Credit Constraints and Financial Efficiency in Peruvian Agriculture

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1. Introduction: Credit Constraints and Farm Profits

Rural credit markets in developing countries continue to frustrate policy makers. High yield and price risk, significant costs accruing from large distances and poor infrastructure, and long time lags between planting and harvest have, to a large degree, prevented in rural areas the type of financial market deepening (especially among low asset entrepreneurs) that has taken place in urban and semi-urban areas thanks to the micro-finance "revolution." In spite of the general perception that rural financial markets perform poorly, relatively little empirical evidence exists about the prevalence and impacts of credit constraints on farm resource allocation (important exceptions include: Carter and Olinto (2003), Foltz (2002), Petrick (2004)).

This paper makes two main contributions. First, it addresses the empirical void by estimating the impact of credit constraints on farm profits in Peru. We follow the general approach of Fare, Grosskopf, and Lee (1990) and Blancard et. al. (2006) and estimate a farmer-specific financial (in)efficiency coefficient using non-parametric, data envelope analysis. We then examine the determinants of financial inefficiency with a Tobit regression framework. The empirical analysis is based on a panel data set of 367 Peruvian farms surveyed in 2003 and again in 2004.

Second, it extends the methodological approach of Fare, Grosskopf, and Lee (FGL) and Blancard et. al. (BBBK), who use non-parametric, data envelope analysis (DEA) to estimate the size of foregone profits due to credit constraints. Our extension has two components. First, we acknowledge that non-price rationing in the credit market may manifest themselves not only as quantity constraints (quantity rationing) but also as risk and transaction cost constraints. Each of these forms of non-price rationing, rooted in asymmetric information, can adversely affect farm profits. The existing literature, in contrast, admits only quantity constraints (rationing). The second contribution is more empirical. Due to data constraints, the existing literature assumes that "the total expenditures over the accounting period indicate the maximum amount the farmer can spend on organizing production" (Blancard et. al. page 354). Under this method, any farmer who could have reached a higher profit by spending more is classified as financially constrained. The result is an overestimation of the importance of financial constraint as this method "reveals the subset of potentially credit-constrained farms" (Blancard et. al. page 355). Our survey instrument enables us to reduce this source of bias as it directly elicits the farmer's constraint status with respect to the credit market. If the frontier generated by DEA suggests that a given farmer could have increased his profit by spending more on variable inputs, the forgone profit is attributed to financial inefficiency only if this farmer indeed expressed excess credit demand.[1]

The structure of the paper is as follows. Section 2 discusses the multiple forms of non-price rationing that may obtain in credit markets and describes the "direct-elicitation" survey methodology that provides information to directly classify each farm household as constrained or unconstrained with respect to the formal credit market. Section 3 lays out the linear programming framework underlying the DEA analysis. It also provides a graphical analysis that illustrates the various efficiency measures. Section 4 introduces the data and the specification of the non-parametric empirical model. Section 5 presents empirical results of the frequency and depth of financial inefficiency. Section 6 presents the specification and results of the tobit model that examines the determinants of financial inefficiency. Section 7 concludes.

2. Non-price rationing in credit markets: Definitions and measurement

In this section we carefully define the term *credit constraint*, arguing for an expanded definition that goes beyond conventional quantity rationing to include demand-induced withdrawal from credit markets as a result of transaction costs and risk. We then briefly describe a survey methodology to directly measure each household's rationing "mechanism" in the formal credit sector.

2.1 *Multiple manifestations of credit constraints*

High degrees of risk combined with poorly defined property rights and lack of information infrastructure imply that rural credit markets in developing countries are likely to suffer from serious imperfections, with the result that many farmers find themselves facing a binding credit constraint. The root of endogenous credit rationing is asymmetric information.[2] Beginning with the seminal work of Stiglitz and Weiss (1981), a long theoretical literature demonstrates that the moral hazard and adverse selection problems endemic to credit transactions may lead to quantity rationing, whereby lenders refuse to raise the interest rate to eliminate excess demand. In an agricultural context, a quantity rationed farmer is unable to gain access to her desired amount of credit and, as a result, is unable to apply the profit maximizing level of inputs.

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[1] Excess demand corresponds to an unmet credit demand with respect to a first best world of perfect information.
[2] Exogenous credit rationing occurs, for example, when government imposes a binding interest ceiling (Gonzales Vega ,1990).

Quantity constraints are thus a supply-side manifestation of asymmetric information. Quantity rationed farmers are involuntarily excluded from the credit market by lenders. Several recent papers have pointed out that the same underlying information problems can also reduce participation in credit markets by restricting farmers' demand (Boucher, Carter and Guirkinger 2006; Guirkinger and Boucher 2006). The key insight is that lenders' responses to asymmetric information go beyond the decision of whether or not and how much to lend. As described by Hoff and Stiglitz (1990), lenders have two additional means of responding to information asymmetries. On one hand, they may directly attack information asymmetries by screening applicants and monitoring borrowers. While these actions may help lenders avoid granting loans to undesirable "types" and provide borrowers with the incentives to avoid undesirable "actions", they also may imply significant monetary and time costs for the borrower. A farmer is *transaction cost rationed* if the non-interest monetary and time costs are sufficiently large that they lead a farmer to refrain from borrowing.

On the other hand, lenders may indirectly address incentive problems by requiring that borrowers post collateral. Perhaps the most obvious impact of collateral requirements is that they can lead to quantity rationing; farmers lacking assets of sufficient quantity or quality (i.e., titled) are excluded from collateral-based contracts. As demonstrated by Boucher, Carter and Guirkinger (2006), collateral requirements may lead to another form of non-price rationing that they call "risk rationing". A farmer is *risk rationed* if she has access to an expected-income-enhancing credit contract but does not take it because the collateral requirement implies that she bear too much risk. Risk rationing in developing country agriculture may be particularly problematic because of the almost complete absence of formal risk management tools such as crop and health insurance.

2.2 Measuring credit rationing: The direct elicitation approach

The previous discussion argued that each form of non-price rationing (quantity, transaction costs, and risk) has similar implications for farm resource allocation; namely that efficiency is reduced and profits are foregone. Any empirical evaluation of the performance of the credit market should thus account for all forms of credit constraints, whether they derive from the supply side (quantity rationing) or demand side (transaction cost and risk rationing). The next section will discuss how previous analyses applying DEA analysis to evaluate the impact of credit constraints on farm efficiency can be augmented to incorporate transaction cost and risk rationing. First, however, we briefly describe the survey methodology we employ to classify households' rationing status.[3] This method allows us to directly observe whether or not a farmer is constrained and, if so, which non-price rationing mechanism is at play.

The primary objective of the direct elicitation approach is to classify households as constrained or unconstrained with respect to a particular sector (for example formal) of the credit market and, if constrained, to further identify whether the constraint derives from quantity, transactions cost or risk rationing. The approach utilizes a combination of observed outcomes and qualitative questions. First, households are separated into those that applied versus those that did not apply for a loan. The rationing category of applicant households is determined based on the outcome: rejected applicants are quantity rationed (constrained), while those whose application was approved are price-rationed (unconstrained).

Classification of non-applicant farmers requires additional information. They are first asked whether or not any lender would offer them a loan if they were to apply. If yes, they were then asked why they did not apply. Those that said they had sufficient own-liquidity or that the interest rate was too high (relative to their farm opportunities) were classified as price-rationed (unconstrained). Non-applicant households who stated that the time, paperwork and fees of applying were too costly were classified as transaction cost rationed (constrained); while those that cited fear of losing land pledged as collateral are classified as risk rationed (constrained). Finally, households that stated that no lender would offer them a loan were asked whether or not they would apply for a loan if they were certain that a bank would approve their application. Those that said yes were classified as quantity rationed (constrained). Those that said no were then asked why not, and their answers were used to classify them as above.

3. The impacts of credit constraints on farm efficiency: DEA framework

3.1 Depiction of technology

We follow FGL and generate individual measures of performance based on a series of linear programming problems, with and without an expenditure constraint. This enables us to estimate the loss in profit resulting from the presence of credit constraints. We extend their approach by using additional information about the constraint status of farmers with respect to the formal loan sector. Specifically, we allow the expenditure constraint to bind only for those households who expressed excess demand in the credit market. This yields more

[3] See Boucher, Guirkinger, and Trivelli (2006) for a detailed discussion of the direct elicitation methodology.

conservative estimates regarding the presence of credit constraint. We illustrate the difference between their and our approach by presenting both set of measures.

An attractive feature of DEA analysis is that no functional form is imposed on technology. Technology transforms inputs into outputs via a convex production set. Observations are used to define a non-parametric frontier of the production set. Suppose we have *K* farms who produce outputs $(u_1...u_M)$ using inputs $(x_1...x_{I+J})$, such a non-parametric frontier is defined by the boundary of:

$$T = \left\{ \begin{array}{l} (x,u): \sum_{k=1}^{K} z^k u_m^k \geq u_m, m = 1,...,M, \\ \sum_{k=1}^{K} z^k x_n^k \leq x_n, n = 1,..., N, \\ \sum_{k=1}^{K} z^k = 1, z \in \Re_+^K \end{array} \right\}$$

The vector *z* is used to form convex combinations of the observed input and output mixes. As discussed in FGL, this technology accommodates constant, increasing and decreasing return to scale.

3.2 The farmer's optimization problem

The farmer's optimization problem in the absence of an expenditure constraint is specified as in FGL. Partition inputs between variable inputs $(x_{v1}...x_{vI})$ and fixed inputs $(x_{fI+1}...x_{fJ})$. We assume that all farms face the same price vector for outputs $(r_1...r_M)$ and variable inputs $(P_1...P_I)$. Farmers choose variable inputs and outputs to maximize farm profit subject to the technology available. The short-term profit for farm *k* is then the solution to the following linear programming problem:

$$\pi(r, P, x_f^k) = \max_{u_m, x_v, z} \sum_{m=1}^{M} r_m u_m - \sum_{i=1}^{I} P_i x_{vi}$$

$$s.t.$$

$$\sum_{k=1}^{K} z^k x_{vi}^k \leq x_{vi}, i = 1,..., I$$

$$\sum_{k=1}^{K} z^k x_{fi}^k \leq x_{fi}, i = I + 1,..., I + J$$

$$\sum_{k=1}^{K} z^k = 1, z \in \Re_+^K$$

Households who are credit constraint face a binding expenditure constraint; their expenditures on variable inputs cannot exceed their observed expenditure. This is represented by the introduction of the following constraint in the maximization problem:

$$\sum_{i=1}^{I} P_i x_{vi}^k \leq E^k \quad (1).$$

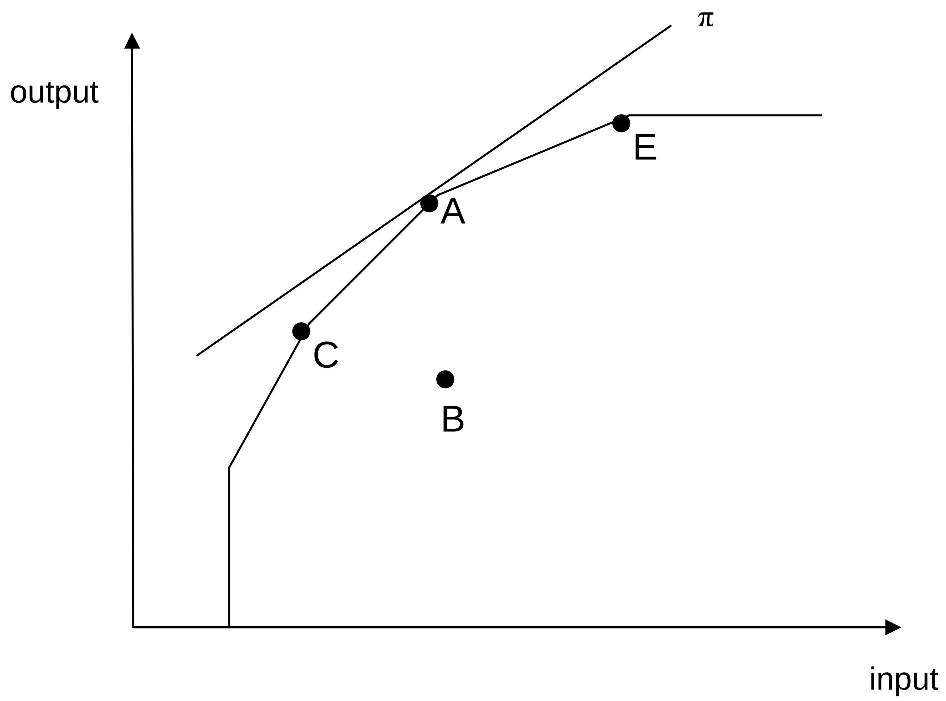
Let $\pi^C(r, P, x_f^k, E^k)$ denote the maximum attainable profit for a constrained household. We define financial efficiency as the ratio $F^k = \dfrac{\pi^C(r, P, x_f^k, E^k)}{\pi(r, P, x_f^k)}$, so that $F^k < 1$ corresponds to a binding credit constraint. Financial efficiency thus represents the reduction in profit attributable to the existence of a binding credit constraint. In contrast, actual efficiency is the profit loss due to a deviation between observed profit, π^{Ok}, and the maximum attainable profit, given the frontier T and the potential existence of an expenditure constraint: $A^k = \dfrac{\pi^{Ok}}{\pi(r, P, x_f^k, E^k)}$. As described by FGL, overall efficiency is thus the product of financial and actual efficiency: $O^k = A^k F^k$.

3.3 Illustration of financial and actual efficiency

Figure 1 illustrates FGL approach to financial efficiency for a simple, single-input technology and illustrates how we can improve on their measure by incorporating the additional information made available regarding farm households' credit constraint status. Given input and output prices we can represent profit by a line π. The technological frontier is represented by the piecewise concave curve. Unconstrained profit is maximized at *A*, so that a farm observed at *A* is both financially and actually efficient. Consider now a farm at point *B*. This farm is actually inefficient, as it could increase profit without increasing input expenditures by moving vertically to *A*. Similarly, a farm at *E* is actually inefficient and could increase profit by reducing input expenditures. To see how financial constraints appear, consider a farm at point *C*. Such a firm is actually efficient, as it cannot increase profit without increasing expenditures (or moving to the right). Without additional information on this farm's liquidity (own and access to external credit) FGL must classify this farm as financially inefficient because in order to increase profit (move from *C* to *A*), the household would have to increase its expenditures. However, as noted by BBBK, this leads to an overestimation of financial efficiency. Consider, for example, the household at *E*. The same factors that explain why a farmer is at *E* instead of *A*, for example lack of experience and managerial know-how, may also explain why a farmer is at *C* instead of *A*. If so, then without any additional information, the profit foregone by the farmer at *C* would the mistakenly be attributed to a binding credit constraint.

To avoid this problem we only attribute the profit difference between *C* and *A* to a binding credit constraint if the farmer expressed excess credit demand when directly asked about his participation in and terms of access to the credit market. Note that we cannot out rule that a farmer at *C* who expressed excess demand also lacks knowledge and would not be able to move all the way to A, but we may reduce the bias compared to FGL.

Figure 1. Technological frontier and profit function



As discussed in the previous section, quantity rationing is only one form of credit constraints that would prevent a farmer at *C* from moving to *A*. Even farmers who have access to a loan and who know that, by taking a loan they could (in expected value terms) reach point *A* may be reluctant to borrow because of the risk and/or transaction costs implied by the credit contracts available to them in the market. These two factors can lead farmers to solicit less than the profit maximizing amount of credit or even withdraw completely from the credit market. Risk and transaction cost rationing, just like quantity rationing, constraint farmer's expenditure and result in profit losses.

4. Context, data and model specification

4.1 Sample

Our empirical analysis is based on a panel data set of farm households that were surveyed in 2003 and 2004, in Piura, one of the main agricultural regions on the North Coast of Peru. The sample was drawn in 1997 to be representative of farming household in Piura. From the original sample of 547 farmers, 490 were re-surveyed in both 2003 and 2004. Our present analysis focuses on households who generated more than $150 of annual gross farm output and who did not raise more than 5 cows.[4] Finally, we also excluded 5 farms that reported very contradictory information in 2003 and 2004. We are thus left with a sample of 367 households whose production technology is fairly homogenous.[5]

Sample farms are small with a mean area of 3.8 ha. Agriculture in this area is exclusively irrigated. Rice, cotton and corn are the main annual crops, with 58% of farmers growing some rice, 34% growing corn and 18% growing cotton. Bananas, lemons and mangos are the main perennials, with 24% of the farmers growing bananas and 24% having fruit tree production. Piura is particularly relevant for an analysis of credit constraints for several reasons. First, financial constraints are likely to be prevalent as expenditures on variable inputs are important relative to farmers wealth, and farmers rely heavily on credit to finance production. Second, improving small farmers' access to market oriented formal institutions has been high on the political agenda for many years. An illustration is the recent land titling program that is intended to increase the collateral value of land and thereby the supply of formal credit for small farmers.

4.2 Description of rural credit markets in Piura

The rural credit market in Peru has undergone significant changes in the last fifteen years. Until 1992, the Agrarian Development Bank (*Banco Agrario*) held a monopoly over formal agricultural credit. The government of Alberto Fujimori (1990-2000) implemented a financial liberalization program that shut down the Agrarian Development Bank in 1992, and eliminated interest rate controls in an effort to induce commercial banks to increase their presence in rural areas. The government also promoted the establishment of rural banks (*cajas*

[4] The threshold of $150 constitutes a break-point in the distribution of gross output. Households with a gross farm output of less than $150 have production resembles gardening. 77 households were excluded by this rule. Half of them had no production at all and half had very limited production. 46 farmers were excluded because they were heavily engaged in raising cattle. Significantly less detailed data are available on the cost structure of livestock operations. Since livestock production technology is substantially different to cropping technology, we chose to exclude these farmers.

[5] For example, several farms had changes in the value of output of over $10,000 without any change in area cropped. Scrutiny of the survey forms leads us to conclude that these are data collection errors.

rurales), and the strengthening of municipal banks (*cajas municipales*). These local banks are the primary formal financial intermediaries for small farmers in the post-liberalization environment. Alongside this set of formal institutions, a vibrant informal credit sector coexists. Informal loans are primarily offered by local business owners, such as grain traders, rice mills and input supply stores. Finally, there is a small set of microfinance institutions run by NGO's and local government that provide subsidized loans to small farmers.

The survey allows us to use the direct elicitation approach described in Section 2 to directly classify each household as constrained or unconstrained in the formal credit market and, if constrained, to further identify whether the constraint derive from quantity, transaction cost or risk rationing. As a result, our empirical measure of financial inefficiency evaluates the profit loss due to the existence of constraints with respect to the *formal* credit sector. If the informal sector is a good substitute for an imperfect formal sector, then the profit loss due to *formal* credit constraint is likely to be small. We have reason to believe that the informal market offer less favourable terms than the formal market, as interest rates are much higher, loan size are smaller and maturity shorter.[6]

Table 1 gives the frequency of the various rationing mechanisms in the pooled sample of household in 2003 and 2004. 29% of farmers had a formal loan during the last 12 months and thus are price rationed with loan. Along with the 21% who had no profitable project to finance with a formal loan (the price rationed without loan), they constitute the group of unconstrained households. The most prevalent form of non-price rationing appears to be risk with 23% of the sample risk rationed, while 15% and 12% are transaction cost and quantity rationed respectively. The survey thus suggests that exactly 50% of households are non-price rationed, or constrained with respect to the formal sector.

[6] Given the existence of alternative sources of loans, we may wonder whether it is appropriate to translate the existence of a constraint in the formal sector into an expenditure constraint such as equation (1), that strictly restrict the amount of expenditure. In fact, the problem may be reformulated with a constraint on the cost of fund rather than equation (1). It is easy to show that having a binding expenditure constraint for credit constrained farmers is equivalent to impose them a tax on expenditure (with the value of the tax equal to their shadow value of liquidity in the first formulation). Thus, as long as alternative sources of funds are more expensive than formal sector loans, a formal sector credit constraint may be represented by equation (1).

Table 1: Frequency of formal sector rationing outcomes

Rationing mechanism	Frequency (pooled sample)
Price rationed with loan	29%
Price rationed without loan	21%
Transaction cost rationed	15%
Risk rationed	23%
Quantity rationed	12%

4.3 Linear programming model specification

We assume that all farmers in the sample face the same prices, which is not implausible given the good communication infrastructure of the region and the similar structure and size of farms. FGL show that, with this assumption, revenue and costs can be directly used to derive the efficiency measures instead of physical units and price. Similar to BBBK, we separately estimate a frontier for each year and thus impose minimal assumptions on technological change and on potential changes in price and climatic conditions that would affect the whole sample.

We define five fixed factors and four variable inputs. Three fixed factors are related to owned land, as we separate total area owned into area with annual crops (that may be rented out), area with bananas, and area with fruit trees. The reason for this separation is that land cannot be easily and quickly converted from permanent crop production to annual crop production (or vice versa). We thus assume that farmers take this land allocation as given when they maximize short run profit. The remaining two fixed factors are the household's endowment of family labor and farm equipment. Family labor is measured in adult equivalents with weights defined by age and sex.[7] Farm equipment is measured as the flow value of agricultural machinery held by the household. Variable inputs are hired labor, irrigation costs, expenditures on chemical inputs and machinery rentals. All are expressed in Peruvian Soles. Given our fixed inputs, the financial efficiency coefficient we construct is implicitly of a short run nature. It ignores longer term impacts of credit constraints that would, for example, influence farmers' permanent crop planting decisions or investment in

[7] Children under 10 years old are given a weight of zero while those between 10 and 15 are given weight of 0.5. Men are given a weight of 1 and women a weight of 0.75.

machinery. As a result we obtain a lower bound estimate of the overall impact of credit constraints.

Table 2 present descriptive statistics for these inputs and for the three types of output we consider: revenue from annual crops, permanent crops and from land rental. Note that variable input cost and output are aggregated into a single measure of revenue and expenditure in the linear programming problem.

Table 2: Descriptive statistics inputs and outputs over 2003 and 2004

Variable	mean	SD
Output (u_m)		
Value of annual crops (soles)	11,759	15,027
Output of fruit and bananas (soles)	3,087	10,999
Revenue from land rental (soles)	98	386
Fixed Factors (x_f)		
Area in annual crop production or rented out (ha.)	2.8	2.5
Area in fruit trees (ha.)	0.60	2.15
Area in bananas (ha.)	0.37	19.62
Family labor endowment (days)	417	232
Value of farm equipment (soles)	11,700	26,200
Variable Inputs (x_v)		
Expenditure on hired labor (soles)	1,599	2,181
Expenditure on irrigation (soles)	433	448
Expenditure on chemical inputs (soles)	2,693	3,397
Expenditure on machinery rental	914	1,392

All figures are in 2004 soles. $1 = 3.47 Soles.

5. The depth of financial inefficiency: Results from the DEA analysis

The efficiency analysis described in Section 3 was carried out using three different methods to classify constrained versus unconstrained farms. The first method uses no auxiliary information on farmers' credit rationing outcomes and thus mimics the approach of FGT and BBBK. As described above, this method assumes that observed expenditures represent the maximum possible expenditure so that all farmers in the sample could potentially be classified as credit constrained. The second and third methods draw on auxiliary information from the direct elicitation module of the survey to restrict the subset of potentially financially inefficient households. In the second method, the expenditure constraint is only imposed on households that are identified as quantity rationed. The third method imposes the expenditure constraint on households facing any form of non-price rationing (quantity, risk, transaction cost) in the formal credit market.

Table 3. Comparison of efficiency decomposition by method

	No auxiliary information		Constrained restricted to quantity rationed		Constrained restricted to non-price rationed	
	(1) financially inefficient	(2) financially efficient	(3) financially inefficient	(4) financially efficient	(5) financially inefficient	(6) financially efficient
Number of farms	429	439	57	677	239	495
Financial efficiency (F^K)	0.79 (0.24)	1 (0.00)	0.75 (0.26)	1 (0.00)	0.76 (0.25)	1 (0.00)
Actual efficiency (A^K)	0.37 (0.31)	0.43 (0.36)	0.35 (0.36)	0.39 (0.34)	0.31 (0.30)	0.46 (0.36)
Overall efficiency (O^K)	0.28 (0.26)	0.51 (0.40)	0.23 (0.27)	0.39 (0.34)	0.21 (0.32)	0.46 (0.36)

Table 3 summarizes the results. When no auxiliary information is used, 429 (just under one-half) of sample households are classified as financially constrained, as maximising profit given their endowment would have required greater spending on variable inputs. In contrast, when we restrict potentially financially constrained households to those that are self-reported to be quantity rationed, we find that only 57 of the households are financially constrained. When transaction cost and risk rationed households are also included in the pool of potentially financially constrained households, this number increases to 239. While half of the sample appeared credit constraint according to the direct elicitation approach, the DEA analysis reveals that one-third face a binding short run expenditure constraint. Some farmers that were classified as non-price rationed using the direct elicitation survey method thus appear financially efficient in the short run. Two factors can explain this. First, as mentioned above, we only capture short term impacts of credit constraints. If, for example, a farmer wishes to invest in banana plantation but has to forgo his project because of credit constraint, he would not necessarily appear financially inefficient using our DEA approach as land allocation across bananas and annual crops is treated as a fixed factor. Second, our measures of efficiency are relative to what other households in the sample are doing. Thus if a farmer could increase his profit with a larger loan, but this unconstrained profit cannot be obtained from a convex combination of profits of farmers in the sample, the farmer would appear financially efficient (loosely: nobody with greater liquidity does better than him). To put it more dramatically, if all farmers in the sample do the same and are all credit constrained, they would appear financially efficient.

While the method used clearly affects the fraction of households considered constrained, it has less of an impact on the mean *level* of financial efficiency for constrained households. For constrained households, the profit loss due to credit constraints is 21% when no auxiliary information is used to restrict the set of constrained farmers, 25% when only quantity rationed are allowed to be financially constrained and 24% when all non-price rationed household may be financially constrained. The overall level of farm efficiency is also lower for financially constrained households. Relative to the constrained maximum profit, profit losses due to actual inefficiency are 79% when we use the full information set to classify households. For financially efficient farmers, profit losses are 54% relative to maximum attainable profit.

6. Accounting for financial inefficiency: A Tobit analysis

In this section we seek to explain the measured heterogeneity in financial inefficiency. As we have a mass of observations at 1 (i.e., farms that are financially efficient), we use a tobit model where the dependent variable has an upper bound at 1. As argued above, credit constraints can derive from both the supply and demand side of the credit market. Thus to explain financial (in)efficiency need regressors that influence both demand and supply.

Table 4 presents definitions and summary statistics for the variables included in the estimation. Formal credit supply is likely to be positively influenced by the following factors: farm size, the proportion of a household's land that has a registered property title, whether or not the household has alternative sources of liquidity such as a business, and the value of durable goods the household owns. The first two variables influence the value of collateral the farmer may put up for a loan, while the last two increase the likelihood that the household is able to pay back his loan in case of a negative agricultural shock. Land quality may also increase credit supply if it positively impacts the profitability of farm investment and if the lender observes land quality. Conversely the use of pumps for irrigation indicates a lower availability of irrigation water (compared to farmers able to rely solely on gravity) and implies higher irrigation costs, so that banks may be more reluctant to lend to farmer who rely on pumps. As discussed in Section 3, credit demand is likely to depend on the size of transaction costs and on a farmer's risk environment and risk aversion. Financial efficiency is thus expected to decrease with distance to the closest local bank and to increase with the wealth of farmers (and thus the value of durables for example). Note that the effect of household wealth on financial efficiency may stem from greater credit supply and demand, but also from alternative sources of funds such as savings. The household's labor endowment and the existence of credit programs in the community are also expected to increase financial efficiency, as they are likely to mitigate the potential negative impacts of a binding credit constraint in the formal sector, through a substitution of labor or of other sources of liquidity for the lack of formal funds. Finally, a regional dummy controls for the location of the household within a zone particularly favoured by communication infrastructure and the proximity of dynamic local banks.

Table 4: Definition and summary statistics of explanatory variables

Variable Name	Variable Definition	Mean	Standard Deviation
areaowned	Total area owned (ha)	3.81	4.34
business	1 if household has a business with more than $150 of assets	0.06	0.23
edhhh	Number years of education of household head	4.66	3.91
v_durab	Value of household durables (soles)	1,182	2,925
proptit	Proportion of household land that is titled	0.65	0.46
availL	Total family labor available on the farm (weights by sex and age)	2.25	1.19
credprog	1 if the village has a micro-credit program	0.31	0.46
distcaja	Distance to the closest local bank (in min)	25.0	24.5
bombeo	1 if part of the irrigation is through pumping	0.11	0.32
wmqual	Average self-reported land quality on a scale of 1 to 5 (5 = best)	3.42	0.67
Ch	Regional dummy (Chira valley)	0.50	0.50

We estimate the tobit model in two ways : (1) Tobit on the pooled sample and ; (2) random effects Tobit to exploit the panel nature of the data set. Table 5 reports the results of the tobit estimations. Columns 1 (pooled Tobit) and 2 (random effects Tobit) present the parameter estimates when the dependent variable is the financial efficiency coefficient calculated using no auxiliary information. Columns 3 and 4 do the same when the financial efficiency coefficient is calculated using the auxiliary information (potentially constrained households are those that are classified as non-price rationed). The results are surprisingly similar both across estimation techniques and across the type of financial efficiency measure used. As expected, owning a business, being more educated, having more durables, a greater portion of land titled, being in a community with a credit program and land quality are all positively correlated with financial efficiency. Pumping water for irrigation has the expected negative sign on financial efficiency but is not significant; whereas farm size and distance to the closest bank have a counter-intuitive sign but are not significant.

Table 5: Results of tobit estimation on the determinants of financial efficiency

Regressor	(1) tobit re	(2) tobit pooled	(3) FGL tobit re	(4) FGL tobit pooled
areaowned	-0.01 (1.36)	-0.01 (1.53)	-0.00 (1.03)	-0.01 (1.36)
business	0.22836 (2.04)**	0.23937 (0.38)	0.16412 (2.40)**	0.16700 (2.58)**
edhhh	0.01 (1.96)*	9.97e-03 (1.90)*	0.01 (3.89)***	1.39e-02 (3.50)***
v_durab	0.00 (2.30)**	0.00 (2.29)**	0.00 (0.75)	0.00 (1.20)
proptit	0.09 (2.18)**	0.10 (2.06)**	0.06 (2.05)**	0.07 (2.76)***
availL	-0.01 (0.44)	-0.01 (0.38)	-0.02 (1.51)	-0.01 (1.37)
credprog	0.09 (1.92)*	0.10 (1.91)*	0.09 (2.64)***	0.10 (3.05)***
distcaja	0.00 (0.75)	0.00 (0.81)	-0.00 (0.43)	-0.00 (0.37)
bombeo	-0.04 (0.72)	-0.05 (0.92)	-0.00 (0.06)	-0.01 (0.23)
wmqual	0.09 (3.00)***	0.09 (3.70)***	0.04 (1.69)*	0.03 (1.38)
Chira	0.18 (3.40)***	0.19 (3.48)***	0.08 (2.24)**	0.08 (2.55)**
t	-0.09 (2.51)**	-0.09 (2.20)**	-0.05 (2.45)**	-0.05 (2.19)**
Constant	0.70 (5.73)***	0.69 (5.41)***	0.75 (8.69)***	0.75 (7.81)***

7. Conclusion

Our empirical analysis of efficiency of small-farms in Northern Peru reveals a moderate degree of financial inefficiency deriving from constraints in the formal credit market. We used non-parametric, Data Envelope Analysis to identify those farm households that are credit constrained. We find that the method of classifying households as constrained or unconstrained has a significant impact on the reported frequency of credit rationing. When no additional information is available regarding farmer's credit access or their reasons for not participating in the credit market, we classify nearly 50% of households as credit constrained. In contrast, when we use auxiliary information gathered via the "direct elicitation" survey methodology and allow only those households identified as non-price rationed in the formal credit market to be potentially credit constrained, this number falls to 32%. This suggests that previous estimates of the frequency of credit constraints are likely to significantly over-estimate the incidence of credit rationing. In contrast, the impact of credit constraints on the resource allocation of *constrained households* is less sensitive to the choice of technique; with each technique estimating a loss in profits of between 21 – 25%.[8] We also find that the parameter estimates of the determinants of financial efficiency (from the Tobit model) are relatively insensitive to the choice of technique.

[8] Note, however, that the estimate of the overall impact of credit constraints on the sample is affected by the choice of technique because the overall impact is the product of the frequency of credit constraints and the impact of the constraint on the constrained households.

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