Overcoming Credit Market Failures: A Paradigm of Diversification for Technology Adoption in Peru

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Abstract

This paper explores the relationship between cash constraints, income diversification and technology adoption. Using farm-household level data from Peru, we show that income diversification can serve as an alternative source of cash that allows farmers with limited access to credit adopt new technologies. This diversification provides an otherwise non-existant mechanism for these farmers to overcome credit market failures and adopt better technologies. In this context, diversification complements adoption.

Keywords: technology adoption, credit, diversification, complementarities, Peru

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1 Introduction

Technology adoption in developing countries has received renewed attention in recent years. A lot of importance has been placed on the role of agricultural innovations and the tremendous opportunity to increase production and incomes through the use of these new technologies and improved crop varieties. Yet, the vast heterogeneity of the economic environments where new technologies are being applied, as well as the low observed rates of adoption of different technologies around the developing world open a debate as to how to increase both the speed and the extent of adoption.

Adoption literature, both theoretical and empirical, has focused on identifying the factors that affect adoption decisions and the different constraints that may exist when such decisions are contemplated (Feder et al. [8] and Feder and Umali [9] provide an extensive literature review). In general, these factors can be divided in two categories: farm attributes and technology attributes. Literature on farm attributes looks at the links between adoption and farm characteristics. In these studies, issues like small vs. large, subsistence vs. market oriented farming (Kaliba [11]), human capital (Strauss et al. [17]), risk and risk management strategies (Hiebert [10], Saha [16]), institutional support systems, asymmetric information (Feder [6]), production factors availability, factor endowments, level of off-farm income, other income sources and credit constraints (Dimara and Skuras [2]), and their links with adoption decisions are investigated.

The second body of literature addresses how technological attributes themselves can affect adoption. For example, one technology can be better in one aspect of production (e.g. the new seed is resistant to a pest) but another technology may have other advantages (e.g. lower risk). As a result, these attributes combined with the idiosyncratic characteristics of the farmer can affect adoption (Misra et al. [12]).

In spite of the vast literature that addresses adoption and the influence of the factors mentioned above on the adoption process, there is still not a consensus on why some farmers adopt new technologies and others do not. Many reasons have been debated as to the lack of such consensus. On one hand, it may not be sensible to talk about one adoption policy given the complexity and heterogeneity of both new technologies and the setting where they are applied. However, even for the same technology, research methodologies to assess the barriers to adoption vary considerably. For example, most adoption studies treat adoption as a discrete phenomenon. Thus, a farmer that adopts ten percent of a new input will be treated the same as a farmer who adopts one hundred percent. Therefore, the researcher may fail to capture particular intricacies that the continuous case offers (Feder et al. [8], Rauniyar and Goode [15]).

Another shortcoming of adoption studies has been the type of link they have assumed between adoption and other farm practices. Most adoption studies generally assume (implicitly or explicitly) that adoption of new technologies generates important ex-post changes in the agricultural product mix (Ellis [5]). It is argued that adoption increases farmers' incomes so that those who have adopted new technologies are more likely to engage in other new activities, thus creating a more diversified income portfolio. In addition, adoption of new technologies may interact with agroclimactic and other biological constraints and enable the introduction of new crops or varieties, altering the product mix. An example is the introduction of soybean cultivation and Zebu cattle due to new water conservation technologies into areas of Brazil considered otherwise too hot and dry to support them (Nerlove [14]).

Yet, the reverse may also be true. Farmers facing an adoption decision and confronted with a cash constraint in the growing season may be able to relax it by altering their product mix and shifting resources to cash generating activities. In particular, while new technology profit realizations will come at the end of the harvest season, as in the case of potato cultivation, by reallocating resources to activities that generate cash income in the interim, farmers may be able to increase their ability to invest more in the new technology. This cash may not only mitigate the seasonality problem of unstable stream of income but may also help reducing risk aversion in farm production decisions (Eswaran and Kotwal [3], [4]). Therefore, self-financing has important policy ramifications as it suggests an alternative mechanism to alleviate and overcome institutional failures such as those in credit markets.

In the case Peru, the adoption of high-yield potato varieties has been slow. While the technology exists, adoption of such varieties has not diffused at the level of small and poor farmers. In the highlands of Peru, the majority of the farmers are small-scale ones with usually less than five hectares of land (Crissman [1]). They generally farm with oxen or by hand. Moreover, even if access to markets is relatively easy, the demand for new varieties of potato seeds is low due to the high costs associated with it. Specifically, potato seed is an input whose quality is observed only after it has been purchased. In addition, unlike other crops, clonal potato seed is bulky and can easily transmit diseases. As a consequence, the costs of buying new seed varieties are high. It is estimated that seed costs represent up to fifty percent of the total production costs for potato cultivation in Peru (Monares [13]). In most instances, small-scale farmers cannot afford these high monetary costs to buy these inputs. The unavailability or failure of institutional support such as credit institutions further impedes or binds the extent of adoption. Thus, understanding the adoption process and the role of credit in this setting is a high priority.

This paper addresses the "diversification for adoption" idea with data of small-scale farm potato producers in rural Peru. Using a continuous measure to capture adoption intensity, we argue that while credit constraints dramatically decrease adoption rates, farmers can alleviate and overcome these market failures via alternative mechanisms. In particular, by diversifying the farm's income sources through inclusion of cash generating activities, credit constrained farmers can increase their liquidity and access the new technologies. Cash income, such as dairy, flows in the farm in many frequent time intervals, as opposed to the large lump-sum payment that the farmers get during the harvest of seasonal crops like potatoes.

In the area of Cajamarca, Peru, where our data comes from, dairy farming has been a recent phenomenon. Nestle and a local company have established dairy centers in the region where farmers can sell their milk. In this sense, at least in the short run, only farmers that a priori had the capability to engage in dairy farming would do so. Therefore, while there is a high positive correlation between wealth and dairy farming, as we discuss below, the exogenous introduction of dairy farming allows us to link dairy income to adoption of new potato varieties. Our empirical results show that such an inflow of cash relaxes the cash liquidity constraint and allows farmers to access expensive inputs (seeds of new improved potato varieties) and therefore increase their adoption rates.

The paper proceeds as follows: section 2 develops the theoretical framework. The empirical methodology is discussed in section 3, the data is introduced in section 4, while section 5 presents the results. Section 6 concludes.

2 An adoption model with two technologies and a cash activity

We use a static adoption model that links diversification with credit market failures. We begin by assuming a profit maximizing farm-household and a missing labor market. While the latter may seem a strong assumption, it corresponds to the labor market conditions (or lack of) faced by the Peruvian small farm-households that comprise the data.

The farmer allocates labor between crop production and a cash activity. In addition, the farmer chooses between two crop varieties: either adopting new variety (N) that requires additional inputs X_N, or the traditional variety (T) that only requires labor. Formally, the farmer's problem is:

$$\underset{l_N,l_T,l_C,x_N}{Max}\ \Pi = p_N q_N(l_N, x_N, z^q) + p_T q_T(l_T, z^q) + p_C q_C(l_C, z^c, z^q) - p_{x_N} x_N \quad (1)$$

where:

N, T, C are subscripts for the new crop variety, traditional variety and the cash activity respectively,

p_j is the exogenous price of product j,

q_j is a production function of j,

l_j is the labor allocated to the production of j,

x_N are variable inputs for the production of the new variety N,

z^q are production related characteristics for all activities,

z^c are characteristics specifically related to the cash activity.

The farmer faces a labor constraint:

$$\overline{L} - l_N - l_T - l_C \geq 0 \quad (2)$$

where $\overline{L}$ is the total labor endowment of the farm,

a cash liquidity constraint:

$$C - p_{x_N} x_N \geq 0 \quad (3)$$

where C is the total income from the cash activity:

$$C = p_C q_C(l_C, z^c, z^q) \tag{4}$$

and the non-negativity constraints:

$$l_N \geq 0 \tag{5}$$

$$x_N \geq 0 \tag{6}$$

$$l_T \geq 0 \tag{7}$$

$$l_C \geq 0 \tag{8}$$

We can solve the maximization problem in two parts. Below we present the main results. Appendix B has a complete derivation of the solution to this maximization problem. First, we assume that the labor constraint is binding (i.e. equation (2) holds with equality) and focus on the case where farmers produce both the traditional and the new variety. This implies that none of the corresponding non-negativity constraints are binding. Substituting equation (2) for l_T, the maximization problem becomes:

$$\underset{l_C}{Max}\{Max \;\; p_N q_N(l_N, x_N, z^q) + p_T q_T(\overline{L} - l_N - l_C, z^q) + p_C q_C(l_C, z^c, z^q) - p_{x_N} x_N\} \tag{9}$$

subject to constraints (3), (8) as well as (5), (6), (7) being strictly positive.

The first order Kuhn Tucker conditions that describe the interior solution are:

$$\frac{\partial \Pi(\cdot)}{\partial l_N} : p_N \frac{\partial q_N}{\partial l_N} - p_T \frac{\partial q_T}{\partial l_N} = 0 \tag{10}$$

and

$$\frac{\partial \Pi(\cdot)}{\partial x_N} : p_N \frac{\partial q_N}{\partial x_N} - p_{x_N}(1 + \mu) = 0, \;\; \mu \geq 0 \tag{11}$$

where μ is the multiplier associated with the cash liquidity constraint.

Two cases arise depending on whether the cash constraint is binding or not.

Case 1 *Unconstrained*

If the cash constraint is not binding ($\mu = 0$), the optimal quantities of x_N and l_N are given by:

$$x_N^u = x_N^u(p_N, p_{x_N}, p_T, z^q, \overline{L} \big| \, l_C^u) \tag{12}$$

and

$$l_N^u = l_N^u(p_N, p_{x_N}, p_T, z^q, \overline{L} \big| \, l_C^u) \tag{13}$$

where the superscript u refers to the unconstrained case.

In addition, since

$$l_T = \overline{L} - l_N - l_C$$

and given (l_C):

$$l_T^u = l_T^u(p_N, p_{x_N}, p_T, z^q, \overline{L} \big| \, l_C^u) \tag{14}$$

Notice that the optimal levels of these inputs depend on the labor demand for the cash activity (l_C). Substituting for l_N^u, x_N^u and l_T^u in equation (9), the reduced form for the cash activity's labor demand l_C can be solved as:

$$l_C^u = l_C^u(p_N, p_{x_N}, p_T, z^q, \overline{L}, p_C, z^c) \tag{15}$$

Case 2 *Constrained*

On the other hand, if the cash constraint is binding ($\mu > 0$) then:

$$x_N^c = x_N^c(p_N, p_{x_N}, p_T, z^q, \overline{L}, l_C^c, C) \tag{16}$$

$$l_N^c = l_N^c(p_N, p_{x_N}, p_T, z^q, \overline{L} \big| \, l_C^c, C) \tag{17}$$

and

$$l_T^c = l_T^c(p_N, p_{x_N}, p_T, z^q, \overline{L} \big| \, l_C^c, C) \tag{18}$$

where the superscript c refers to the constrained case.

In this case, these quantities do not only depend on the labor demand for the cash activity, but also the cash activity income itself. These are given by:

$$\begin{cases} l_C^c = l_C^c(p_N, p_{x_N}, p_T, z^q, \overline{L}, p_C, z^c) \\ C = C(p_N, p_{x_N}, p_T, z^q, \overline{L}, p_C, z^c) \end{cases} \tag{19}$$

The important implication of the model above is that while cash income (C) does not influence the adoption decision for liquidity unconstrained farmers, it does so for the constrained. By engaging in the cash activity, cash constrained farm-households generate income that allows them to substitute for their inability to access credit. This in turn allows them to purchase cash inputs (X_N) and increase their adoption rates of the new technology. It is in this context that diversification can be thought as an alternative mechanism to overcome credit market failures that impede adoption.

3 Econometric specification

The findings of section 2 show that cash income (C) affects the adoption decision only for those farm-households that are cash constrained. This has important consequences for statistical modeling. In particular, while in the unconstrained case crop production and cash income practices are unrelated in terms of cash liquidity, this is not true for those farmers that are cash constrained. The implication is that to correctly model the adoption process, we need to simultaneously model both decisions.

To formalize, we first define adoption (A) to be the share of the seeds planted of the new variety over the total quantity of seeds planted. Then, from equations 16 and 19, adoption for cash constrained farm-households can be specified in the following system:

$$A^c = A^c(x, C, l_C^c; \beta) + \varepsilon_1 \tag{20}$$

$$C = C(x, w; \gamma) + \varepsilon_2 \tag{21}$$

$$l_C^c = l_C^c(x, w; \delta) + \varepsilon_3 \tag{22}$$

where:

$x = \{p_N, p_{x_N}, p_T, z^q, \overline{L}\}$ is a vector of characteristics that affect both the adoption decision and the cash activity,

$w = \{p_C, z^c\}$ are instruments correlated with the cash activity but not with adoption,

$\varepsilon_1, \varepsilon_2, \varepsilon_3$ are uncorrelated, normally distributed, i.i.d. disturbances and

β, γ and δ are vectors of coefficients to be estimated.

Equations (20) through (22) constitute a recursive system. However, both the cash activity labor demand and cash activity income are endogenously determined with the adoption decision. We can consistently estimate this system using instrumental variable techniques.

On the other hand, our theory suggests that cash income does not affect the adoption decision for farmers that are unconstrained. For them, the correct specification using equations (12) and (15) is:

$$A^u = A^u(x, l_C^u; \nu) + \omega_1 \tag{23}$$

$$l_C^u = l_C^u(x, w; \xi) + \omega_2 \tag{24}$$

where

x and w are defined as above,

ω_1, ω_2 are uncorrelated, normally distributed, i.i.d. disturbances and

ν and ξ are vectors of coefficients to be estimated.

This latter case, as we discuss below, provides us with a counterfactual test between the relationship of cash income and adoption by testing whether cash income indeed does not affect the adoption process for these farmers. For both specifications we implement a two-stage least squares estimation.

4 Data

The data comes from the province of San Miguel, which is located in the state of Cajamarca, in northern Peruvian Andes. The economy in the region is dominated by small farms with potatoes being the main agricultural crop. In addition to potatoes, production of dairy (cash activity) has evolved in recent years as another important activity. The farmers sell their milk to Nestle, which operates refrigeration posts throughout the region. Farmers bring their milk daily to these posts. Recently, another dairy company has entered the market, offering competitive prices for milk. The World Bank collected this data in 1999 with the goal of obtaining baseline data to evaluate the impact of a pilot farmer field school program being administered by the International Potato Center and CARE International.

Following Feder et al.[7], we classify a farmer as credit constrained if she wanted credit and could not get it either because collateral was missing or credit was not available. A farmer who did not get credit because credit was too expensive is classified as credit unconstrained (Table 1). Since the level of our analysis is within the constrained subpopulation, we treat this classification as exogenous. That is, since we are interested in understanding behavior among constrained farmers only (by showing that dairy income allows those who engage in dairy farming to adopt more), we do not endogenize the credit constraint.

The distribution of adoption intensities of the new potato variety is presented in a kernel density in Figure 1. Intensity of adoption is defined as the ratio between the quantity of new variety seeds planted to the total seeds planted. The striking observation from the figure is to notice that credit unconstrained farm-households have a very similar adoption distribution to that of the credit constrained farm-households that produce dairy. In addition, credit constrained farmers that do not engage in the dairy activity have much lower rates of adoption. On average, farmers in dairy have adoption rates of around fifty percent (also see Tables 2 and 3) compared with only twenty five percent for those with no dairy income. These observations suggest the existence of complementarities between the dairy activity and adoption of the new varieties of potatoes. In fact, if the adoption rates for the unconstrained are thought to be the outcome of "optimal" rules, then dairy income seems to compensate those farm-households that are credit constrained so that they can achieve similar adoption rates to those of the unconstrained.

Descriptive statistics for the *credit constrained* households are presented in Table 2. In terms of income, more than half of a typical farm-household's income is derived from potatoes[1]. Yet, for credit constrained households engaged in dairy, potato income only comprises half of total income compared to more than two thirds for those not engaged in dairy. In addition, farm-households who are engaged in the cash activity are wealthier than those who are not. They own more than twice the amount of land and have both more farm and

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[1] At the time of the survey, not all households had finished harvesting. Therefore, the results are likely to be underestimating potato income. Any comparisons are only suggestive and should be treated cautiously.

household assets. They are also closer to the main market and have better road infrastructure. The average annual dairy income for those who engage in it is 2877 soles (around US $ 800), a considerable amount.

Finally, Table 3 compares credit constrained and unconstrained farm-households. Unconstrained farm-households are wealthier and they adopt more than constrained ones. Interestingly, while they adopt almost twice as much of the new variety seed in quantity, their adoption rate is not significanlty different from that of constrained households that have dairy income (from Table 2).

To summarize, the descriptive statistics seem to indicate that while access to credit may hinder some households to adopt new potato varieties, credit constrained farmers engaging in dairy have significanltly better adoption rates. This suggests that dairy income may be compensating, to some extent, for the lack of credit. Yet, even though dairy income may compensate for adoption **rates**, the **level** of adoption is lower for the credit constrained.

Section 5 presents the empirical findings and analyzes the impact of dairy on adoption.

5 Results and analysis

Dairy income and adoption

Estimation of equations (20), (21) and (22) is presented in Table 4. Indeed, dairy income positively and significantly affects adoption. This supports the hypothesis that diary (cash) income complements adoption of new varieties. However, the strength of these results depends to the extent that dairy income "relaxes the credit constraint"-and thus increases the cash liquidity for these farm-households- and is not the product of a "wealth effect." In other words, for our results to be consistent with our story of diversification for adoption, dairy income should have no impact on adoption decisions for credit unconstrained households. This would correspond with the predictions of our theoretical model and in particular with equation (12). We implement a counterfactual test by estimating equations (20), (21) and (22) for the credit unconstrained. Table 5 presents the results. As expected, for the credit unconstrained farm-households, dairy (cash) income does not affect adoption decisions.

Combining the above findings with the summary statistics from section 4, we can conclude that while dairy enables credit constrained farmers to achieve desired rates of adoption by overcoming liquidity constraints, there are still significant differences in the level (quantity) of adoption between credit constrained and unconstrained. Therefore, dairy income has a wealth effect only to the extent that it allows farmers to produce a higher quantity for the new potato variety and it does not alter the production behavior of those who do not need it (credit unconstrained).

The cost of dairy

As we have shown, for the credit constrained, shifting resources away from potato production and into dairy production positively affects the adoption intensity of the new potato varieties. However, this shift of resources may come at a cost. Under our assumption that potatoes are a more profitable activity than dairy, it would imply that there is an excess resource use (and hence a cost) in producing dairy via the necessary reallocation of resources (and especially labor) to the dairy activity. That is, even though credit constrained households improve adoption rates by producing dairy, the fact that they shift labor to do that implies that they may be overproducing milk in order to ameliorate their ability to adopt.

One way to capture and test such an effect is to estimate the additional labor that is shifted towards the dairy activity by credit constrained households. To implement this, we use the estimated coefficients $(\widehat{\xi})$and predicted error $(\widehat{\omega_2})$ from equation (24) to predict the dairy activity's labor demand for credit constrained households that also engage in the dairy activity. This demand can be interpreted as the quantity of labor that would have been used for dairy if these credit constrained households were not constrained, that is:

$$l^c_C|\ if\ unconstrained = l^c_C(x, w; \widehat{\xi}) + \widehat{\omega_2} \tag{25}$$

The hypothesis is that if we compare this labor demand to the predicted values of labor demand for dairy from equation (22), we should find that the latter predicted values are larger, implying that indeed credit constrained overproduce dairy (to reach higher adoption rates).

We compare the two distributions of the predicted labor demand functions in Figure 2. Indeed, on average, credit constrained households work more on the dairy activity as opposed to the amount they would use if they were not constrained (seen by comparing the peaks of the two curves). Perhaps a more interesting observation is the fact that the overall distribution of the simulated unconstrained labor demand is shifted to the left, indicating that indeed the credit constrained would use less labor in dairy. These simulations support our previous results to show that while resource reallocation is essential for adoption, it comes at a cost.

6 Conclusions

This paper explores the relationship between cash constraints, diversification and technology adoption. Building on a simple model of adoption, we show that income diversification can serve as an alternative source for cash liquidity that allows farmers with limited credit access to adopt new technologies. While this diversification comes at a cost, it provides an otherwise non-existent mechanism for these farmers to overcome market failures and adopt better technologies. In this context, diversification complements adoption.

The results show that dairy income, a new practice in the area of study, is not displacing potatoes. On the contrary, it complements the adoption of improved potato varieties for credit constrained farm-households. While programs to help farmers' adoption rates such as input-credit or input subsidies are important, facilitating farmers' ability to diversify income sources such as dairy income, at least in the short-run, seems to provide another channel from which farmers can achieve higher adoption rates. Further research to understand these complementarities between diversification and adoption is an important next step for implementing better policies and apprehending the adoption process and long-run diffusion of new technologies.

References

[1] C. Crissman and J. Uquillas. *Seed potato systems in Ecuador: a case study.* CIP, Lima, 1989.

[2] E. Dimara and D. Skuras. Adoption of new tobacco varieties in greece:impacts of empirical findings on policy design. *Agricultural economics*, 19:297–307, 1998.

[3] M. Eswaran and A. Kotwal. Credit as insurance in agrarian economies. *Development economics*, 31:37–53, 1989.

[4] M. Eswaran and A. Kotwal. Implications of credit constraints for risk behavior in less developed countries. *Oxford economic papers*, 42:373–82, 1990.

[5] Ellis F. Household strategies and rural livelihood diversification. *The journal of development studies*, 35:1–38, 1998.

[6] G. Feder. Adoption of interrelated agricultural innovations: complementarity and the impact of risk, scale and credit. *American journal of agricultural economics*, 64:94–101, 1982.

[7] G. Feder and M. Huppi. The role of groups and credit cooperatives in rural lending. *World Bank research observer*, 5(2):187–204, 1990.

[8] G. Feder, R. E. Just, and D. Zilberman. Adoption of agricultural innovations in developing countries: a survey. *Economic development and cultural change*, 33(2):255–298, 1985.

[9] G. Feder and D. L. Umali. The adoption of agricultural innovations:a review. *Technological foercasting and social change*, 43:215–239, 1993.

[10] D. Hiebert. Risk, learning and the adoption of fertilizer responsive seed varieties. *American journal of agricultural economics*, 56:764–768, 1974.

[11] A. Kaliba, A. Featherstone, and D. Norman. A stall-feeding management for improved cattle in semiarid central tanzania: factors influencing adoption. *Agricultural economics*, 17:133–146, 1997.

[12] S.K. Misra, D.H. Carley, and S.M. Fletcher. Factors influencing southern dairy farmer's choice of milk handlers. *Journal of applied econometrics*, 25:197–207, 1993.

[13] A. Monares. *Analytical framework for design, and assessment of potato seed programs in developing countries.* CIP, Lima, 1988.

[14] Marc Nerlove, Stephen Vosti, and Wesley Basel. Role of farm-level diversification in the adoption of modern technology in brazil. *Research Report No.104 IFPRI*, 1996.

[15] Ganesh P. Rauniyar and Frank M. Goode. Technology adoption on small farms. *World Development*, 20(2):275–282, 1992.

[16] A. Saha, H.A. Love, and R. Schwart. Adoption of emerging technologies under output uncertainty. *American journal of agricultural economics*, 76:836–846, 1994.

[17] John Strauss, Mariza Barbosa, Sonia Teixeira, Duncan Thomas, and Raimundo Gomes Junior. Role of education and extension in the adoption of technology: a study of upland rice and soybean farmers in central-west brazil. *Agricultural economics*, 5:341–359, 1991.

[18] Graham Thiele. Informal potato seed systems in the andes: why are they important and what should we do with them? *World Development*, 27(1):83–99, 1999.

A Tables and Figures

Table 1: Typology of farm-households

	Cash activity		
Credit constrained	Yes	No	Total
Yes	187	46	233
No	224	29	253
Total	411	75	486

Table 2: Household descriptive statistics for the credit constrained only by dairy activity

	No dairy activity	With dairy activity
Potato seeds planted		
New variety(kg.)	119	313*
Traditional (kg.)	277	251
Total (kg.)	396	564*
Adoption rate (%)	26	50*
Dairy (cash) activity		
Dairy income (soles)	0	2887*
Herd size (#)	1.8	7.4*
Dairy pickup stop (%)	85	79*
Total labor applied (days)	64	310*
Dairy refrigeration in the community (%)	33	55*
Inherited cows (#)	0.2	0.3
Wealth-assets		
Total land owned (hectares)	4.7	10.0*
Total farm assets (soles)	293	394*
Total household assets (soles)	459	709
Rooms (#)	2.0	2.2
Income sources		
Potatoes (%)	66	54*
Dairy (%)	0	36*
Off-farm (%)	31	9*
Other crops (%)	3	1*
Production characteristics		
Total arable land owned (hectares)	4.3	8.6*
Household labor force (#)	2.7	2.8
Household head age (years)	43	44
Household head education (years)	4.5	4.8
Transaction costs		
Distance to main market (km)	362	258*
Good road quality (%)	0	7*
CARE in the community (%)	72	83*
obs	46	187

* means that there is significant difference between the two groups at the 90% level or more

Table 3: Household descriptive statistics by credit constrained

	Constrained	Unconstrained
Potato seeds planted		
New variety(kg.)	275	470*
Traditional (kg.)	256	389*
Total (kg.)	531	859*
Adoption rate (%)	45	49
Dairy (cash) activity		
Dairy income (soles)	2317	3502*
Herd size (#)	6.3	9.3*
Total labor applied (days)	271	262
Dairy pickup stop (%)	80	58*
Dairy refrigeration in the community (%)	50	62*
Inherited cows (#)	0.3	0.5
% with cash activity	80	88*
Wealth-assets		
Total land owned (hectares)	9.0	11.6*
Total farm assets (soles)	374	541*
Total household assets (soles)	660	671
Rooms (#)	2.2	2.5*
Income sources		
Potatoes (%)	55	49
Dairy (%)	32	41
Off-farm (%)	12	10
Other crops (%)	1	1
Production characteristics		
Total arable land owned (hectares)	7.8	9.5*
Household labor force (#)	2.8	3.0*
Household head age (years)	43	45*
Household head education (years)	4.8	4.8
Transaction costs		
Distance to market (minutes)	278	241*
Good road quality (%)	6	11*
Member or CARE (yes/no)	74	64*
obs	233	253

* means that there is significant difference between the two groups at the 90% level or more

Table 4: Adoption of new variety for the credit constrained (2SLS)

	Adoption (A^c)	Dairy income (C)	Dairy labor (l_C^c)
	Coeff	Coeff	Coeff
Dairy (cash) income ($\widehat{C}$)	**0.00008****		
Total labor applied to dairy activity ($\widehat{l_C^c}$)	-0.003		
Household labor force (#) ($\overline{L}$)	-0.0006	101	-0.6
Production characteristics (z^q)			
Total arable land owned (hectares)	-0.015	45***	1.1**
Household head age (years)	0.0009	58***	1.9***
Household head education (years)	-0.004	130*	6.1**
Transaction costs (p)			
Distance to market (minutes)	-0.003***	-5.7***	-0.5***
Good road quality (yes/no)	0.220***	-728	3.4
Dairy (cash) activity (z^c)			
Dairy refrigeration in the community (yes/no)		890**	-11.0
Dairy pickup stop (yes/no)		1195**	54.4**
Inherited cows (#)		413***	4.3
Constant	1.73***	-1317	241***
obs	233	233	233
R^2	0.23	0.27	0.20

Adoption: $\frac{Quantity\ of\ new\ variety\ seed\ planted}{Quantity\ of\ total\ seed\ planted}$

Dairy income: income from dairy production

Dairy labor: labor used for dairy production

Significance levels:*:90%, **:95%, ***:99%

The Sargan test for overidentification cannot be rejected at the 95% confidence level

Table 5: Adoption of new variety for the credit unconstrained (counterfactual) (2SLS)

	Adoption (A^u)	Dairy income (C)	Dairy labor (l_C^u)
	Coeff	Coeff	Coeff
Dairy (cash) income ($\widehat{C}$)	**-0.00006**		
Total labor applied to dairy activity($\widehat{l_C^u}$)	0.002		
Household labor force (#) ($\overline{L}$)	0.014	254*	2.0
Production characteristics (z^q)			
Total arable land owned (hectares)	0.0007	105***	1.6***
Household head age (years)	-0.001	96***	1.5***
Household head education (years)	0.003	384***	3.1
Transaction costs (p)			
Distance to market (minutes)	-0.002***	-4.8*	-0.3***
Good road quality (yes/no)	0.162	1951**	1.3
Dairy (cash) activity (z^c)			
Dairy refrigeration in the community (yes/no)		144*	2.2
Dairy pickup stop (yes/no)		68**	37**
Inherited cows (#)		70*	3.3*
Constant	0.351	-3654***	224***
obs	253	253	253
R^2	0.21	0.36	0.18

Adoption: $\frac{Quantity\ of\ new\ variety\ seed\ planted}{Quantity\ of\ total\ seed\ planted}$

Dairy income: income from dairy production

Dairy labor: labor used for dairy production

Significance levels:*:90%, **:95%, ***:99%

The Sargan test for overidentification cannot be rejected at the 95% confidence level

Figure 1: Adoption intensities of new variety

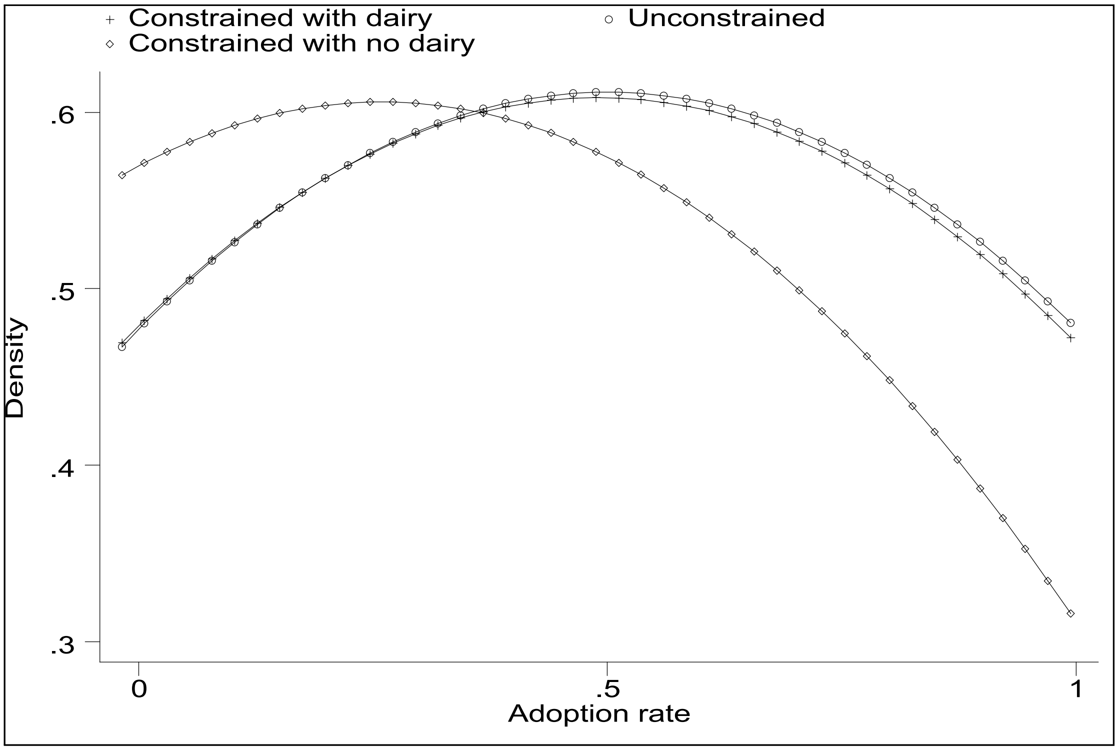
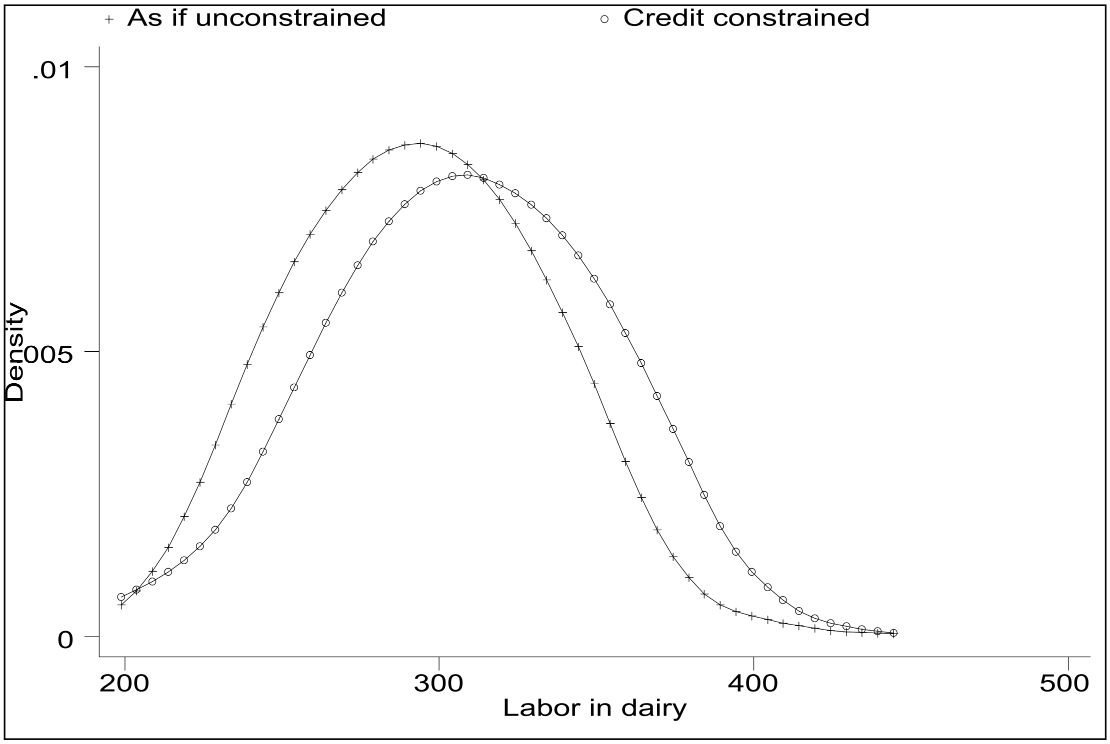


Figure 2: Labor in dairy for credit constrained
(observed and counterfactual)



B Derivation of the optimal input quantities

The farmer faces the following problem:

$$\underset{l_N,l_T,l_C,x_N}{Max}\ \Pi = p_N q_N(l_N, x_N, z^q) + p_T q_T(l_T, z^q) + p_C q_C(l_C, z^c, z^q) - p_{x_N} x_N \tag{26}$$

subject to a labor constraint:

$$\overline{L} - l_N - l_T - l_C \geq 0 \tag{27}$$

a cash liquidity constraint:

$$C - p_{x_N} x_N \geq 0 \tag{28}$$

where $C = p_C q_C(l_C, z^c, z^q)$ and the non-negativity constraints:

$$l_N \geq 0 \tag{29}$$

$$x_N \geq 0 \tag{30}$$

$$l_T \geq 0 \tag{31}$$

$$l_C \geq 0 \tag{32}$$

This problem can be solved in two parts. First, we assume that the labor constraint is binding so that

$$\overline{L} - l_N - l_T - l_C = 0$$

In addition, we focus at the case where farmers produce both the traditional and new variety i.e. $l_N > 0$, $x_N > 0$, $l_T > 0$. Substituting the labor constraint for l_T, we rewrite the maximization problem as:

$$\underset{l_C}{Max}\{\underset{l_N,x_N}{Max}\ p_N q_N(l_N, x_N, z^q) + p_T q_T(\overline{L} - l_N - l_C, z^q) + p_C q_C(l_C, z^c, z^q) - p_{x_N} x_N\} \tag{33}$$

subject to constraints (28) and (32) as well as (29), (30), (31) being strictly positive.

The first order Kuhn Tucker conditions that describe the interior problem are:

$$\frac{\partial \Pi(\cdot)}{\partial l_N} : p_N \frac{\partial q_N}{\partial l_N}(l_N, x_N, z^q) - p_T \frac{\partial q_T}{\partial l_N}(\overline{L} - l_N - l_C, z^q) = 0 \tag{34}$$

and

$$\frac{\partial \Pi(\cdot)}{\partial x_N} : p_N \frac{\partial q_N}{\partial x_N}(l_N, x_N, z^q) - p_{x_N}(1 + \mu) = 0,\ \mu \geq 0 \tag{35}$$

where μ is the multiplier associated with the cash liquidity constraint.

Intuitively, and given our setting, this multiplier represents the additional amount of the new variety input (x_N) that the farmer can purchase if he has an additional unit of cash. However, this will only be relevant if, given the optimal demand for input x_N, the farmer does not have the corresponding cash available and is thus constrained. If, on the other hand, the farmer has the required cash, the multiplier has no effect in this decision. Formally, we can look at two cases that arise depending on whether the cash constraint is binding or not.

Unconstrained case If the cash constraint is not binding ($\mu = 0$), the Kuhn-Tucker conditions become:

$$\frac{\partial \Pi(\cdot)}{\partial l_N} : p_N \frac{\partial q_N}{\partial l_N}(l_N, x_N, z^q) - p_T \frac{\partial q_T}{\partial l_N}(\overline{L} - l_N - l_C, z^q) = 0 \tag{36}$$

and

$$\frac{\partial \Pi(\cdot)}{\partial x_N} : p_N \frac{\partial q_N}{\partial x_N}(l_N, x_N, z^q) - p_{x_N} = 0 \tag{37}$$

Given l_C, from the equations above we can solve for for the optimal quantities of l_N and x_N:

$$x_N^u = x_N^u(p_N, p_{x_N}, p_T, z^q, \overline{L}, l_C^u) \tag{38}$$

$$l_N^u = l_N^u(p_N, p_{x_N}, p_T, z^q, \overline{L}, l_C^u) \tag{39}$$

where the superscript u refers to the unconstrained case.

In addition, using the fact that:

$$\overline{L} - l_N^u - l_T^u - l_C^u = 0$$

we can solve for l_T^u :

$$l_T^u = \overline{L} - l_N(p_N, p_{x_N}, p_T, z^q, \overline{L}, l_C^u) - l_C^u = l_T^u(p_N, p_{x_N}, p_T, z^q, \overline{L}, l_C^u) \tag{40}$$

Notice, that the optimal levels of these inputs depends on the labor demand for the cash activity (l_C^u).

To solve for l_C^u, we first substitute l_N^u, x_N^u and l_T^u in equation (33). The maximization problem becomes:

$$\begin{aligned} \underset{l_C^u}{Max}\ & p_N q_N(l_N^u(p_N, p_{x_N}, p_T, z^q, \overline{L}, l_C^u), x_N^u(p_N, p_{x_N}, p_T, z^q, \overline{L}, l_C^u), z^q) + \\ & p_T q_T(\overline{L} - l_N^u(p_N, p_{x_N}, p_T, z^q, \overline{L}, l_C^u) - l_C^u, z^q) + \\ & p_C q_C(l_C^u, z^c, z^q) - p_{x_N} x_N^u(p_N, p_{x_N}, p_T, z^q, \overline{L}, l_C^u) \end{aligned} \tag{41}$$

subject to (32).

The Kuhn Tucker condition is:

$$\frac{\partial \Pi(\cdot)}{\partial l_C^u} : \frac{\partial l_N^u}{\partial l_C^u}(\cdot)[p_N \frac{\partial q_N}{\partial l_N^u}(\cdot) - p_T \frac{\partial q_T}{\partial l_N^u}(\cdot)] + \frac{\partial x_N^u}{\partial l_C^u}(\cdot)[p_N \frac{\partial q_N}{\partial x_N^u}(\cdot) - p_{x_N}] + p_C \frac{\partial q_C}{\partial l_C^u}(\cdot) - p_T \frac{\partial q_T}{\partial l_C^u}(\cdot) = 0 \tag{42}$$

which is simplified as:

$$\frac{\partial \Pi(\cdot)}{\partial l_C^u} : p_C \frac{\partial q_C}{\partial l_C^u}(l_C^u, z^c, z^q) - p_T \frac{\partial q_T}{\partial l_C^u}(p_N, p_{x_N}, p_T, z^q, \overline{L}, l_C^u) = 0 \tag{43}$$

The optimal choice of l_C^u is in reduced form:

$$l_C^u = l_C^u(p_N, p_{x_N}, p_T, z^q, \overline{L}, p_C, z^c) \tag{44}$$

Constrained case If the cash constraint is binding ($\mu > 0$) then

The first order Kuhn Tucker conditions that describe the interior problem now are:

$$\frac{\partial \Pi(\cdot)}{\partial l_N} : p_N \frac{\partial q_N}{\partial l_N}(l_N, x_N, z^q) - p_T \frac{\partial q_T}{\partial l_N}(\overline{L} - l_N - l_C, z^q) = 0 \tag{45}$$

and

$$\frac{\partial \Pi(\cdot)}{\partial x_N} : p_N \frac{\partial q_N}{\partial x_N}(l_N, x_N, z^q) - p_{x_N}(1 + \mu) = 0, \ \mu > 0 \tag{46}$$

Using these two equations, given l_C (and hence C) and the observation that:

$$C - p_{x_N} x_N = 0$$

(since the cash constrained is binding), allows us to solve for the optimal quantities of l_N, x_N, and μ. In particular:

$$x_N^c = x_N^c(p_N, p_{x_N}, p_T, z^q, \overline{L}, l_C^c, C) \tag{47}$$

$$l_N^c = l_N^c(p_N, p_{x_N}, p_T, z^q, \overline{L}, l_C^c, C) \tag{48}$$

and

$$\mu = l_T^c(p_N, p_{x_N}, p_T, z^q, \overline{L}, l_C^c, C) \tag{49}$$

where the superscript c refers to the constrained case.

Finally, we use the fact that

$$\overline{L} - l_N^c - l_T^c - l_C^c = 0$$

to solve for l_T^c :

$$l_T^c = l_T^c(p_N, p_{x_N}, p_T, z^q, \overline{L}, l_C^c, C) \tag{50}$$

The important difference from the unconstrained case is that here the farmer cannot afford to purchase his optimal quantity of the new variety input (x_N). It is at this point where the income from the cash activity C becomes crucial. The ability of the farmer to adopt the new variety is directly linked with cash income: higher levels of cash income relax the cash constraint and thus enabling the farmer to adopt more. This is the reason why the level of input for the crop activities depend not only on the labor demand for the cash activity (l_C^u) but on cash income itself (C).

Finally, we substitute these quantities back in the maximization problem (equation (33)) in order to solve for l_C^u and hence C (since $C = p_C q_C(l_C, z^c, z^q)$). The problem is:

$$\begin{aligned} \underset{l_C^c}{Max} \ & p_N q_N(l_N^c(p_N, p_{x_N}, p_T, z^q, \overline{L}, l_C^c, C), x_N^c(p_N, p_{x_N}, p_T, z^q, \overline{L}, l_C^c, C), z^q) + \\ & p_T q_T(\overline{L} - l_N^c(p_N, p_{x_N}, p_T, z^q, \overline{L}, l_C^c, C) - l_C^c, z^q) + \\ & p_C q_C(l_C^c, z^c, z^q) - p_{x_N} x_N^c(p_N, p_{x_N}, p_T, z^q, \overline{L}, l_C^c, C) \end{aligned} \tag{51}$$

subject to (32).

The Kuhn Tucker condition is now:

$$\begin{aligned}&\tfrac{\partial \Pi(\cdot)}{\partial l_C^c} : \tfrac{\partial l_N^c}{\partial l_C^c}(\cdot)[p_N \tfrac{\partial q_N}{\partial l_N^c}(\cdot) - p_T \tfrac{\partial q_T}{\partial l_N^c}(\cdot)] + \tfrac{\partial x_N^c}{\partial l_C^c}(\cdot)[p_N \tfrac{\partial q_N}{\partial x_N^c}(\cdot) - p_{x_N}] + \\ &p_C \tfrac{\partial q_C}{\partial l_C^c}(\cdot)[p_N \tfrac{\partial q_N}{\partial l_N^c}(\cdot) \tfrac{\partial l_N^c}{\partial q_C}(\cdot) + p_N \tfrac{\partial q_N}{\partial x_N^c}(\cdot) \tfrac{\partial x_N^c}{\partial q_C}(\cdot) - p_T \tfrac{\partial q_T}{\partial l_N^c}(\cdot) \tfrac{\partial l_N^c}{\partial q_C}(\cdot) - p_{x_N} \tfrac{\partial x_N^c}{\partial q_C}(\cdot) + 1] \\ &-p_T \tfrac{\partial q_T}{\partial l_C^c}(\cdot) = 0\end{aligned} \tag{52}$$

which is simplified as:

$$\frac{\partial \Pi(\cdot)}{\partial l_C^c} : p_C \frac{\partial q_C}{\partial l_C^c}(l_C, z^c, z^q) - p_T \frac{\partial q_T}{\partial l_C^c}(p_N, p_{x_N}, p_T, z^q, \overline{L}, l_C^c, C) = 0 \tag{53}$$

The only unknown, l_C^c, is given by:

$$l_C^u = l_C^u(p_N, p_{x_N}, p_T, z^q, \overline{L}, p_C, z^c) \tag{54}$$

and by definition:

$$C = p_C q_C(l_C^c(p_N, p_{x_N}, p_T, z^q, \overline{L}, p_C, z^c), z^c, z^q)) = C(p_N, p_{x_N}, p_T, z^q, \overline{L}, p_C, z^c) \tag{55}$$