yogo (2005) for a 5% maximal relative bias which is 13.91. We hence reject that the instruments are weak.

It is well known that instrumental variables induce a substantial gain in consistency with respect to OLS if some of the RHS variables are endogenous. However, the price to pay is a severe loss in efficiency. To balance consistency and efficiency, we run the Durbin-Wu-Hausman test and check if our instrumental variables setup should be preferred to the OLS. The calculated test statistic is 1.25, which is much smaller than a Chi square with one degree of freedom (3.84). We therefore do not reject the null that the difference in coefficients is not systematic.

In the light of the latter test, it is legitimate to rely on OLS estimates. However, for the sake of completeness, we present in Table 8 below the results obtained with both the OLS (see the first two columns) and the 2SLS (see the last two columns) estimation methods

controlling for fixed effects (results without fixed effects are close enough not to warrant additional discussion). The estimates for the first-stage equation, which closely resembles the innovation adoption equation discussed in the previous section, are presented in Appendix 2. Two specifications are used, one in which the producers of high quality cheese are included, and the other in which they are excluded. The removal of this category of producers in the second specification is justified by their highly specific characteristics while the small size of this group prevents us from introducing a separate effect for its members in the regression. Overall, the similarity between the results obtained through the simple OLS and the IV models is striking, which confirms that the bias caused by the use of a simple OLS model is rather small. In the following, we discuss the results achieved through the IV method only. Note that, since the 2007 incomes have not been deflated, the size of the coefficients associated with most explanatory variables is overestimated. This does not affect the type of interpretations that matter here.

When all categories of producers are taken into account, the coefficient of *diffinnovations* is significant and equal to 0.273, implying that one additional innovation adopted during the years 2002-2007 results in an annual increase of about 273 soles in the final per-capita income of the household. Since there are, on average, five members per household, this represents an increase of 1,365 soles or about 428 US$ per household. This is equivalent to 32% of the yearly annual average income of a household in 2007, and 47% of such a statistic measured in 2002. Bearing in mind that a household has adopted, on an average, five additional innovations during the years 2002-2007 (see Table 3), we can conclude that technical change has sparked decisive income increases in the area covered by the *promotores*. Bear in mind that we measure income as the monetary value of the marketed surplus of milk and milk products. To the extent that households increase their self-consumption in response to productivity increases resulting from technical change (a reflection of the income effect of such change), monetary incomes as we measure them clearly under-estimate the impact of additional innovations.

*Table 8: The role of initial wealth and innovation adoption as determinants of final household monetary income*s *(including and excluding high-quality cheese producers)*

Dependent variable	*Income_head_07*			
Explanatory variables	OLS		IV	
	whole sample	high-quality	whole sample	high-quality

		cheese producers excluded		cheese producers excluded
Rich_02	1.243***	0.776***	1.247***	0.783***
	(3.93)	(4.58)	(4.11)	(4.74)
Wealth_02	0.173**	0.131***	0.167**	0.128***
	(2.38)	(2.86)	(2.26)	(2.64)
(Rich_02)(Wealth_02)*	0.548**	0.435**	0.549**	0.437***
	(2.09)	(2.54)	(2.22)	(2.68)
Milk_02	0.038	0.208**	0.011	0.197**
	(0.16)	(2.41)	(0.05)	(2.26)
Diffinnovations	0.155***	0.110***	0.273***	0.161***
	(3.77)	(3.33)	(3.31)	(3.14)
Cow_productivity_02	-0.021	-0.001	-0.028	-0.005
	(1.05)	(0.08)	(1.20)	(0.29)
Irrigation1	0.303*	0.287*	0.337*	0.305*
	(1.66)	(1.67)	(1.70)	(1.74)
Irrigation2	-0.018	0.079	0.011	0.095
	(0.04)	(0.21)	(0.03)	(0.26)
Irrigation3	-0.107	0.057	-0.106	0.058
	(0.47)	(0.51)	(0.44)	(0.49)
Constant	0.058	0.156	-0.409	-0.059
	(0.30)	(0.80)	(0.68)	(0.16)
Geographical Control	YES	YES	YES	YES
Nr of Observations	416	406	416	406
High Quality Cheese Producers	YES	NO	YES	NO
R-squared	0.51	0.65		

Robust t statistics in parentheses
** significant at 10%; ** significant at 5%; *** significant at 1%*

As expected, when the special group of high quality cheese producers is left out, the coefficient of *diffinnovations* becomes lower (0.16), suggesting that one additional innovation gives rise to an annual household income of 800 soles (252 US$) representing 23% of the total monetary income of milk and low quality cheese producers in 2007. This effect is again significant at 99% confidence level.

The path dependence effect of wealth is sizable and significant: for a given amount of additional innovations adopted in the years 2002-2007, a higher initial wealth in 2002 determines a higher monetary income in 2007. As for the innovation-induced wealth effect, its effect can be roughly computed by using the coefficient $d(\Delta innov)/dw_{02}$ obtained from the first-stage equation and multiplying it by the coefficient $dy_{07}/d(\Delta innov)$ obtained from Table 8. When all categories of producers are considered, this yields a value equal to $0.351 \times 0.273 = 0.096$, to be compared to a direct, path dependence effect of about 0.167 (see in Table 8, the coefficient of *wealth02*, which reflects the situation for the poor households). We may therefore conclude that the wealth effect running through the channel of innovation behaviour (which, we know, operates only for poor households) is close to 60 percent of the

size of the direct, path-dependence effect of initial wealth. When high quality cheese producers are removed from the sample, the indirect effect is equal to 0.068 (=0.422x0.161), amounting to roughly 50% of the direct effect (0.128).

As is evident from Table 8, the level of monetary income in 2007 is explained essentially by the initial level of household wealth (per member) –an effect significantly enhanced for well-to-do households−, by the adoption of new innovations, and by the field of specialisation of the household −once high quality cheese producers are excluded, milk producers appear to have much higher incomes than (low quality) cheese producers (which confirms the evidence presented in Table 7). No other factor appears to have exerted a statistically significant influence on the level of final incomes. This means, in particular, that innovativeness of the household as measured by average cow productivity does not have a separate impact on the final income once its influence on innovation adoption has been allowed for (which causes multicollinearity between *cow_productivity_02* and *diffinnovations)*.

In Table 9, the simple OLS model with fixed effects has been re-run, this time by distinguishing between costly and costless innovations. (Estimation of the IV model proved to be difficult due to a lack of effective instruments when separation of innovations by type is attempted). A puzzling result is the absence of effect of technical change on final income insofar as costless innovations are concerned, which contrasts with the expected positive effect of technical change caused by the adoption of costly innovations. Interestingly, when we modify the definition of innovation types so as to include the comparatively cheap innovation N° 8 (improved pastures) in the category of costless (rather than costly) innovations, there is now a positive and significant impact (at 90% confidence level) of the adoption of costless innovations on final household income (results not shown). For costly innovations (original definition), and limiting our attention to the restricted sample (high quality cheese producers excluded), one additional innovation causes an increase in final household income equal to 675 soles, representing almost 20% of the total amount of this income. The indirect, innovation-induced impact of initial wealth is 0.059 (=0.135x0.434), to be compared to a direct, path dependence impact of 0.118, again pointing to a 0.50:1 ratio.[8]

*Table 9: The role of initial wealth and innovation adoption as determinants of final household monetary income*s, *distinguishing between costly and costless innovations (including and excluding high-quality cheese producers)*

Dependent variable	*Income_head_07*

[8] The coefficient of 0.434 has been extracted from Table 5 since we do not have available a first-stage equation when innovations are differentiated.

Explanatory variables	OLS	
	whole sample	High-quality cheese producers excluded
Rich_02	1.239***	0.776***
	(3.89)	(4.52)
Wealth_02	0.184**	0.118**
	(2.09)	(2.55)
(Rich_02)(Wealth_02)*	0.539**	0.445***
	(2.09)	(2.61)
Milk_02	0.042	0.201**
	(0.18)	(2.31)
Cow_productivity_02	-0.021	-0.001
	(1.06)	(0.07)
Irrigation1	0.298*	0.298*
	(1.66)	(1.74)
Irrigation2	-0.007	0.064
	(0.02)	(0.17)
Irrigation3	-0.111	0.058
	(0.50)	(0.45)
Diff_costly	0.142***	0.135***
	(3.44)	(3.94)
Diff_costless	0.221	-0.002
	(1.04)	(0.03)
Constant	0.036	0.187
	(0.18)	(0.95)
Geographical Control	YES	YES
Observations	415	405
High Quality Cheese Producers	YES	NO
R-squared	0.51	0.65

Robust t statistics in parentheses
** significant at 10%; ** significant at 5%; *** significant at 1%*

Since there is no ground to think that costless innovations are any less effective in enhancing short- or medium-term productivity than costly innovations, the following hypothesis comes to mind: while adoption of costly innovations induces households to increase their sales of marketable products (which we measure), adoption of costless innovations prompts them to increase self-consumption (which we do not measure). Here is a plausible way to interpret this differentiated response of households to innovation adoption. When out-of-pocket recurrent expenses have to be incurred to finance the purchase of modern inputs in which an innovation is embedded, the household is eager to use these inputs to generate additional monetary incomes so as to repay the outlays and reconstitute its working capital for the next round. When no such outlays are involved however, there is no such pressure to increase monetary income and self-consumption is allowed to grow.

5. The supply of extension services and the wealth constraint

5.1 Creation of a market for extension services and credit transactions

The "*promotores*" programme launched by ITDG in the two districts of La Encanada and Hualgayoq was actually the outcome of a rethink of a previous so-called "*kamayoq*" programme. Under the latter scheme, extension agents trained at the initiative of this NGO (and elected by their village community) were supposed to "return" or transfer to their community the benefit of such donor-funded training by providing free services to willing local users. Revealingly, in only 24% of their deals did the *kamayoq* ask for a payment exceeding the cost of the products supplied as part of their extension services (Demont, 2006). This approach, however, yielded disappointing results reflected in low activity rates and considerable attrition of *kamayoq*. Hence the shift to the new programme based on the idea that grassroots operators should activate a genuine market for extension services by charging prices that allow their business to be profitable and sustainable.

From Table 10 below, it is apparent that in 2007 the (gross) income earned from extension activities by the new brand of agents represented, on an average, one-fourth of their total (gross) income. The average proportion of *promotores* for whom the income obtained from supplying technical assistance exceeds that obtained from domestic activities (sale of milk and cheese) works out to 13%. On the other hand, comparing monetary incomes of innovation adopters with those obtained by extension agents from their domestic activities reveals that the ratio of the former to the latter is 0.68. This ratio was greater than one in year 2002, yet it was then not significantly different from unity. Such a reversal suggests that the extension agents themselves have been quite active in adopting new innovations, which is not a surprising result.

*Table 10: Gross incomes earned by extension agents from domestic and extension activities, and gross incomes earned by innovation users from domestic activities (in soles per household per month)**

	Promotores 2002	Innovation users 2002	*Promotores* 2007	Innovation users 2007
a. Income from domestic activities	182	233	493	337
b. Income from extension services	–	–	168	–
Total income: a + b	182	233	661	337
Ratio b/(a+b)	–	–	25.4%	–
Proportion of households for which b > a	–	–	13.0% (6/46)	–

* For the *promotores*, the incomes have been drawn from our own dataset of the incomes earned during the month preceding the survey. For innovation users, on the other hand, we use the information from the first dataset which report average monthly incomes pertaining to the rainy and the dry seasons (see Section 2).

As we know from Section 2, providers of veterinary services (VET) constitute the majority of the *promotores*. During the month preceding our field survey (toward the end of year 2007), they had an average of 24 customers with a minimum of 1 and a maximum of 120, and these customers were residing in three different communities, again on an average. Their average income derived from extension services amounted to 182 soles (with a range of variation going from 0 to 1,000 soles). Most of the VET (21 out of 23) typically include a profit margin when setting the price for their services. The two of them who do not have a very low activity rate (not more than five services per month) and restrict their services to close relatives or acquaintances. It is also interesting that all VET (except one) who operate with a profit occasionally provide free services. The main reasons adduced to justify strict cost pricing of extension services are, by decreasing order of importance: the short time spent in supplying the service (in 50% of the cases), the poverty of the customer (35%), a personal relationship (either a friend or a relative) between the extension agent and the customer (10%), and the high socio-political status of the customer (5%).

In the standard case, the profit margin is computed as a percentage of the total value of the products delivered. In many instances, though, the price charged by the VET also depends on a number of specific factors, namely: the distance between his place of residence and that of the customer (this happens in 46% of the reported transactions), the difficulty in finding the product required (36%), and the character of the service provided (18%). The gross income earned for a given service is thus equal to $(1+x\%)x$product price + variable margin. To make things even more complicate, the level of the fixed margin x varies from agent to agent.

In 80% of the transactions, the VET sell their services on credit, a practice vindicated on the ground that customers are short of liquidities. The term set for the settlement of the service price is 15 days in 40% of the cases and one month in the remaining 60%. Two VET only refuse adamantly to extend this period whereas it is common practice among others to double the time initially granted for loan repayment. On the other hand, only a small minority of the VET (8%) charge an interest on the credit given to their customers. Even allowing for the possibility of grace periods, default has occurred in 16% of the deals struck during the month preceding the date of our survey.

Uncertain (re)payment is the alleged motive underlying rationing practices on the part of service suppliers: 37% of the VET said that their response to the risk of default consists of

limiting the scope of their activities and 61% of them stressed their willingness to only cater to a fixed set of carefully selected customers (these two answers obviously overlap). When default nevertheless occurs, a VET always starts by going to the customer in order to exert pressure and issue warnings. In the next step, he appeals to the local *Ronde* (a local committee charged with settling conflicts in an informal manner), or to the Judge of Peace if he resides in a so-called *centro poblado*.[9] If he is compelled to take up such costly steps, the extension agent always inflicts a punishment on the defaulting customer by refusing to deal with him (her) in the future. Since information circulates well among the VET, who meet regularly through their professional associations, defaulting by a customer is likely to lead to ostracisation by all the *promotores* in the region, a mechanism known as multilateral punishment (Greif, 1993, 1994, 2006; Platteau, 2000; Aoki, 2001; Fafchamps, 2004; Dixit, 2009).

The above account leads to several important conclusions. First, VET tend to behave in a business-like manner looking for reliable and creditworthy customers. Second, by providing credit to their customers, they relax the wealth constraint weighing on the latter, yet only to a certain extent (hence the risk of default which prompts VET to resort to rationing of service supply). Third, since they are selling their services on credit, they may subject themselves to a wealth constraint. Their need for liquidity also arises from another source: as a matter of fact, they must finance the purchase of products ahead of delivery to customers. In order to economise on transaction costs, these purchases are actually pooled inside one of the two VET professional associations.

In the beginning of the experience, the NGO endowed the veterinary associations with an initial capital so that they could operate collectively as a rotating fund. Not only were members thus enabled to purchase products ahead of their sale and the payment of associated services, but special interventions of the NGO insured them against the risk of losses caused by customer defaulting. Such schemes, however, collapsed in 2005-2006 as a consequence of various rather familiar problems (embezzlement, lack of discipline on the part of certain members) which ended up eroding the rotating fund of each association. Since a few years, therefore, the two associations serve only two functions: the pooling of product purchases (but the VET have to pay cash upon receiving the products ordered), and exchange of technical and other information (in particular, regarding the creditworthiness of customers).

[9] The *centro poblado* is an administrative unit just below the district level which regroups several villages and where a Justice of Peace is often located.

Let us now turn to the situation of the agricultural service providers (AGR). All of them actually sell their services on credit since they supply seeds for improved pastures at sowing times and get paid after the (third) harvest of the fodder crops.[10] Defaulting on this obligation to return seeds has been widespread: from interviews with the AGR, we estimate that about one-third of the seeds supplied to customers have never been returned with the result that the rotating fund created at the initiative of the NGO could not be adequately replenished and eventually collapsed. In this specific instance, the default risk has been considerably enhanced as a result of unfair competition caused by the distribution of free seeds and free technical assistance by the YANACOCHA mining company. This intervention sparked a protest movement against the *promotores* who were accused of exploiting their communities. The response of the AGR, organised in a professional association (called *Naturaleza Andina*) built on the same principles as the VET associations, consisted of adopting a strategy of careful screening of potential customers so as to minimise the risk of default. The average monetary income of this category of *promotores* amounts to 290 soles per month, and individual income varies from 0 to 1,100 soles. As for the average number of their customers (per month), it is equal to 27, and it varies from 1 to 80.

Finally, agro-processing and marketing service providers (APM) differ from the above two categories in that they do not earn directly observable incomes from the technical assistance they provide. This free assistance aims at helping cattle herders to improve the quality of their milk (raising its fat content and degree of purity) so that it can be transformed into high quality cheese. APM actually have a direct stake in their extension work because they are themselves producers and sellers of high quality cheese, and they generally want to increase the volume of their cheese-making activities. They therefore have a clear interest in maintaining collaborative relationships with privileged customers so that they become regular suppliers of a product that meets strict quality standards. In these conditions, it is not surprising that the APM provide, on average, a much smaller number of extension services per month than the VET and the AGR. This said, they sometimes supply veterinary or agricultural extension services in addition to their agro-processing services. On the whole, however, the monetary incomes derived from these activities are comparatively small: their average income is 7 soles per month and the range of variation is between zero and 50 soles. Unfortunately, there is no reliable way in which we can impute a monetary value to the benefits obtained from their relationships with privileged customers/suppliers.

[10] There are, indeed, three consecutive harvests of fodder crops, and the last of them is earmarked as seeds for use in the next period, or for reimbursement of a loan in kind.

5.2 Extension agents and the liquidity constraint: econometric evidence

Descriptive evidence provided above strongly suggests that extension agents themselves may have their activities constrained by liquidity, yet not the agro-processing and marketing experts (APM) among them. In the last part of our empirical analysis, we test this hypothesis by estimating the impact of wealth on the scope of extension activities of the *promotores* concerned (VET and AGR), controlling for their personal characteristics (age and education) and a set of control covariates.

Two key issues concern the way to measure the dependent variable, on the one hand, and the wealth or liquidity available to the extension agent, on the other hand. Regarding the former, labelled *value_of_services*, since our objective is to assess the extent to which wealth constrains the scope of business, we make the logical choice of using the total (monetary) value of the extension services supplied by the agent. As far as the latter is concerned, two different routes are trodden in the following analysis. In the first approach, we measure liquidity by using the current monetary income that the extension agent' household obtains from its domestic productive activities (sales of milk and cheese) only. We designate this variable by *domestic_income_07*, which is measured annually in this instance. The idea is that cash incomes currently earned from the sale of milk and cheese products can be easily used to finance expenditures involved in the purchase of inputs associated with extension service activities. The aggregate household (domestic) income that we use as explanatory variable is thus considered as a mass of liquidity available to the household head acting as an extension agent.

It could be objected that the above variable is likely to be endogenous to the value of extension services. There are two grounds on which such an objection could rest: (1°) incomes from extension services could be invested in productive assets (a complementarity effect) and (2°) more intensive extension activities could be at the expense of domestic income-earning activities (a substitution effect). Upon careful look, such arguments are not very convincing, though. Regarding the complementarity effect, it is not very plausible to assume that productive investments made as a result of higher incomes from extension activities, assuming that they have actually occurred, could yield larger monetary benefits during the current period (think, for example, of the purchase of new seeds for pasture improvement). It is true that the purchase of a new cow could have immediate effects on domestic income, yet the expense involved (about 300 soles, on an average) is too high to be

financed by an accumulation of savings over less than a year.[11] On the other hand, since women in age of working are specialised in the day-to-day handling of milk and cheese production within the household, it is difficult to see how greater extension activity on the part of the household head could substitute for working time devoted to domestic production.[12] We nevertheless check the robustness of our results by instrumenting the *domestic_income_07* variable by its five-year lagged value which is obviously exogenous or, at least, predetermined. The results remained unchanged, and the test of Durbin-Wu-Hausman supplies evidence supporting our belief that the current domestic income from herding activities is not endogenous to the value of extension services (the test statistic is 1.33 which is associated with a p-value of 0.25).

In the second approach, we measure wealth as physical assets. To control for the effect of the size of the household or the workforce concerned, we measure physical wealth in per capita terms, using alternatively the number of women of working age (above twelve years old) and the total number of household members as the denominator. For the numerator, we use either the size of the cowherd or the pasture land area. The latter two variables are introduced separately because they are significantly correlated.[13] Whatever measure is used, the idea is that the size of physical assets is a proxy for the household's ability to own a working capital available for extension service activities. As a matter of principle, we believe that it is more meaningful to relate herding-related assets to the number of active women (in which case the variable is labelled *wealth1*) than to the total number of household members (in which case it is labelled *wealth2*) because in the surveyed village communities women are specialised in domestic herding activities.

Let us now comment on the control variables that appear on the RHS of our regressions. Age of the extension agent is measured continuously, and is represented by two terms (*age* and *agesquare*) so as to allow for a non-linear effect. As regards education, two measures are included: an ordered variable, labelled *education*, reflecting the level of formal schooling achieved by the agent, and the number of additional, optional training sessions or workshops organized by ITDG which the extension agent attended after year 2002. This second education-related variable is named *workshop*. The formal education variable comprises six

[11] Note carefully that this figure of 300 soles cannot be compared to the income data displayed in Table 10 because the latter have been estimated by using gross values.
[12] Bear in mind that there are only three out of 39 extension agents in our sample.
[13] The correlation between land area per household member and the number of cows per member is 0.40 while the correlation between land area per active woman and the number of cows per active woman is 0.34. Finally, the correlation between land area and the number of cows is 0.24.

categories defined as follows: no education (value 1), primary school non-completed (value 2), primary school completed (value 3), secondary school non-completed (value 4), secondary school completed (value 5), and higher education, whether completed or not (value 6).

Besides age and education, and the dummy *VET* (equal to one when the agent supplies veterinary services), we introduce another dichotomous variable, designated by *nr_specialisations*, which is equal to one when the extension agent has more than one field of specialisation, and equal to zero otherwise. Another dummy, labeled *mine*, informs us as to whether the agent is working for YANACOCHA mining company or not. This is useful information because a commonly heard opinion is that this company has recruited the most performing *promotores* to operate its aforementioned programme. These *promotores* receive a fixed wage from YANACOCHA (bear in mind that the extension services delivered under this programme are free of charge) and, in addition, they continue to operate as independent agents. As far as these special *promotores* are concerned, the value of their incomes from extension has therefore been computed by summing up their wage and the value of their independently provided services.

Lastly, we control for location-specific effects in two ways. For one thing, we put in a district dummy, named *district*, which takes on value zero when the extension agent resides in Hualgayoq district and value one when he resides in La Encanada district. For another thing, we measure the potential demand for an agent's services (denoted by *income_village_07*), as proxied by the sum of the incomes of all potential customers living in each village where he actually operates. (Here, the data are extracted from our first dataset). We decide not to aggregate all these incomes to obtain a single variable for each extension agent. Indeed, a preliminary analysis reveals a huge between-village heterogeneity that must be taken into account. Ignoring such heterogeneity would actually induce shrinkage of the standard errors and lead to overoptimistic conclusions. Hence, since most extension agents work in more than one village and an observation corresponds to the situation of a particular agent operating in one community only, many agents appear more than once in the dataset. To tackle this issue, we estimate the regression equation by clustering the errors by extension agent, which allows us to correct the inference. Furthermore, to guarantee the representativeness of our sample, we use the sampling weight set in the sample design stage while we estimate the regression.

Note that since several extension agents have two fields of specialization (none of them has three specialisations), they appear twice in the dataset used for our regressions. To take this specific feature of the data into account, we estimate our regressions by attaching a

sample weight of ½ to any agent who has two fields of specialization, so that his ultimate weight is unity. As it turns out, this weighting procedure does not yield different results from a simple procedure in which all observations receive the same weight (results not shown).

The estimates are presented in Table 11 which comprises four columns. In the first two columns, the wealth effect is tested by using the current domestic income variable (through simple OLS and through an IV regression) while in the last two columns, it is tested through the use of the physical asset variable (with the size of the cowherd measured per woman in age of working in the third column and per member of the household in the fourth column).

The existence of a wealth effect, measured either through availability of liquidity (the current domestic income) or through the physical asset approach (using cowherd size as the indicator of physical wealth), is largely borne out by the data: the coefficients of *domestic_income_07* and *wealth1* (but not the coefficient of the more questionable variable *wealth2*) are positive and significantly different from zero. Note that the size of the coefficient of the liquidity variable hardly varies when it is instrumented, yet the degree of its statistical significance improves from 95 to 99 percent (the p value is 0.035 with simple OLS and 0.002 with the IV method). Moreover, when we measure physical wealth as land area (per household member or per active woman) rather than as cowherd size, we find that its coefficient is positive and significantly different from zero (with a level of statistical significance equal to 90 percent). These latter results are not shown here.[14]

[14] Note that when wealth is measured as total pasture land area, its coefficient is again positive and significant (at 90 percent confidence level). On the contrary, when wealth is measured as total cowherd size, its coefficient is no more significantly different from zero.

Table 11: Determinants of the value of extension services supplied and the impact of the wealth constraint

Dependent variable	*Value_of_services_07*			
	OLS	IV	OLS	OLS
VET	-41.867	-47.450	-84.533	-35.640
	(0.88)	(0.97)	(1.36)	(0.61)
Domestic_income_07	0.017**	0.020***		
	(2.15)	(3.08)		
Wealth1			77.253**	
			(2.40)	
Wealth2				75.789
				(1.15)
Age	-47.415***	-46.690***	-31.990*	-46.989***
	(3.69)	(3.74)	(1.94)	(3.03)
Age_Square	0.684***	0.678***	0.499**	0.682***
	(4.11)	(4.27)	(2.46)	(3.46)
Education	84.286**	82.525***	71.938**	78.119**
	(2.67)	(2.79)	(2.55)	(2.07)
Workshop	24.848***	23.095***	11.951	30.905***
	(2.96)	(2.85)	(1.13)	(3.68)
Mine	498.242***	494.896***	479.554***	509.293***
	(16.71)	(15.65)	(12.01)	(14.04)
Nr_specialisations	-61.673	-56.513	-33.654	-83.295
	(0.91)	(0.79)	(0.56)	(1.28)
District	81.363	91.787	115.820**	70.816
	(1.16)	(1.45)	(2.64)	(1.05)
Income_village_07	-0.240	-0.169	0.267	-0.316
	(0.65)	(0.54)	(0.66)	(0.71)
Constant	390.056	-133.828	-357.157	-82.049
	(1.58)	(0.56)	(1.16)	(0.30)
Observations	85	85	85	85
R-squared	0.90	0.90	0.91	0.89

Robust t statistics in parentheses
** significant at 10%; ** significant at 5%; *** significant at 1%*

There are other interesting results worthy of attention. Age has a significant non-linear influence on the gross incomes earned by extension agents from the sale of their services. The relationship is convex and we calculate that the age above which experience accumulated over time seems to boost such incomes is 35 years (when wealth is measured as liquidity). Below that age, being younger is an advantage. As regards education, the level of formal schooling of the extension agent has a significant positive influence whereas the impact of

additional training through participation in workshops is strongly significant (at 99% confidence level) when wealth is measured by the current monetary income from domestic activities and by the number of cows per household member. The effect strangely vanishes when wealth is measured by *wealth1* (with physical wealth measured per active woman). This is due to an inflation of the standard errors (leading to over-pessimistic inference) resulting from a very strong positive correlation (equal to 0.70) between the number of cows per woman (in age of working) within the household and participation of the extension agent in workshops. It is revealing that once we remove the variable *wealth1* from the set of explanatory variables, the coefficient of *workshop* becomes highly significant and of a size comparable to that of the coefficients obtained in the other two specifications.

A final result is the strongly positive effect (at 99% confidence level) of the *mine* variable, which indicates that the agents recruited by YANACOCHA company obtain a higher total income from extension services than the others. Here, caution is needed before concluding that they are better performing because their higher incomes might reflect advantageous wages rather than a higher number of services, or an identical number of more valuable services, compared to their colleagues. However, when we subtract those wages from their total incomes from extension services, all the results displayed in Table 11 continue to hold. Results again persist if the same wages are added to incomes from domestic activities, considering that they, too, can be used to finance independent extension activities, and if the newly defined domestic income variable is interacted with the dummy *mine*.[15] Bearing in mind that the services provided on account of the mining company are free, it is clear that *promotores* working for this company form a special, highly performing category of extension agents.

Through which channel operates the wealth effect weighing on the extension agents is the last question we address in this paper. To answer it, we decompose the aggregate value of their services into a quantity and a price components. In other words, we re-run the regression with exactly the same explanatory variables as those used in the above estimations, but with a newly defined dependent variable. In the first series of regressions, the dependent variable is the number of services supplied by the agent and, in the second series, it is the average value or price of an extension service. The results (presented in Appendix 3) are rather neat when wealth is measured as liquidity: while the first estimation (number of

[15] We then find that the size of the coefficient of the domestic income variable increases slightly (from 0.017 to 0.019), that of the mine variable is substantially reduced (from 498 to 377), and that of the interaction term is not statistically different from zero (results not shown).

services as dependent variable) does not yield any significant effect except for the *mine* variable, the second one (value of the average client) turns out to be a close replica of the estimation displayed in Table 11. The central conclusion to draw is that, when limited by his liquidity (yet not by his physical wealth), an extension agent rations his services not by reducing his number of customers but by decreasing the average price or value of the services offered them. Since product quality is uniform and the available products are standardised so that prices are unique, reduction of service value cannot take the form of substitution of low quality for high quality products. We conclude that wealth-constrained extension agents bring down value by avoiding to supply costly innovations and by concentrating on those requiring comparatively cheap inputs.

Whether the liquidity constraint weighing on the *promotores* results in a rationing of the demand arising from certain customers hinges on the characteristics of the local market for extension services. Indeed, if such a market works perfectly in the sense of allowing service providers to freely move among villagers and across communities, these providers could be expected to find, and deal with, customers whose demand, itself possibly wealth-constrained, matches their own liquidity-constrained supply. If the opposite situation obtains in the form of a segmented market with local monopolies, wealth or liquidity problems on the supply side would inevitably result in the rationing of the demand expressed by certain customers. Unfortunately, our data do not allow us to map out how extension agents are matched with customers (the two datasets cannot be articulated together on individual basis), and we are therefore unable to mobilise quantitative evidence to diagnose the type of market that is at work in the region under concern.

This being said, when combined with some statements made by the extension agents in the course of interviews, the fact that personalised relationships are still pervasive in the communities surveyed, and that several extension agents (ranging from one to five) typically operate in each of them, suggest that the reality lies somewhere in between the two above extreme scenarios. Queried about their relationships with customers, *promotores* have thus stressed that, while it is difficult for them to refuse to deal with a client who requires their services (provided that he or she is trustworthy), a lack of working capital may compel them to reduce the value of the products delivered below what a client is willing to pay. The first part of the statement indicates that an agent may not be free to choose customers of the optimal size, while the second points toward the possibility of demand rationing at least within the framework of a particular supplier-client relationship (we cannot rule out the

possibility that the rationed customer will find another agent to obtain the products he or she could not buy from the privileged one).

Two last remarks are in order. First, when the average price of a service is used as the dependent variable in a regression where wealth is measured as liquidity, the coefficient of *VET* is positive and significant whereas it is negative and (weakly) significant when the dependent variable is the number of customers. (As is evident from Table 11, the coefficient is not statistically different from zero when the gross aggregate value of extension services is the dependent variable). These results reflect the fact that, on average, VET *promotores* give more valuable services than AGR *promotores* because the products involved are more costly. As it turns out, such an effect is broadly compensated by the fact that the former cater to fewer customers than the latter. Second, *promotores* working for the mining company have a significantly larger number of customers, even besides those served on account of the company, than their colleagues. The value of their average customer is also significantly higher. Here are, therefore, exceptional agents: in addition to their work for the company, they cater to more numerous and valuable customers than their colleagues. Note that the latter results hold whether we measure wealth as liquidity or as physical assets (through *wealth1* or *wealth2*).

6. Conclusion

ITDG, an organisation specialised in working with rural communities to enhance their productive abilities, chose to base its initial attempt to stimulate adoption of technical innovations in the Peruvian highlands, on grassroots extension agents asked to return the benefits of their training to their native communities by providing free technical assistance. Since this attempt ended up in glaring failure, the NGO changed its tactic and opted for a market-creating approach in which service providers were allowed to make a profitable business. Treating this momentous change of approach as an exogenous event that shapes a quasi-natural experiment, the paper has assessed the impact of wealth or liquidity constraints weighing on both the demand and the supply sides of a nascent market. The conclusion is that such constraints effectively limit the adoption and the supply of technical innovations.

Regarding the former side, the existence of a wealth constraint is successfully tested for robustness: according to expectations, wealth influences innovation adoption for costly but not for costless innovations, and for poor but not for rich households. Because all the sample households have been duly informed about the available innovations (and have actually taken

active steps toward acquiring that knowledge), and because we are also able to control for the influence of the household's openness to innovation (thanks to a specific feature of our data), it is legitimate to rule out interpretations of wealth as an indicator of informational or innovativeness advantages. Regarding the latter side, we find that wealth, measured as liquidity or physical assets, constrains the aggregate (gross) value of the services provided by grassroots extension agents. The constraint operates in a context where these agents have both to extend credit to their (poor) customers and to purchase in advance the modern inputs in which most innovations are embedded.

Inequality of incomes does not appear to have increased or decreased as a result of the new approach to grassroots extension. Two important forces are actually at work, one equalising and the other disequalising. Income equalisation arises from the widespread dissemination of certain, relatively cheap innovations, in particular the use of modern seed varieties to improve the quality of pastures. As for the disequalising factor, it operates through the adoption of techniques suitable for the production of high quality cheese, which is the province of a small group of especially dynamic households.

Lastly, the level of monetary income in the terminal year is explained essentially by the initial level of household wealth (per member), the adoption of new innovations, and the field of specialisation of the household. No other factor appears to have exerted a statistically significant influence. In particular, innovativeness of the household does not have a separate impact on the final income once its influence on innovation adoption has been allowed for. When we measure the wealth effect running through the channel of innovation behaviour (which, we know, operates only for poor households), we find that it is at least half the size of the direct, path-dependence effect of initial wealth. The relative size of the indirect effect is of the same order whether we exclude or include the dynamic high quality cheese producers.

ITDG has obviously succeeded in activating the market for technical assistance in the targeted Andean communities. Local households, at least those among them which chose to be informed about new possibilities, have been offered a wide range of technical innovations susceptible of enhancing productivity and raising their welfare. Wealth or liquidity constraints, however, have limited the extent of potential benefits from the active presence of grassroots extension agents. From the beginning of the experience, ITDG was aware of such an obstacle, hence its credit programme run through several professional associations and destined to mitigate the shortage of working capital on the side of these agents. Unfortunately, however, poor management of the rotating funds with which these associations were endowed, as well as lack of discipline and collective action failures on the part of the

members, have brought this crucial component of the whole experiment to an end. As a consequence, the wealth constraint weighing on the supply side of the market re-emerged as a significant factor restricting the benefits of technical change in the targeted areas. As often, credit market imperfections and the underlying incentive problems turn out to be the Achille's heel of market development.

APPENDIX 1: Descriptive statistics

Variables	*Mean*	*Standard Deviation*	*Minimum Value*	*Maximum Value*
Diffinnovations	5.042	2.485	0	10
Rich_02	0.270	0.445	0	1
Income_head_02°	0.274	0.918	0	13.716
Innovations_02	0.696	1.146	0	7
Cow_productivity_02	5.967	2.991	0	23.5
Training	0.446	0.838	-2	5
Activity_promotores_07	0.342	0.372	0	2135
Nestlé	0.465	0.499	0	1
Diff_costly	3.868	2.024	0	9
Diff_costless	1.182	0.714	0	2
Costly_innov_02	0.439	0.923	0	6
Costless_innov_02	0.257	0.484	0	2
Income_head_07°	1.245	2.202	0	25.674
Milk_02	0.587	0.493	0	1
Age	34.475	6.643	25	57
Education	3.632	1.036	2	6
Workshop	9.445	5.573	0	20
Mine	0.198	0.399	0	1
District	0.409	0.492	0	1
Income_village_07 °	108.691	77.297	3.088	296.058
Domestic_income_07	6436.97	4103.847	480	30000
Nr_cow	3.547	2.405	0	8
*Nr_activewomen**	1.957	1.316	0	6
*Nr_hholdmembers***	4.935	1.971	2	10
Nr_cow_women	2.166	1.754	0	7
Nr_cow_head	0.729	0.464	0	2
Value_services_07	168.152	265.996	0	1100
Meanvalue_services_07	10.965	11.332	0	40
Nr_services_07	23.194	20.919	1	80

° In thousand soles.

**Nr_activewomen* refers to the number of women in age of working (more than twelve years old) inside the household of an extension agent.

** *Nr_hholdmembers* refers to the total number of members inside the household of an extension agent.

APPENDIX 2: First-stage of the regression estimating the determinants of final household income per head

Dependent variable	*Diffinnovations*	
Explanatory variables	OLS	
Rich_02	0.095	-0.043
	(0.263)	(0.264)
Wealth_02	0.351**	0.422***
	(0.139)	(0.155)
(Rich_02)(Wealth_02)*	-0.366**	-0.447***
	(0.151)	(0.164)
Innovations_02	-0.715***	-0.725***
	(0.124)	(0.131)
Milk_02	0.331	0.277
	(0.254)	(0.257)
Cow_productivity_02	0.078**	0.088**
	(0.038)	(0.038)
Training	0.718***	0.660***
	(0.129)	(0 .128)
Relative_income	0.0136	0.033
	(0.012)	(0.061)
Activity_promotores_07	-2.461***	47.302***
	(0.437)	(13.542)
Irrigation1	-0.211	-0.224
	(0.294)	(0.293)
Irrigation2	-0.242	-0.240
	(0.516)	(0.514)
Irrigation3	0.058	0.021
	(0.467)	(0.508)
Geographical Control	YES	YES
Constant	5.802***	-23.983***
	(0.441)	(8.024)
Nr of Observations	416	406
High Quality Cheese Producers	YES	NO

Absolute value of t statistics in parentheses

** significant at 10%; ** significant at 5%; *** significant at 1%*

APPENDIX 3

A. Determinants of the average value of customers per extension agent in 2007

Dependent variable	*Meanvalue_services_07*			
Explanatory variables	OLS	IV	OLS	OLS
VET	4.550	3.857	5.226	4.543
	(1.60)	(1.30)	(1.49)	(1.53)
Domestic_income_07	0.002**	0.002***		
	(2.46)	(3.54)		
Wealth1			2.096	
			(0.96)	
Wealth1				9.070**
				(2.23)
Age	-1.978**	-1.888**	-1.798	-1.830*
	(2.15)	(2.25)	(1.20)	(1.90)
Age_Square	0.027**	0.026**	0.024	0.026**
	(2.29)	(2.41)	(1.31)	(2.14)
Education	4.991***	4.773**	5.235**	4.016*
	(2.74)	(2.65)	(2.35)	(1.79)
Workshop	0.657*	0.439	0.882	1.146***
	(1.82)	(1.22)	(1.21)	(3.64)
Mine	9.700***	9.285***	10.292**	10.572***
	(3.66)	(3.86)	(2.53)	(3.78)
Nr_specialisations	-5.142	-4.501	-6.077	-7.034**
	(1.48)	(1.29)	(1.49)	(2.10)
District	2.227	3.521	-0.262	2.368
	(0.60)	(0.93)	(0.08)	(0.68)
Income_village_07	-0.024	-0.015	-0.034	-0.023
	(1.29)	(0.83)	(1.14)	(1.12)
Constant	5.454	2.272	7.123	5.130
	(0.27)	(0.13)	(0.21)	(0.25)
Observations	85	85	85	85
R-squared	0.75	0.75	0.68	0.72

Robust t statistics in parentheses

** significant at 10%; ** significant at 5%; *** significant at 1%*

B. Determinants of the number of customers per extension agent in 2007

Dependent variable	*Nr_services_07*			
Explanatory variables	OLS	IV	OLS	OLS
VET	-17.847	-18.404	-24.819**	-15.348
	(1.49)	(1.43)	(2.19)	(1.26)
Domestic_income_07	-0.000	0.000		
	(0.15)	(0.07)		
Wealth1			7.263	
			(1.54)	
Wealth2				-9.886
				(1.06)
Age	-0.217	-0.144	1.618	-0.702
	(0.06)	(0.04)	(0.47)	(0.20)
Age_Square	-0.001	-0.002	-0.022	0.003
	(0.03)	(0.05)	(0.54)	(0.06)
Education	-1.658	-1.834	-3.754	0.191
	(0.41)	(0.41)	(1.09)	(0.04)
Workshop	0.117	-0.058	-2.025	0.366
	(0.08)	(0.04)	(1.30)	(0.35)
Mine	30.295***	29.961***	26.764***	30.838***
	(3.47)	(3.37)	(3.06)	(4.01)
Nr_specialisations	8.583	9.098	13.954	8.343
	(0.90)	(0.99)	(1.35)	(0.85)
District	10.250	11.291	19.018*	5.444
	(0.98)	(0.99)	(2.01)	(0.48)
Income_village_07	0.057	0.065	0.143**	0.025
	(1.27)	(1.27)	(2.33)	(0.49)
Constant	-6.557	-9.118	-43.565	5.242
	(0.12)	(0.17)	(0.76)	(0.10)
Observations	85	85	85	85
R-squared	0.55	0.55	0.58	0.57

Robust t statistics in parentheses

** significant at 10%; ** significant at 5%; *** significant at 1%*

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