

Credit constraints and productivity in Peruvian agriculture

Catherine Guirkinger^{a,*}, Stephen R. Boucher^b

^a*Center of Research in the Economics of Development, University of Namur, 8 Rempart de la Vierge, B-5000 Namur, Belgium*

^b*Agricultural and Resource Economics, Giannini Foundation of Agricultural Economics, University of California, Davis, One Shields Avenue, Davis, CA 95616, USA*

Received 10 August 2007; received in revised form 19 February 2008; accepted 20 May 2008

Abstract

This article evaluates the performance of a rural credit market in Peru. We develop a model that shows that collateral requirements imposed by lenders in response to asymmetric information can lead not just to quantity rationing but also to transaction cost rationing and risk rationing. Just like quantity rationing, these two additional forms of nonprice rationing adversely affect farm resource allocation and productivity. We test the insights of the model using a panel data set from Northern Peru. We estimate the returns to productive endowments for constrained and unconstrained households using a switching regression model. We find that, consistent with the theory, productivity is independent of endowments for unconstrained households but is tightly linked to endowments for constrained households. We estimate that credit constraints lower the value of agricultural output in the study region by 26%.

JEL classification: D82, O13, O16

Keywords: Agricultural production; Credit constraints; Credit rationing; Peru; Risk rationing

A large theoretical literature demonstrates that information and enforcement problems inherent in credit transactions can lead to imperfect and even inexistent credit markets.¹ A small but growing empirical literature suggests that in rural areas of developing countries credit constraints have significant adverse effects on farm output (Feder et al., 1990; Petrick, 2004; and Sial and Carter, 1996), farm profit (Carter, 1989; Foltz, 2004) and farm investment (Carter and Olinto, 2003). In Latin America, additional evidence on the prevalence of credit constraints and their impacts on farm efficiency is particularly important as pressure to relax or overturn the financial liberalization policies widely implemented in the past two decades rises. Part

of this backlash against liberalization stems from frustration with land titling programs which, by enhancing the capacity to provide collateral, were expected to dramatically increase farm households' access to and participation in formal credit markets. In Paraguay, Carter and Olinto (2003) find that land titles only relax supply constraints for the wealthiest farmers. Similarly, Galeana (2005) and Field and Torero (2006) find that titling programs have not led to greater participation in formal credit markets for beneficiary households in Mexico and Peru, respectively.

This article provides additional empirical evidence on the performance of a recently liberalized credit market in Peru by examining the following question: How do formal sector credit constraints impact farm productivity? To answer this question, we estimate the returns to productive endowments for farmers that are constrained and unconstrained in the formal credit market in Northern Peru. We build on the empirical approach of Sial and Carter (1996) and especially Carter and Olinto (2003) by using panel data to estimate the return to productive endowments when farmers are endogenously sorted between constrained and unconstrained regimes. Consistent with theory, we find that while the productivity of unconstrained households is independent of their endowments of land and liquidity, the productivity of constrained households is tightly linked to their

*Corresponding author. (C. Guirkinger). Tel.: 003281724870; fax: 003281724840. E-mail address: catherine.guirkinger@fundp.ac.be

Data Appendix Available Online

A data appendix to replicate main results is available as part of the online article from: www.blackwell-synergy.com (this link will take you to the article abstract). Please note: Blackwell Publishing is not responsible for the content or functionality of any supplementary materials supplied by the authors. Any queries (other than missing material) should be directed to the corresponding author for the article.

¹ Conning and Udry (2005) provide an excellent review of the theoretical literature on credit constraints applied to the agricultural sector in developing countries.

endowments. We then use the econometric results to generate estimates of the efficiency loss associated with these credit constraints. We find this loss to be large: eliminating credit constraints in the formal sector would raise the value of output per hectare in the study region by 26%. An additional implication of our results is that informal alternatives to formal loans do not meet farmers' needs for capital, and that continued policy attention is required to enhance the performance of formal credit markets.

A second contribution of this article is to take up the suggestion of several recent articles (Boucher et al., 2008; Gilligan et al., 2005) that argue for a broader conceptual definition of credit constraints. In most of the empirical literature, households are classified as constrained only if they demonstrate an excess demand for credit. While this quantity rationing may certainly impact farm productivity, there are two additional means by which asymmetric information may affect households' terms of access to the credit market and thus also their resource allocation. First, banks may pass on to borrowers the transaction costs associated with screening applicants, monitoring borrowers, and enforcing contracts. Farmers with investments that are profitable when evaluated at the contractual interest rate may decide not to borrow once transaction costs are factored in. Second, lenders may require borrowers to bear significant contractual risk in order to mitigate moral hazard. If insurance markets are imperfect and if this risk is too great, a farmer will prefer not to borrow even though the loan would, on average, raise his productivity and income. Just like a quantity rationed household, the resource allocation and productivity of a household facing transaction cost rationing or risk rationing will be altered relative to a first-best world. We thus argue that quantity rationed, transaction cost rationed, and risk rationed individuals should all be considered credit constrained.

The questionnaire used to collect our data was designed to detect all three forms of nonprice rationing. We find the impact of these additional forms of credit constraints to be nontrivial. In our sample, risk rationed and transaction cost rationed households account for 26% of the overall sample and 52% of the constrained sample. They also account for 57% of output loss associated with credit constraints.

The remainder of the article is structured as followed. Section 1 develops a model that generates the three types of nonprice rationing underlying credit constraints. The model shows that each form of nonprice rationing breaks the independence between resource allocation and household endowments and, as a result, lowers farm productivity. We then turn to our empirical application. Section 2 describes the economic context in Peru and the data. Peru represents a particularly interesting context for two reasons. First, it recently carried out a far-reaching liberalization of rural credit markets. Second, small farms, for whom we expect information problems to be particularly severe, control the vast majority of high quality land. In Section 3, we turn to the challenge of econometrically identifying the relationship between productivity and endowments using nonexperimental data. We control for potential problems of selection and un-

observed heterogeneity by estimating a switching regression model with panel data. Section 4 presents the model results and develops an estimate of the impact of credit constraints on agricultural output. Section 5 concludes by pointing to several recent policy innovations that hold promise for addressing the multiple sources of credit market imperfections.

1. Multiple forms of credit constraints and household resource allocation: a basic model

As noted in a long line of theoretical literature, multiple market failures can give rise to heterogeneous resource allocation across households with varying endowments of productive assets.² An important conclusion of this literature is that a household that is quantity rationed in the credit market, i.e., one that has unmet demand for contracts that exist in the market, will under-invest relative to a credit unconstrained household. As shown by Stiglitz and Weiss (1981), equilibrium quantity rationing derives from lenders' unwillingness to raise the interest rate to clear excess demand because doing so would result in adverse selection of the applicant pool or morally hazardous behavior by borrowers. Quantity rationing may also result from a household's inability to post the quantity or quality of collateral the lender requires to overcome the information problems intrinsic to credit transactions. The adverse consequences of quantity rationing are clear; quantity rationed individuals are *involuntarily* restricted in their access to credit and forego an expected income enhancing opportunity.

The actions taken by lenders to reduce information problems may also induce some households to voluntarily withdraw from the credit market even though they have investments that are profitable when considered against the interest rate, or price, of available loans. In this article, we focus on two additional forms of nonprice rationing, namely transaction cost rationing and risk rationing. *Ex-ante* screening of applicants and *ex-post* monitoring of borrowers can imply significant monetary and time costs. Meeting collateral requirements may also imply significant costs including verification that the asset has a registered title and is free of liens as well as the registration of the lien in favor of the lender. An individual is transaction cost rationed if the noninterest monetary and time costs that arise because of asymmetric information lead an individual to refrain from borrowing. If individuals lack access to insurance, then collateral may have an additional repressive effect on loan demand as some individuals may not be willing to risk losing their assets. Without asymmetric information, lenders would be willing to write highly state-contingent credit contracts that shift risk from the borrower to the lender. This type of insurance *cum* credit contract is infeasible in the presence of moral hazard, however, because the insurance inherent in the credit contract dilutes the borrower's incentives to reduce default risk.

² Key expositions of nonseparable household models are given by DeJanvry et al. (1991) and Singh et al. (1986).

We follow Boucher et al. (2008) and label as risk rationed those individuals who have access to an expected-income-enhancing loan but do not take it, instead retreating to a lower return but lower risk reservation activity.

We define as credit constrained those individuals whose participation in the credit market is limited as a result of asymmetric information. Quantity rationed individuals' participation is involuntarily limited; they have excess demand for credit that is not met by lenders. In contrast, transaction cost and risk rationed individuals choose not to participate even though they have access to loans that, considering the interest rate, would raise their expected income. For this latter group, the noninterest costs deriving from lenders' strategies to mitigate adverse selection and moral hazard drive their expected utility from borrowing below their reservation utility. A key insight from this discussion is that the interest rate is only one component of the cost of a loan. Transaction costs and the risk implied by the default penalties represent additional costs that create a wedge between the market price and the "true" cost of the loan. As in the market participation literature (Bellemare and Barrett, 2006; Goetz, 1992; and Key et al., 2000), those households whose willingness to pay for a first-best loan contract falls within this "price band" will refrain from participating in the credit market and, as a result, their resource allocation will be tightly linked to their endowments. In the remainder of this section we develop a basic model that demonstrates that each of the three forms of nonprice rationing breaks the independence between household endowments and input intensity, so that credit constrained households reach a lower level of farm productivity than unconstrained households.

Consider a farm household endowed with land, A , and liquidity, K . Land quality is homogeneous across households; however, some farmers have a title for their land while others do not and cannot acquire one. Let T be a binary variable taking value one if the household has a title and zero otherwise. We make the following two assumptions about land markets. First, titled land may be mortgaged and, in case of default, foreclosed upon by lenders. Second, high costs of search and contract enforcement imply a missing rental market. As a result, within a growing season farmers do not make marginal adjustments via land markets.³ Farm production is certain, and is carried out with a technology, $F(N, A)$, that exhibits constant returns to scale in land and a variable input, N , that we call fertilizer. Given that land is a fixed factor, farm profit, P , is:

$$P(n; A) = A[f(n) - pn]; \quad (1)$$

where $n \equiv \frac{N}{A}$ is the per-hectare level of fertilizer, p is the fertilizer price, and $f(n) \equiv F(\frac{N}{A}, 1)$ is the per-hectare production function. The output price is normalized to one. The function

$f(\cdot)$ is strictly concave so that there exists a unique profit maximizing level of fertilizer per hectare, n^* , that is independent of the household's land endowment.

Households may seek a bank loan to finance production. A loan contract specifies three terms: loan size, B ; interest rate; and collateral. We do not explicitly endogenize the latter two terms. Instead, we assume that, in response to asymmetric information, lenders require that all loans be fully collateralized. We also assume that the bank's opportunity cost of funds is zero so that, under competition, the interest rate charged on loans is also zero.⁴ Borrowers potentially face two types of transaction costs. First, all borrowers incur a fixed cost, t , representing the time and monetary costs of loan application and disbursement and the costs of collateral registration. Second, defaulters incur an additional cost, v , representing the administrative cost of land foreclosure which is passed on to the borrower.

The household maximizes the expected utility of its end-of-period consumption which is financed by farm income and the value of end-of-period assets which includes any liquidity not used in farming plus the value of land. Liquidity not used in farming earns a zero interest rate, and the household sells any land that was not foreclosed upon at price r per unit area. To capture uncertainty, assume that with probability $1 - \pi$, the household confronts a consumption shock, such as a medical emergency, of size s . The shock is sufficiently large such that, when hit by it, households who borrowed to finance production must divert farm revenues intended to repay their loan to instead cover the consumption need and, as a result, they default. The lender forecloses on the land and sells it to recover the principal plus the foreclosure cost, v .

The consumption shock captures nonproduction sources of risk facing rural households such as sickness, injury, theft, and ceremonial obligations. The primary reason for invoking this additive form of risk is analytical simplicity. The additive shock implies that, conditional on their credit market participation decision, households will behave as profit maximizers in their production decisions. Household risk aversion will, however, influence the decision of whether or not to participate in the credit market.⁵ Nonproduction shocks are, in northern Peru as in many rural areas of the developing world, an important source of uncertainty. In the sample, 80% of the negative shocks

⁴ A more complete model would fully endogenize collateral and interest rate, recognizing that these two terms are substitutes in the lender's return function. As demonstrated by Boucher et al. (2008), moral hazard limits the degree to which lenders can substitute higher interest for lower collateral and thus truncates the menu of available contracts. The model in this article can thus be viewed as a severe version of this truncation in which all contracts that are not fully collateralized are ruled out.

⁵ Stated another way, this assumption limits the impacts of risk rationing to the credit market participation decision and not the level of borrowing. Moving to a more realistic risk structure such as multiplicative production risk would instead lead to risk rationing on both the extensive margin (participate versus not participate) and the intensive margin (the amount of loan demanded). As both our theoretical and empirical applications focus only on the extensive margin, we likely understate the adverse impact of risk rationing on resource allocation.

³ This assumption about land markets is roughly consistent with the economic environment of northern Peru, where the empirical analysis is situated. In the sample, only 4% of the total area farmed by households is rented. Rental includes both fixed rent and sharecropping.

reported by households for the 12 months preceding the survey in 2003 were unrelated to farm production. This type of risk can significantly influence households' credit market participation.

With this background, the household chooses the level of input, n , and borrowing B , to maximize expected utility according to the following program:

$$\max_{n, B} \pi U(C^g) + (1 - \pi)U(C^b) \quad (2)$$

subject to:

$$C^g = P(n; A) + K + rA - tI(B > 0) \quad (3)$$

$$C^b = P(n; A) + K + rA - s - (t + v)I(B > 0) \quad (4)$$

$$pAn \leq K + B \quad (5)$$

$$0 \leq B + t + v \leq rAT. \quad (6)$$

Equations (3) and (4) give the household's consumption under the two states of nature. C^g is the household's consumption under the good state of nature and is the sum of the household's full income minus the transaction cost of loan application if, as indicated by the indicator function I , the household borrows. C^b is consumption under the bad state which is reduced by the consumption shock, s , and, if the household borrowed, by the cost of foreclosure, v . Equation (5) limits expenditures on fertilizer to the value of the household's liquidity plus borrowing. Finally, Eq. (6) describes the household's credit limit and states that, after accounting for transaction costs, the farmer can borrow up to the value of his titled land. We assume that the credit limit for a farmer with title is large enough to enable him to purchase the profit maximizing level of fertilizer.⁶

This framework enables us to explore the interplay between endowments, the various types of credit constraints, and resource allocation. Of particular interest is whether or not a household reaches the maximum attainable farm profits given its land endowment. First, consider households with $K \geq pAn^*$. Given that there is no production risk, these high liquidity households will self-finance farm production and reach the maximum attainable profit. These households are unconstrained—or price rationed—in the credit market.

Next, consider the remainder of households with $K < pAn^*$. These households have insufficient liquidity to reach the maximum attainable profit without borrowing. Households with land titles have the option of borrowing or self-financing production. If the household borrows, its choice of fertilizer intensity is governed by the first order condition: $f'(n) = p$. Borrowing households thus mimic the production decision of the high liquidity, self-financing households and reach the profit maximizing level, n^* . If instead the household self-finances, it invests its entire stock of liquidity in farm production and falls short of the profit maximizing input level, so that: $f'(n) > p$.

Why would a low-liquidity household that is able to borrow choose not to reach the profit maximizing input level? There are two reasons. First, for households with intermediate liquidity to land ratios, the fixed transaction costs of borrowing may drive the expected value of consumption with a loan below the expected value under self-finance. Households in this situation are transaction cost rationed.⁷ Second, compared to self-finance, borrowing implies an additional risk. If borrowers experience the negative consumption shock, they default and incur the foreclosure cost, v . Thus, even if a loan raises expected consumption relative to self-finance, a household will forego the loan if the additional risk is too large.⁸ For these risk rationed households consumption is, on average, higher with a loan; however, it is lower in the bad state when it is most valuable.⁹ It is important to note that the existence of risk rationing hinges on imperfect insurance markets. In our model, the provision of an actuarially fair health insurance market would eliminate this form of nonprice rationing.

The final group to consider includes those households that have neither title, and thus cannot qualify for a loan, nor sufficient liquidity to purchase the unconstrained profit maximizing input level. These households will be either quantity rationed, transaction cost rationed, or risk rationed. Quantity rationed farmers are those who would borrow if they had access to a loan (i.e., if they had title). Households who would not borrow, even if they had a title, are either transaction cost rationed or risk rationed.

To summarize, all three forms of nonprice rationing break the independence between a household's endowments and its resource allocation decisions. Unconstrained farmers, whether they self-finance or borrow, operate at the profit maximizing level of inputs per hectare. An increase in their endowment of land or liquidity would have no effect on either output or profit per hectare. In contrast, for credit constrained households, a change in endowments will affect output per hectare. Consider the effect of an increase in liquidity for a constrained household. As discussed above, whether this constraint derives from transaction cost, risk, or quantity rationing, the household applies less than the profit maximizing level of inputs per hectare. Since there is no risk-return tradeoff in the investment of own liquidity in farm production, any increase in a constrained household's endowment of liquidity will be invested

⁷ Transaction cost rationed households are characterized by the following equation:

$$t + (1 - \pi)v > A[P(n^*; A) - P(n^{SF}; A)]$$

where $n^{SF} = \frac{K}{pA}$ is the optimal input level under self-finance.

⁸ Sufficient conditions for the existence of risk rationing are available from the authors.

⁹ Our definitions lead to the assignment of households to a unique rationing category. Thus a household that is transaction cost rationed cannot also be risk rationed. This assignment is somewhat arbitrary since, in the presence of transaction costs and missing insurance markets, both risk and transaction costs adversely affect farmers' willingness to pay for a loan. This conceptual classification anticipates our empirical classification which, given the survey structure, does not allow for multiple nonprice rationing categories per household.

⁶ Formally, we assume $pn^* + \frac{t+v}{A} < r$, where A is the minimum farm size.

in farm production. Thus, for constrained households, output per hectare is increasing in liquidity. Conversely, an increase in a constrained household's land endowment will lower productivity since scarce variable inputs will be spread over a larger area. These comparative static relationships are the focus of the ensuing empirical analysis.

2. Data and context

2.1. The study area

The study is set on the northern coast of Peru in the department of Piura. Agriculture in this area is exclusively irrigated and the well-developed system of reservoirs and irrigation and drainage canals greatly reduces risk associated with the amount and timing of water. Rice, cotton, and corn are the main annual crops and are destined primarily for the domestic market. Piura's tropical climate and relatively good ports also favor the production of perennial export crops including bananas and mangos.

As a result of Peru's agrarian reform (1969–1979), small farms control the majority of agricultural land. In Piura, 91% of irrigated land is controlled by farmers that own less than 10 ha, and the mean farm size is just under 3 ha. While all land is individually operated, not all land has a formally registered property title. In 1997, the first year of our panel data set, there were two main reasons that a parcel might not have been titled. First, a significant portion of agricultural land is controlled by peasant communities (*comunidades campesinas*). Similar to Mexico's ejidos, the community owns the land and grants usufruct rights to individual community members. While use rights over community land can be bequeathed, land cannot be sold without community authorization nor can it be registered in the private property registry. As a result, community land cannot be mortgaged. Second, a large fraction of parcels were previously part of the collectively operated agrarian reform cooperatives. By the end of the 1980s, virtually all cooperatives completed a privatization process that allocated land to individual cooperative members. In many cases, this process was not accompanied by a formal survey of the individual parcels so that owners of these parcels were unable to acquire a registered property title. By the end of the 1990s, two policies were implemented to extend private property titles. First, congress passed a law allowing peasant communities to privatize their land. Second a large scale titling program was carried out both in the peasant communities that opted for privatization as well as throughout the ex-cooperative areas.

The limited liquidity of most small farmers plus the high input requirements of the commercial crops grown in the region combine to make credit a critical determinant of farm production. The rural credit market, in turn, has undergone significant changes in the last 15 years. Until 1992, the Agrarian Development Bank (*Banco Agrario*) held a monopoly over formal agricultural credit in Peru. 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 order to induce commercial banks to increase their presence in rural areas. The government also promoted the establishment of rural banks (*cajas 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 NGOs and local government that provide a small amount of subsidized loans to small farmers. We refer to these institutions as the semi-formal sector. The informal and semi-formal sectors represent alternatives to the formal sector. If they offered close substitutes for formal sector loans, then we would expect to find little difference in the resource allocation of households that are constrained versus those that are unconstrained in the formal sector. However, as we show in the econometric analysis, formal sector credit constraints indeed affect resource allocation, suggesting that the informal sector is not a perfect substitute to the formal sector.

2.2. Sample and data

Our econometric analysis is based on a panel data set of farm households that were surveyed in 1997 and again in 2003. The full 1997 sample included 547 farm households. In 2003, 499 of the original households were found and re-interviewed, of which 443 were still farming. The analysis that follows is based on the 443 households for whom we have farm production data for both years.¹⁰ Detailed information was collected about farm output, production costs, off-farm income, assets, and the household's participation in and perceptions of credit markets.

The survey allows us to use a "direct elicitation" approach to classify households as constrained or unconstrained in the formal credit market and, if constrained, to further identify whether the constraint derives from quantity, transaction cost, or risk rationing. This approach utilizes a combination of observed outcomes and qualitative questions to detect credit constraints.¹¹ The first step is to separate households that applied versus those that did not apply for a formal loan. Applicant

¹⁰ Attrition may bias our estimation results if attritors are systematically different from nonattritors after conditioning on our explanatory variables. Given the panel structure of the econometric model, we are not aware of a formal test of attrition bias. To get a feel for whether or not attrition bias is a concern we ran a probit of attrition against the explanatory variables plus the residuals from the productivity equations. The coefficient on the residuals is not significantly different from zero, suggesting that once we control for observed characteristics, attritors are not systematically different from nonattritors in a way that affects productivity.

¹¹ Feder et al. (1990) and Jappelli (1990) were among the first to utilize this direct survey approach. Boucher et al. (forthcoming) provide a detailed description of the approach. Petrick (2005) provides a critical discussion of the approach and contrasts it with alternative methodologies.

Table 1
Credit market participation by sector

Percent of sample using	1997	2003
Formal loan	27.5%	25.0%
Informal loan	35.5%	33.5%
Semi-formal loan	16.0%	7.0%
No loan	28.0%	42.0%

households are classified according to the outcome: rejected applicants are quantity rationed (constrained), while those whose demand was met are price-rationed (unconstrained). Classification of nonapplicant households requires additional information. These households were first asked whether or not any formal lender would offer them a loan if they were to apply. If they said yes, they were then asked why they had not applied. Those that said they had sufficient liquidity, the interest rate was too high, or they had no profitable investments were classified as price-rationed (unconstrained). Those that instead 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 their land were classified as risk rationed (constrained). Finally, households that stated that no formal lender would offer them a loan were asked whether or not they would apply for a loan if they were guaranteed 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 price rationed, transaction cost rationed, or risk rationed as above.^{12,13}

2.3. Descriptive statistics

In this section, we briefly describe households' participation in credit markets and the prevalence of credit constraints in the sample. We also provide descriptive evidence on the differences in farm productivity between constrained and unconstrained households that will motivate the ensuing econometric analysis. Table 1 reports the fraction of sample households that borrowed from each sector in the two survey years. In both years, the majority of households used some credit, although the frequency of households with a loan drops between the two years. This drop in borrowing is mainly due to a decrease in the use of semi-formal loans. Several NGOs offering loans at the

¹² As argued by Boucher et al. (forthcoming), if households refrain from borrowing because they overestimate contract risk or underestimate their access they behave as credit constrained, and are therefore correctly classified as such with the direct elicitation approach. As suggested by one referee, exploring the empirical relevance of this alternative form of asymmetric information in which economic agents are dissuaded from borrowing because of incorrect perceptions of the terms and conditions of loans available in the market is important. If common, then a policy of financial market education would be an effective means of strengthening rural credit markets.

¹³ The empirical analysis restricts quantity rationing to those who are completely excluded from the credit market. It does not include households who obtained less than their desired amount on the formal market.

time of the first survey were either shut down or significantly curtailed their agricultural loan portfolios due to widespread loan default in 1999 and 2000 resulting from the 1998 El Niño occurrence and the general financial and political crisis facing Peru at the end of President Fujimori's term.

Table 2 compares loan terms across the three sectors. The first two columns report interest rates for those loans that charged a strictly positive interest rate.¹⁴ On average, informal lenders charged just over 8% per month in 1997 and 10% in 2003. The average interest rate on formal loans was about 4% per month in both years. The lowest interest rates are found in the semi-formal sector, reflecting their subsidized status.

The next four columns of Table 2 compare loan size and maturity across sectors and years. In 1997, formal loans in the sample were significantly larger and had longer terms than loans from the other two sectors. The differences across sectors decreased, however, by 2003 as the mean loan size in the formal sector fell by 45%, from \$2,965 to \$1,560. In 2003, the mean maturity increased substantially in the formal and semi-formal sector. This increase is driven by the refinancing of a few formal and semi-formal loans over a 20-year period.¹⁵ In fact, median maturities across loan sectors (not reported in the table) decreased between 1997 and 2003 from 7 to 6 months for formal loans, from 6 to 5 months for informal loans and from 8 to 6 months for semiformal loans. These maturities are consistent with households' reporting that loans from all sectors were overwhelmingly used to finance variable costs of agricultural production. Formal loans, in general, require borrowers to post titled property (either agricultural land or homes) as collateral while informal and semi-formal lenders only rarely require any form of physical collateral.

Table 3 gives the frequency of formal sector rationing outcomes for the two survey years. The fraction of households that reported being constrained in the formal sector decreased from 56% to 43% between the two years. This decrease was spurred by a large decrease in the fraction of households that were quantity rationed (37% to 10%). This is consistent with the advances in the government's land titling program between survey years. The fraction of sample households with a registered title increased from 50% to 70% between 1997 and 2003, and among those who switched from quantity rationed to unconstrained, the increase was even larger from 33% to 73%. This large decrease in the incidence of quantity rationing was partially offset, however, by an increase in the incidence of risk rationing (9% to 22%). This decrease in households' willingness to enter into loan contracts that require them to bear significant risk is consistent with the high degree of political and economic instability of recent years in Peru. Many sample

¹⁴ Zero-interest loans are excluded because the majority of these loans are in the form of interlinked contracts from local traders, processors, and input suppliers. The data do not contain sufficient details on the noncredit component of these linked transactions to compute the effective interest rate of these loans.

¹⁵ Following the 1998 El Niño, the state implemented a "financial rescue program" (*rescate financiero*) which facilitated the refinancing of certain delinquent loans.

Table 2
A comparison of mean loan terms across sectors (standard deviation in parentheses)

Sector	Interest rate (monthly)		Size (US\$ 2003)		Maturity (months)		Percent requiring collateral	
	1997	2003	1997	2003	1997	2003	1997	2003
Formal	3.8 (1.3)	4.2 (1.5)	2,965 (6,481)	1,560 (1,994)	9.3 (9.2)	11.9 (27.0)	58	60
Informal	8.5 (3.6)	10.1 (4.0)	492 (508)	360 (810)	5.6 (1.9)	5.3 (3.6)	0	9
Semiformal	1.7 (0.8)	3.4 (1.2)	1,132 (999)	677 (850)	7.1 (1.69)	35.9 (43.9)	0	14

Note: All loan terms in the informal and semi-formal sectors are significantly different (at 5%) from the same term in the formal sector.

Table 3
Rationing mechanisms in the formal sector

	1997	2003
Constrained	56%	43%
Quantity rationed	37%	10%
Risk rationed	9%	22%
Transaction cost rationed	10%	11%
Unconstrained	44%	57%
Borrowers	28%	25%
Nonborrowers	16%	32%

Table 4
Productivity indicators: pooled sample means and standard deviations (in parentheses)

	Revenue (per ha)	Cost (per ha)	Net revenue (per ha)
Constrained	\$884 (921)	\$350 (299)	\$534 (753)
Unconstrained	\$1537 (1110)	\$652 (498)	\$885 (818)

households were adversely impacted by the 1998 El Niño occurrence and the regional economic downturn that ensued.

We now turn to descriptive evidence regarding the impact of credit constraints on farm productivity. The specific question we seek to answer is: By how much would productivity increase if formal credit constraints were eliminated? Table 4 compares various productivity measures across constrained and unconstrained households and thus can be used to generate a naive, or unconditional, impact estimate. The first column shows that the average revenues of constrained farmers were \$884 per hectare, while for unconstrained farmers revenues were \$1,537 per hectare. The second column shows that expenditures per-hectare on variable inputs were also significantly less for constrained than unconstrained farmers. The final column shows that, subtracting expenditures from gross revenues, unconstrained farmers' net revenue per-hectare was about \$350 more than that of constrained farmers. According to these unconditional estimates, credit constraints have a large dampening effect on farm productivity. While this unconditional estimate suggests significant imperfections in the credit market, it neither tells us about the underlying relationship between productive assets and farm productivity, nor does it account for the potential for systematic differences in the determinants of productivity across constrained and unconstrained households. Thus, we

cannot attribute this difference in mean productivity to credit constraints. In the next section, we develop an econometric model that enables us to examine the returns to productive assets across constraint regimes and use the model to generate an estimate of the efficiency loss attributable to credit constraints.

3. Econometric model and identification strategy

The first objective of the econometric analysis is to evaluate whether or not the relationship between farm productivity and productive endowments differs across constrained and unconstrained households. This suggests the use of a switching regression model of the following form:

$$y_{it} = \begin{cases} y_{it}^C = \beta^C A_{it} + \gamma^C K_{it} + \delta^C X_{it} + \alpha_i^C + \varepsilon_{it}^C, & \text{if } d_{it} = 1 \\ y_{it}^U = \beta^U A_{it} + \gamma^U K_{it} + \delta^U X_{it} + \alpha_i^U + \varepsilon_{it}^U, & \text{if } d_{it} = 0 \end{cases} \quad (7)$$

$$d_{it}^* = \sigma' Z_{it} + \eta_i + v_{it} \quad (8)$$

$$d_{it} = \begin{cases} 1 & \text{if } d_{it}^* > 0 \\ 0 & \text{if } d_{it}^* \leq 0 \end{cases} \quad (9)$$

In Eq. (7), y_{it} is observed farm productivity and is equal to either constrained productivity, y_{it}^C , or unconstrained productivity, y_{it}^U , depending on whether the household is constrained or unconstrained in the credit market in period t ; A_{it} and K_{it} are the household's endowments of land and liquidity; X_{it} is a vector of other observed factors that explain productivity; α_i^C and α_i^U are unobserved, time invariant factors affecting productivity; and ε_{it}^C and ε_{it}^U are mean zero, time varying factors affecting productivity that are uncorrelated with A_{it} , K_{it} , and X_{it} . Equations (8) and (9) represent the process by which households are selected into either the constrained or unconstrained regimes. The continuous variable d_{it}^* is the latent propensity to be constrained for household i in period t and is modelled as a linear function of observed factors affecting credit supply and demand, Z_{it} , a household fixed effect, η_i , and unobserved time varying factors v_{it} . The binary variable d_{it} takes value one if d_{it}^* exceeds a threshold value set at zero and corresponds to household i being

observed as constrained, either by quantity, transaction costs, or risk, in the formal credit market in period t . If the household is instead unconstrained, d_{it} takes value zero.¹⁶

The parameters β^C , γ^C , β^U , and γ^U give the marginal impact of endowments on constrained and unconstrained productivity and are thus our main parameters of interest. The theoretical model of the previous section predicts that $\beta^C < 0$, $\gamma^C > 0$, and $\beta^U = \gamma^U = 0$. Generating unbiased estimates of these parameters is complicated by two potential problems. First, nonzero correlation between the household fixed effects, α_i^C and α_i^U , and household endowments may result in biased parameter estimates. Second, even if the unobserved terms in the productivity equation are uncorrelated with the regressors at the population level, the endogenous (nonrandom) selection process can induce a nonzero correlation between unobservables and regressors within the constrained and unconstrained sub-samples. In order to deal with these two issues, we estimate the parameters in Eq. (7) in two ways. First, we run OLS on the first difference of each productivity equation using the sub-samples of households that do not change constraint regime across periods. As it “sweeps out” the household fixed effects, this first difference approach eliminates potential biases due to time invariant unobserved heterogeneity. In addition it would eliminate selection bias if $\text{cov}(\eta_i + v_{it}, \varepsilon_{it}) = 0$; in other words if the unobserved factors governing selection are uncorrelated with the time varying unobservables affecting production. If, however, the unobserved factors governing selection are correlated with the time varying unobservables affecting production, then the parameter estimates obtained through a first difference approach would be subject to what Carter and Olinto (2003) call “residual selection bias.” To illustrate this, we define ζ as the vector of all regressors and explicitly write out the conditional expectation of the first difference in productivity for a household constrained in both periods as follows:

$$\begin{aligned} E(y_{i1}^C - y_{i0}^C \mid d_{i0} = 1, d_{i1} = 1, \zeta_i^C) \\ = \beta^C(A_{i1} - A_{i0}) + \gamma^C(K_{i1} - K_{i0}) + \delta^C(X_{i1} - X_{i0}) \\ + E(\varepsilon_{i1}^C - \varepsilon_{i0}^C \mid d_{i0} = 1, d_{i1} = 1, \zeta_i^C). \end{aligned} \quad (10)$$

Note that α_i^C , representing the unobserved fixed factors affecting productivity, has been differenced out. Even after first differencing however, residual selection may imply that the last term on the right-hand side is nonzero. To see this, rewrite this term as:

$$\begin{aligned} E(\varepsilon_{i1}^C - \varepsilon_{i0}^C \mid d_{i0} = 1, d_{i1} = 1, \zeta_i^C) \\ = E(\varepsilon_{i1}^C \mid v_{i0} < -(\delta'Z_{i0} + \eta_i), v_{i1} < -(\delta'Z_{i1} + \eta_i), \zeta_i^C) \\ - E(\varepsilon_{i0}^C \mid v_{i0} < -(\delta'Z_{i0} + \eta_i), v_{i1} < -(\delta'Z_{i1} + \eta_i), \zeta_i^C). \end{aligned} \quad (11)$$

If there is a nonzero correlation between ε_{it}^C and v_{it} , then each of the conditional expectations on the right-hand side will be nonzero. There are several techniques to deal with residual selection in panel data. Wooldridge (1995) develops a parametric technique that is similar to Heckman’s cross-sectional selection correction method. As it imposes strong distributional assumptions, in our second estimation strategy we instead follow the semi-parametric approach of Kyriazidou (1997).¹⁷

The intuition behind Kyriazidou’s approach is as follows. Although each of the two conditional expectation terms on the right-hand side of Eq. (11) may be nonzero, if the propensity that a household is constrained does not change across the two periods, then the *difference* in the conditional expectations will be zero. Thus estimating Eq. (7) using only observations that meet this criterion would yield consistent estimates. As this trimming of the sample would dramatically reduce the sample size, Kyriazidou proposes using all observations for which the difference is “small enough,” and weighting them in inverse proportion to the change in the propensity of being constrained. The estimation proceeds in two steps. First we estimate the parameters of the selection equation with a fixed effect logit model. The parameter estimates are used to construct the change in the predicted propensity to be constrained which, in turn, is used to generate a weight for each household using a kernel density function. These weights are used in the second stage, in which a weighted OLS on the first difference of each productivity equation is estimated.

4. Estimation and results

We estimate the parameters of the switching regression model of productivity specified in Eq. (7) using both the Kyriazidou approach described above and simple first difference. Our productivity measure is the value of output per hectare.¹⁸ Under each approach first difference regressions are run separately for

¹⁷ In particular it requires a full specification of the underlying distribution of the individual effects in the selection equation. Wooldridge suggests a test for the presence of residual selection bias relying on the same distributional assumptions. When we run this test, we cannot reject the null hypothesis of no residual selection. As we may still face residual selection if the errors in the selection and productivity equations do not follow the joint distribution assumed by this technique, we prefer to implement the Kyriazidou procedure.

¹⁸ Output quantities, output price, and expenditure data on the previous twelve months were collected immediately after harvest. As a result, the quality of recall data for output quantity and price is greater than for the many components of farm expenditures. We thus use the value of output instead of net revenues per hectare as our productivity measure. Feder et al. (1990) also use the value of output per hectare to measure productivity in their exploration of the impacts of credit constraints and productivity in China.

¹⁶ An alternative estimation approach would be to estimate a multinomial logit model in the first stage and then estimate separate productivity equations for each rationing mechanism (transaction costs, risk, quantity, and price). DeSilva et al. (2006) use this approach to control for potential selectivity resulting from contract form on the determinants of labor supervision. This approach is limited, however, by its inability to eliminate farmer specific fixed effects, which are likely to be important in our productivity application.

the constrained and unconstrained sub-samples. As a result, the estimations include only those households that do not change credit constraint regime across periods.¹⁹ The same regressors are used in both techniques. As explained earlier, in the Kyriazidou approach we also estimate the parameters of the selection equation in order to generate the weights used in the estimation of the productivity equations.

Table 5 defines the regressors used in both the productivity and selection equations and provides their means and standard deviations for constrained and unconstrained households separately. In addition to farm size and liquidity, control variables include: the number of adults in the household, the dependency ratio, the number of adults holding a salaried job, the herd size, the value of durable goods, and dummy variables indicating which crops were grown. We include the first three variables because farm productivity of credit constrained households may depend on the amount of available family labor.²⁰ The stock of durable goods is included to control for shocks between survey years that may have affected productivity. A health shock, for example, could imply a large expenditure and lead to a change in the stock of durables. The herd size and crop choice variables are included to control for differences in input requirements and expenditures across households.

In addition to the variables in the productivity equation, the selection equation includes two variables that are likely to affect productivity only via their impact on credit constraint status. The first variable, Title, is a dummy variable indicating whether or not the household owns at least one parcel with a registered property title. As formal lenders in the study area typically require farmers to post their land as collateral (or at least hand over their title), possession of a title should relax quantity rationing.²¹ The second variable, Network, measures the proportion of the household's neighbors with a formal loan. A higher fraction of neighbors participating in the formal credit market is also anticipated to relax credit constraints as it likely reduces both the transaction costs associated with loan application and the uncertainty resulting from an incomplete understanding of contractual terms. In particular, focus group sessions suggest that borrowers with minimal experience with and information about formal credit contracts overestimate the probability of foreclosure; they are less aware than experienced borrowers

that lenders exhaust all options, including loan restructuring, before initiating foreclosure.^{22,23}

Before turning to the main results, we briefly comment on the parameter estimates of the selection equation which are used in the Kyriazidou but not the linear panel approach. These parameter estimates are reported in column A of Table 6. As expected, possession of a registered property title reduces the probability of being credit constrained. As it enables households to meet the collateral requirement of lenders, possession of a title is likely to reduce quantity rationing. Although not quite significant, the parameter estimate on the network variable indicates that a larger proportion of neighbors participating in the formal credit market also reduces the probability of being credit constrained. Discussions in focus groups with farmers from the sample revealed that new borrowers face significant transaction costs associated with learning about the application process. Those who have neighbors who can guide them through the process are less likely to be transaction cost rationed. In addition, households who have no contact with borrowers tend to overstate the risk associated with formal loans and are thus more likely to be risk rationed.

We now turn to the primary results of the article. We divide the discussion into two parts. First, we examine the relationship between endowments and productivity for constrained versus unconstrained households. Second, we use the regression results to estimate the reduction in productivity attributable to credit constraints.

4.1. Credit constraints, endowments, and productivity

Columns B and C of Table 6 give parameter estimates for the unconstrained and constrained productivity equations respectively for the Kyriazidou estimation. Columns D and E do the same for the linear panel estimation. Recall the main hypotheses relating farm productivity and household's endowments that were generated by the model of Section 2. The model predicts that for constrained households, the value of output per hectare is decreasing in the household's endowment of land and increasing in its endowment of liquidity. In contrast, farm productivity of unconstrained households is independent of both types of endowments. The results of both estimation techniques are consistent with these predictions. The coefficients on farm size and liquidity are not significantly different from zero for unconstrained farmers. Given that these farmers do not face a binding credit constraint, their production decisions are unaffected by a marginal change in either liquidity or land.

¹⁹ Of the 443 households that farmed in both years, 252 remained either constrained or unconstrained in both years.

²⁰ If family and hired labor are imperfect substitutes, the available family labor will also affect productivity of unconstrained households.

²¹ While the literature on property rights (Besley, 1995) suggests that a title may also have a direct impact on productivity if title augments tenure security, in Piura, a registered title is unlikely to have this direct tenure security effect because nontitled farmers possess alternative documents recognized by local authorities. The other reason title might be directly correlated with productivity would be reverse causality: farmers with a greater intrinsic productivity and thus greater credit needs may be more likely to seek a title. This again is improbable in the context of Piura. The national titling program organizes the distribution of title geographically, based on an administratively established plan that is unlikely to be related to local heterogeneity in productivity.

²² The network variable is constructed using a weighting matrix where the weights are inversely proportional to the distance between households in the sample. Neighbors are defined as households living within 10 km of the household considered.

²³ Note that some regressors from the productivity equation do not appear in the selection equation. The reason we did not include cropping variables or liquidity in the first stage is because of simultaneity, as both crop choice and liquidity available will directly depend on whether the household is credit constrained.

Table 5
Means and standard deviations of explanatory variables by constraint status (pooled sample)

Variable	Definition	Unconstrained (N = 437)		Constrained (N = 447)	
		Mean	Standard deviation	Mean	Standard deviation
A	Farm size (ha)	4.943	6.492	4.001	4.152
K	Liquidity: credit + saving (000 \$)	2.193	4.809	0.558	1.108
Labor	# adults (>15 years)	4.257	2.043	4.050	1.872
Dep ratio	Children/household size	0.178	0.194	0.200	0.207
Reg Inc	# adults w/ salaried job	0.150	0.415	0.103	0.333
Herd	Head of cattle	1.525	4.417	1.644	4.032
Rice	1 if cultivates rice	0.587	0.493	0.466	0.499
Cotton	1 if cultivates cotton	0.147	0.355	0.276	0.448
Banana	1 if cultivates banana	0.205	0.404	0.217	0.413
Corn	1 if cultivates corn	0.257	0.437	0.441	0.497
Durables	Value of durable goods (000 \$)	6.325	23.169	2.947	3.791
Title	1 if has a title	0.710	0.454	0.482	0.500
Network	Proportion of neighbors w/ formal loan	0.362	0.274	0.204	0.221

In contrast, for constrained farmers the coefficients on both endowments are significantly different from zero and are of the predicted sign. For constrained farmers, whether the constraint is due to risk, transaction cost, or quantity rationing, the shadow value of liquidity is positive. These constrained households would use additional liquidity to invest in farm production. According to the Kyriazidou estimates, a thousand dollar increase in liquidity would raise the value of production per hectare by \$260. The corresponding increase using the linear panel estimates is slightly smaller, \$183 per hectare. Given that the mean value of output per hectare reported in Table 4 was just under \$900 for constrained households, this represents a 20–30% increase in productivity. The results of the Kyriazidou and linear panel estimates indicate that a one hectare increase in farm size would decrease the value of output per hectare for constrained farmers by \$164 and \$131, respectively. Given their constrained access to liquidity, increasing the area cultivated would reduce the intensity of input use per unit of land thereby lowering productivity.²⁴

To examine the robustness of the results, we repeat the linear panel estimations under two alternative specifications. In the per-hectare specification, the dependent variable is again the value of output per hectare, while the household endowment of liquidity and labor are expressed per-unit of land. In the log-linear specification, productivity and households' endowment of land, liquidity, and labor are expressed in log form. The parameter estimates are reported in the columns F through I of Table 6. In general, the results discussed above hold in both alternative specifications. Constrained productivity is a decrease-

ing function of the land endowment, while unconstrained productivity is independent of the household's land endowment. The only departure from the theoretical predictions comes when the log-linear specification is estimated via linear panel. Liquidity has a positive and significant impact on both constrained and unconstrained productivity. We take some comfort in the fact that the magnitude of the coefficient on liquidity is smaller for unconstrained productivity.

4.2. Efficiency loss due to credit constraints

The results discussed above suggest that household resource allocation is impacted by credit constraints. We now turn to quantifying the magnitude of this impact on farm productivity. The specific question we ask is: By how much would the productivity of farmers constrained in the formal sector increase if their credit constraint were removed? We are thus interested in constructing an estimate of $\Delta_{it} \equiv y_{it}^U - y_{it}^C$ for households that are credit constrained. The conditional expectation of interest is thus:

$$E(\Delta_{it} | d_{it} = 1) = (\beta^U - \beta^C)A_{it} + (\gamma^U - \gamma^C)K_{it} \\ + (\delta^U - \delta^C)X_{it} + (\theta^U - \theta^C)Z_{it} \\ + (\alpha_i^U - \alpha_i^C) + E(\varepsilon_{it}^C - \varepsilon_{it}^U | d_{it} = 1). \quad (12)$$

The last two terms of Eq. (12) complicate the estimation of this impact.²⁵ The final term will be nonzero if there is residual selection. Since the semi-parametric technique of Kyriazidou does not impose a functional form on the joint distribution of ε_{it} and v_{it} , we cannot estimate this conditional mean. We, therefore, rely on the results from the linear panel estimation. Estimating the household fixed effects is also problematic. At most, we have two observations to identify α_i^C and α_i^U .²⁶ As a

²⁴ We have no clear expectation about the sign and significance of the other explanatory variables. They serve mainly as controls so that the comparison of productivity per hectare is based on farms that have similar sets of characteristics. Consistently across categories and estimation techniques, it appears that households who raise cattle or grow rice have a higher productivity per hectare. Cotton growers on the other hand have a lower productivity per hectare, which is in part due to the fact that climatic conditions adversely affected cotton yields in 1997 and 2003.

²⁵ For brevity, the other conditioning variables in the last term are suppressed.

²⁶ Households that do not switch credit constraint status provide two observations to estimate one of the fixed effects and zero to estimate the other fixed effect, while switchers provide one observation for each fixed effect.

Table 6
 Estimation results for the productivity equations under two alternative specifications of the endowment variables (standard errors in parentheses)

	Kyriazidou			Linear panel			Per ha specification			Log-linear specification			
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	
Pr (constant)		Unconstrained productivity	Constrained productivity	Unconstrained productivity	Constrained productivity	Unconstrained productivity	Constrained productivity	Unconstrained productivity	Constrained productivity	Unconstrained productivity	Constrained productivity	Unconstrained productivity	Constrained productivity
A	-0.09 (0.09)	-48.86 (74.83)	-164.3** (60.47)	-85.57 (58.78)	-130.62** (48.65)	-88.65 (59.57)	-116.20** (48.20)						
K		31.83 (30.18)	260.3** (90.65)	14.45 (13.26)	182.67** (82.27)	-24.27 (42.06)	645.98** (236.42)						
K/A						7.71	-34.93 (33.08)						
Labor/A													
ln(A)													
ln(K)													
ln(Labor)	0.15 (0.09)	-138.3* (74.96)	-12.64 (52.55)	-61.50 (48.74)	2.33 (38.08)								
Labor	0.63 (0.69)	-29.82 (516.60)	-182.20 (302.60)	490.90 (418.87)	10.34 (330.09)	696.21*	29.13 (318.23)						
Dependency ratio													
Reg income	0.42 (0.38)	-479.30 (297.90)	3.65 (221.10)	263.85 (167.80)	-14.79 (214.76)	244.34 (171.22)	32.22 (202.05)						
Herd size	0.05 (0.04)	21.40 (35.56)	39.82 (30.39)	53.66** (20.12)	40.89* (21.76)	56.55** (20.31)	38.94 (21.02)						
Rice		826.4** (261.00)	333.1* (194.50)	632.30** (252.99)	93.30 (147.59)	672.66** (269.00)	115.47 (146.87)						
Cotton		-628.4** (271.30)	-245.70 (238.00)	-279.51 (223.06)	-27.99 (153.51)	-236.15 (226.56)	-23.86 (147.37)						
Banana		182.90 (414.40)	190.50 (206.50)	-374.69 (267.39)	754.11** (275.51)	-395.52 (272.64)	759.00** (271.02)						
Corn		52.01 (234.80)	-145.60 (203.30)	61.04 (186.70)	-64.55 (117.97)	12.66 (185.75)	-38.67 (116.86)						
Durables	-0.01 (0.03)	8.17 (24.28)	-64.86 (42.40)	5.03* (2.67)	4.83 (28.11)	5.92** (2.64)	6.38 (26.34)						
Constant		1233** (388.60)	1495** (317.60)	1493.80** (344.02)	977.59** (262.72)	1229.67** (344.68)	948.34** (248.31)						
Title	-1.18** (0.30)												
Network	-1.24 (0.83)												

Symbols * and ** indicate that the coefficient is different from zero at 10% and 5% significance levels.

result we cannot generate reliable estimates of the fixed effects. In order to estimate the impact, we assume that the household fixed effects have the same impact on constrained and unconstrained productivity: $\forall i, \alpha_i^U = \alpha_i^C$. The predicted impact for each constrained household is thus computed as:

$$\hat{\Delta}_{it} = (\hat{\beta}^U - \hat{\beta}^C)A_{it} + (\hat{\gamma}^U - \hat{\gamma}^C)K_{it} + (\hat{\delta}^U - \hat{\delta}^C)'K_{it} + (\hat{\theta}^U - \hat{\theta}^C)'Z_{it} \quad (13)$$

where $\hat{\beta}^U$, $\hat{\beta}^C$, $\hat{\gamma}^U$, $\hat{\gamma}^C$, $\hat{\delta}^U$, $\hat{\delta}^C$, $\hat{\theta}^U$, and $\hat{\theta}^C$ are the parameter estimates reported in columns D and E of Table 6.

Table 7 summarizes the predicted impact of eliminating the three types of credit constraints. Column A gives the frequency over the two years of each type of constraint in the sample. The last row of this column shows that, on average, 49.5% of households were constrained each year. Column B reports the mean change in productivity, $\bar{\Delta}$, for each type of constraint. The productivity loss due to credit constraints is large. We estimate that, on average, the value of output would increase by \$482 per hectare if all types of credit constraints were fully eliminated. As shown in column C, this represents an increase of 59% over the average observed productivity of constrained households. The final two columns are used to generate a rough estimate of the value of output foregone in the region due to credit constraints. Column D reports an estimate of the percentage of land in Piura in the hands of constrained households. Note that constrained households are estimated to control 44.3% of the region's land, although they account for 49.5% of sample households. This reflects the fact that the average farm size of constrained households, at 4.5 ha, is slightly below the mean of 4.9 ha for unconstrained households. Finally, column E, the product of columns C and D, reports the estimated percentage increase in the value of regional output resulting from eliminating each type of credit constraint. If all constraints were eliminated, the value of output would increase by 26%. The vast majority of the impact derives from quantity and risk rationing. While the frequency of risk rationing is less than that of quantity rationing, the increase in regional output due to risk rationing, 10.9%, is almost the same as the increase due to quantity rationing, 11.9%. This is due in part to the fact that the relative impact of credit constraint on productivity is larger among risk-rationed households. Ignoring constraints due to transaction cost and particularly risk rationing would result in a significant under-statement of the impact of credit constraints and thus lead to an overly optimistic evaluation of the health of rural financial markets.²⁷

5. Conclusion

In this article, we developed a basic model to show that credit constraints can take multiple forms, each of which breaks the

independence between a household's resource allocation and endowments. We then empirically compared the relationship between productivity and endowments across credit constrained and unconstrained farm households in Peru. While most empirical studies consider only quantity rationed households as constrained, we also consider as constrained households that are risk and transaction cost rationed. Theory indicates that the resource allocation of these households, just like that of quantity rationed households, is adversely affected by the information and enforcement problems underlying credit transactions. We find that the productivity of constrained households, unlike that of unconstrained ones, indeed depends upon their endowments of productive assets. We show that formal credit constraints have a large negative impact on the efficiency of resource allocation in the study region. We estimate that the value of agricultural production in Piura would increase by 26% if all formal credit constraints were eliminated.

Several policy relevant conclusions can be drawn from this analysis. First, our results suggest that the informal sector does not fully meet the liquidity need of households constrained in the formal market. This is an important result because there are reasons to expect that the information advantage informal lenders enjoy vis-a-vis banks would allow them to relax each of the three types of constraints that households may face in the formal sector. For example, since informal lenders tend to offer loans to households they know through previous transactions in input or output markets, loan applications in the informal sector imply minimal transaction costs (Mushinski, 1999). In addition, informal lenders rely less on physical collateral and more on monitoring and social sanctions to enforce contracts. As a result, informal lenders may be able to offer the types of low collateral, high interest rate loans that banks are unable to supply, thereby eliminating both quantity and risk rationing that households face in the formal sector (Boucher and Guirkinge, 2007). Indeed, if the informal sector is a good substitute for an imperfect formal sector, then we would expect to find little difference in the resource allocation of households that are constrained versus those that are unconstrained in the formal sector. However, as our econometric analysis demonstrated, formal sector credit constraints indeed adversely affect resource allocation, suggesting that the informal sector is not a perfect substitute to the formal sector in the region of study.

Second the broader definition of credit constraints used here suggests that mitigating rural credit market imperfections requires a broader policy response than contemplated in recent financial liberalization efforts. The first stage of most financial liberalization programs in Latin America was accompanied by liberalization of agricultural land markets in the form of land titling programs, investment in land registry institutions, and the elimination of legal restrictions on land transfer. The deepening of these reforms, by facilitating the use of land as collateral, may reduce the incidence of quantity rationing. Indeed, in our sample 80% of households that borrowed in the formal sector had a registered property title compared to 59% of the overall sample and only 37% of quantity rationed households. This

²⁷ Misclassifying risk and transaction cost rationed households as unconstrained may also lead to bias in the parameter estimates of the productivity equations.

Table 7

The impact of eliminating credit constraints on productivity and regional output (bootstrapped standard errors in parentheses)

Type of credit constraint	A Frequency in sample	B Productivity change \$ ($\hat{\Delta}$)	C Relative change ($\frac{\hat{\Delta}}{\bar{y}}$)	D Land controlled	E Impact on regional output
Quantity rationed	23.5%	516 (176)	58.2%	20.5%	11.9% (4.5)
Risk rationed	15.5%	478 (175)	68.2%	16.0%	10.9% (4.7)
Transaction cost rationed	10.5%	413 (216)	49.0%	7.8%	3.8% (2.1)
All constrained holds	49.5%	482 (149)	58.9%	44.2%	26.0% (8.4)

suggests that consolidation of the first stage property rights reform would yield additional gains in the efficiency of rural financial markets. As a portion of the transaction costs associated with loan application derives from collateral registration, these reforms, along with reforms aimed at enhancing the efficiency of the legal system and strengthening information sharing via credit bureaus, may also reduce transaction cost rationing. For example, DeJanvry et al. (2006) find that in Guatemala the implementation of a credit bureau led to enhanced repayment performance of a large microlender by reducing problems of moral hazard and adverse selection.

The aforementioned property rights reforms are likely to do little, however, to alleviate risk rationing. Indeed, 73% of the risk rationed households in our sample possess a title, suggesting that access *per se* is not a binding constraint. Instead it is the terms of access, in particular the risk implied by available credit contracts, that suppress these households' credit demand and lead them to pursue alternative lower return strategies. The prevalence of risk rationing suggests that enhancing the performance of rural credit markets also requires addressing the insurance market failures endemic to rural areas of developing countries. One particularly interesting area of research and policy innovation in this direction is index-based insurance which can be implemented at relatively low cost and is less susceptible to the moral hazard and adverse selection plaguing conventional crop insurance programs. With the support of the World Bank several such initiatives have been launched in various developing countries.²⁸ Although initial evidence is promising, additional research is required to evaluate the full impact of these programs and their potential positive synergies with rural credit markets.

Acknowledgments

This work is based on Chapter 4 of Guirkinger's dissertation. Guirkinger's field work was supported by a Risk and Development Fellowship and by an International Dissertation Field Research Fellowship from the Social Science Research Council

²⁸ World Bank (2005) provides an overview of index insurance and its application to risk management in developing countries. Rainfall insurance products in Morocco, India, and Malawi are described by Gine and Yang (2007), Hess (2003), and Skees et al. (2001). Skees (2002) describes an index insurance product based on regional livestock mortality levels for herders in Mongolia.

with funds provided by the Andrew W. Mellon Foundation. The data collection was supported by a grant from the BASIS Collaborative Research Program. We thank Julian Alston, Bradford Barham, Michael Carter, Rachael Goodhue, Alejandro Lopez-Feldman, and Pierre Merel for useful comments.

References

- Bellemare, M., Barrett, C., 2006. An ordered tobit model of market participation: Evidence from Kenya and Ethiopia. *Am. J. Agric. Econ.* 88, 324–337.
- Besley, T., 1995. Property rights and investment incentives: Theory and evidence from Ghana. *J. Polit. Econ.* 103(5), 903–937.
- Boucher, S., Carter, M., Guirkinger, C., 2008. Risk rationing and wealth effects in credit markets: Theory and implications for agricultural development. *Am. J. Agric. Econ.* 90(2), 409–423.
- Boucher, S., Guirkinger, C., 2007. Risk, wealth and sectoral choice in rural credit markets. *Am. J. Agric. Econ.* 89(4), 991–1004.
- Boucher, S., Guirkinger, C., Trivelli, C., forthcoming. Direct elicitation of credit constraints: Conceptual and practical issues with an empirical application. *Econ. Dev. Cultural Change*.
- Carter, M.R., 1989. The impact of credit on peasant productivity and differentiation in Nicaragua. *J. Dev. Econ.* 103, 13–36.
- Carter, M., Olinto, P., 2003. Getting institutions right for whom? Credit constraints and the impact of property rights on the quantity and composition of investment. *Am. J. Agric. Econ.* 85(1), 173–186.
- Conning, J., Udry, C., 2005. Rural financial markets in developing countries. In: Evenson R., Pingali P., Schultz T. (Eds.), *The Handbook of Agricultural Economics*, 3. Elsevier, North-Holland.
- DeJanvry, A., McIntosh, C., Sadoulet, E., 2006. The supply and demand side impacts of credit market information. Mimeo.
- DeJanvry, A., Sadoulet, E., Fafchamps, M., 1991. Peasant household behavior with missing markets: Some paradoxes explained. *Econ. J.* 101(409), 1400–1417.
- DeSilva, S., Evanson, R., Kimhi, A., 2006. Labor supervision and institutional conditions: Evidence from Bicol rice farms. *Am. J. Agric. Econ.* 88(4), 851–865.
- Feder, G., Lau, L.J., Lin, J.Y., Luo, X., 1990. The relation between credit and productivity in Chinese agriculture: A model of disequilibrium. *Am. J. Agric. Econ.* 72(5), 1151–1157.
- Field, E., Torero, M., 2006. Do property titles increase credit access among the urban poor? Evidence from a nationwide titling program. Mimeo, Harvard University.
- Foltz, J., 2004. Credit market access and profitability in Tunisian agriculture. *Agric. Econ.* 30, 229–240.
- Galeana, F., 2005. Demanda del dominio pleno en el ejido: Derechos de propiedad y credito rural. *Estudios Agrarios* 29, 19–28.
- Gilligan, D., Harrower, S., Quisumbing, A., 2005. How accurate are reports of credit constraints? Reconciling theory with respondents' claim in bukidnon, Philippines. BASIS Collaborative Research Support Program Working Paper, University of Wisconsin-Madison.

- Gine, X., Yang, D., 2007. Insurance, credit, and technology adoption: Field experimental evidence from Malawi. Unpublished World Bank Working Paper.
- Goetz, S., 1992. A selectivity model of household food marketing behavior in sub-Saharan Africa. *Am. J. Agric. Econ.* 74, 444–452.
- Hess, U., 2003. Innovative financial services for rural India. Agriculture and Rural Development, Working Paper 9, The World Bank.
- Jappelli, T., 1990. Who is credit constrained in the U.S. economy? *Q. J. Econ.* 105(1), 219–234.
- Key, N., Sadoulet, E., De Janvry, A., 2000. Transactions costs and agricultural household supply response. *Am. J. Agric. Econ.* 82, 245–259.
- Kyriazidou, E., 1997. Estimation of a panel data sample selection model. *Econometrica* 65, 1335–1364.
- Mushinski, D., 1999. An analysis of loan offer functions of banks and credit unions in Guatemala. *J. Dev. Stud.* 36(2), 88–112.
- Petrack, M., 2004. A microeconomic analysis of credit rationing in the Polish farm sector. *Eur. Rev. Agric. Econ.* 31, 23–47.
- Petrack, M., 2005. Empirical measurement of credit rationing in agriculture: A methodological survey. *Agric. Econ.* 33, 191–203.
- Sial, M.H., Carter, M.R., 1996. Financial market efficiency in an agrarian economy: Microeconomic analysis of the Pakistani Punjab. *J. Dev. Stud.* 32(5), 771–798.
- Singh, I., Squire, L., Strauss, J. (Eds.), (1986). *Agricultural Household Models: Applications, Extensions, and Policy*. The Johns Hopkins University Press, Baltimore, MD.
- Skees, J., Gober, S., Varangis, P., Lester, R., Kalawakonda, V., 2001. Developing rainfall-based index insurance in Morocco. World Bank Policy Research Working Paper No. 2577.
- Skees, J., Inkha-Amgalan, A., 2002. Examining the feasibility of livestock insurance in Mongolia. World Bank Policy Research Working Paper No. 2886.
- Stiglitz, J., Weiss, A., 1981. Credit rationing in markets with imperfect information. *Am. Econ. Rev.* 73(3), 383–410.
- Wooldridge, J.M., 1995. Selection corrections for panel data models under conditional mean independence assumptions. *J. Econom.* 68, 115–132.
- World Bank, 2005. *Managing agricultural production risk: Innovations in developing countries*. The World Bank, Washington, DC.