AGRICULTURAL ECONOMICS

Agricultural Economics 43 (2012) 403–413

# Women rule: potato markets, cellular phones and access to information in the Bolivian highlands

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Received 28 April 2011; received in revised form 16 September 2011; accepted 31 October 2011

**Abstract**

In highland Bolivia, potato markets are widespread and access to market information has entered the digital age. Information networks lubricated by ubiquitous cellular technologies are supplanting traditional means of information-gathering. We explore the impacts of access to cellular phones on market selection, use of social networks to acquire information, and gendered responsibilities within the potato market chain near Cochabamba. The entire family participates in potato production and marketing, but responsibilities are differentiated by gender. Men take a leading role in potato production and women in marketing. Access to cellular phones affects decisions about where to market potatoes and improves the potato marketing process.

*JEL classification*: O13, P42, O18

*Keywords:* Andean Region; Bolivia; Markets; Gender; Cell-phones; Transactions costs

## 1. Introduction

Potato is grown in more than 100 countries and ranks as the world's fourth most important food crop, after maize, wheat, and rice (FAO, 2007). Bolivia and Peru form the origin and center of potato domestication, and household food security in the region depends on the potato. Per capita potato consumption in Bolivia averages between 80 and 140 kg/year and as much as 50% of farm household incomes come from potatoes (Amaya, 2009). Throughout the Andes, women are heavily engaged in agricultural work (Duryea et al., 2002; Grynspan, 1999). In rural Bolivia, it is estimated that more than 80% of female adults participate in agricultural-related activities (Alemán, 2002; INE, 2000). Women and men work together producing potatoes; men devote their efforts to activities requiring more physical effort such as soil preparation, but many tasks are shared (Amaya, 2009).

Gender differentiation is, however, pronounced in Andean potato markets where women negotiate prices, make sales, and control potato-generated incomes. Marketing decisions require information about conditions in multiple markets, timing of sales, and other factors. In many Andean areas, most communication is still oral, and people obtain information through informal social networks.[1]

Information technology is transforming how people obtain market information. Cellular telephones and other innovations are leading to rapid diffusion of market information and are affecting participants in unexpected ways (Aker, 2011; Jensen, 2010). As poor producers in remote areas become more integrated into regional markets the value of information to them increases (Escobal, 2001). To reduce vulnerability in the face of social, economic, and environmental challenges, households throughout the region need better access to market information. Enhanced information will expand options to producers, but the degree to which it affects marketing choices is unknown. As information and communications technology (ICT) can bypass

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**Data Appendix Available Online**

A data appendix to replicate main results is available in the online version of this article. Please note: Wiley-Blackwell is not responsible for the content or functionality of any supporting information supplied by the authors. Any queries (other than missing material) should be directed to the corresponding author for the article.

[1] A social network is a social structure made of nodes which are generally individuals or organizations. These nodes are tied by one or more specific types of interdependency, such as values, friendship, kinship, conflict or trade.


DOI: 10.1111/j.1574-0862.2012.00592.x

traditional information networks, its introduction might imply changes in gender roles including reduced roles of women in sales and marketing.

The objectives of this study are to investigate impacts of access to cellular phones on potato marketing in the Bolivian highlands. We address three primary objectives. First, does access to cellular phones affect market choice among highland producers? Second, are cellular pones complementing or supplanting traditional information networks used by potato marketers? Third, are women and their unique roles in potato markets being affected by changing market choices and changing information networks?

Our research combines quantitative and qualitative methods. We use a survey of farm households in Tiraque, Bolivia to estimate models examining the effect of access to cellular phone technologies on decisions about selling in alternative markets. Data collection was structured to include observations from households with good access to cellular phone signals and observations from similar households without signal access. We use this structure and the quasi-randomization it induces to control for the potential endogeneity of cellular phone ownership with the market choice decision. We find that access to cellular phones has a significant effect on marketing decisions; farmers with access to cellular phones are more likely to participate in urban markets, holding all other variables constant.

The market choice analysis was supplemented with qualitative exercises designed to deepen our understanding of gender roles, decision processes, and how cellular phones affect them. We find that women have historically dominated potato markets in the area. Introduction of cellular phone technologies has not substantially changed women's roles, nor has it altered the importance of social networks in acquiring market information. Cellular phones clearly speed the flow of information and enable households to make better choices about where to sell, but have not supplanted existing information networks.

### *1.1. Markets, market access, and telecommunications*

Markets are the main transmission mechanism between growth in the wider economy and the lives of the poor. Access to markets can be uneven and depend on factors such as distance, infrastructure, and other factors affecting transactions costs (Fafchamps and Vargas Hill, 2005). Social and economic barriers (e.g., market power, asymmetric, or costly information) may exclude the poor from markets (Escobal and Torero, 2006). Costs of obtaining reliable market information can be prohibitively high, and limited information can create inefficiencies and welfare losses for participants and potential participants (DFID, 2005).

Newer technologies are affecting agricultural marketing systems, and cellular phones are a prominent ICT with potential for lowering costs of acquiring information. Cellular phones help synchronize supply and demand and help traders identify potential for arbitrage. Aker (2008) studied the impact of cellular phones on grain markets in Niger and found that they reduced search costs. Overa (2006) found in Ghana that traders became more efficient due to reduced transactions costs following the introduction of cellular phones. Jensen (2007) found that mobile phones help fishermen in India choose higher-priced markets, reduce waste and increase profits. His data set was unique as cellular towers were introduced in phases along the Indian coast, creating a natural experiment that helped avoid potential problems of endogeneity between cellular phone purchases and market choice. Cellular phones were found to decrease price dispersions across spatially separated markets. Muto and Yamano (2009) showed that cellular phone network expansion increased market participation among banana producers in Uganda. Producers farthest from markets were most strongly affected by cellular phone access. Reduced information costs can overcome distance-related transactions costs and enable producers to select from multiple markets.

Most studies of telecommunications impacts on agricultural marketing have focused on perishable crops and products, and few have examined how ICT affects decisions and gender relations. The focus on perishable crops is understandable because prices of these products depend on freshness and ICT, by speeding information flow, will enable producers to quickly move in response to price signals. However, in the presence of high transportation costs, many nonperishables (especially those with low value to weight, like potatoes) should exhibit similar properties as perishables. Once a shipment arrives in a market, it must be sold.

In many countries, agricultural marketing is differentiated by gender. Changes in access to market information could influence gender relations. For example, reduced importance (due to cellular phone technologies) of social networks can have differential impacts on men and women. Evidence shows that women's status can be altered by access to ICT. In India, access to cable television improved women's status, increased their influence in household decisions, and reduced domestic violence (Jensen and Oster, 2009). Bayes (2001) found that access to cellular phones in Bangladesh had a positive impact on the status and empowerment of poor women.

ICT services have proven effective in bringing market information to men and women (World Bank, 2008). The latter frequently benefit more from these services, because they have less mobility and lower levels of literacy. In India, for example, access to telephones enabled rural women to obtain information on the price of food crops, empowering them to better negotiate prices with middlemen (Huyer and Sisoska, 2002).

Given the importance of market access to farmer incomes and the important role that transactions costs have in marketing (Fafchamps and Vargas Hill, 2005; Key et al., 2000), it is surprising how little literature examines how access to cellular phones affects market choice. Such technologies can lead to changes in gender relations, roles in the marketing process, and the overall efficiency of alternative marketing arrangements. We examine all these issues.

### 1.2. Study area

The study area is the Jatun Mayu watershed in southern Tiraque Province, about 70 km from Cochabamba. It is comprised of 14 communities, with approximately 3,000 inhabitants between 3,000 and 4,200 meters above sea level. Predominant economic activities are small-scale agricultural production mixed with livestock. Between 20% and 50% of crop output is sold and income depends on agricultural sales, mainly potatoes. Men and women engage in agricultural production and marketing, but gender roles are differentiated (Amaya, 2009).

The main crop in the area is potato, sold in the rural markets of Tiraque and Punata, and in the urban markets of Cochabamba and Santa Cruz. Urban markets offer higher prices, but are located far away, implying high transportation costs and more risk. However, the watershed is small enough so that each of these markets is potentially available to everyone. Verbal communication remains the most important form of information exchange in Bolivian potato markets. Recent technological innovations include radio programs that transmit market information in Quechua and widely available cellular phones. Many farmers and almost all potato wholesalers and retailers now use mobile phones to coordinate sales (Amaya, 2009). However, there are deficiencies in access to information; some areas receive better cellular signals than others.

## 2. Methods

The decision about whether to market potatoes in a higher-value or urban market depends on market prices net of costs of transactions associated with selling in that market. Formally, allow the unit price received in market j be $p_j$ and the unit costs associated with transportation and other transactions be $c_j$. If we express

$$p_j - c_j = y_j^* = x\gamma_j + \eta_j, \tag{1}$$

where the $y^*$ notation reflects the fact that we cannot observe all the components of $c$ and is therefore a latent variable, $x$ is a vector of observable variables affecting, among other things, the costs of transactions, $\gamma_j$ is a vector of parameters to be estimated and $\eta_j$ is an error term. The farmer chooses market $i$ when $p_i - c_i = \max_j[p_j - c_j]$ over the $J$ market choices. We focus on the $c$ component of Eq. (1) because all actors face similar prices and differences in market choices should depend on individual-specific nonprice considerations.

We can decompose $c$ into three elements:

$$c_j = c_F + c_D(q)d_j + c_I(d_j; z), \tag{2}$$

where $c_F$ represents fixed unit costs associated with loading the product onto the transport, $c_D(q)$ is the unit cost of transport ($\partial c_D/\partial q$ is likely to be negative because larger shipments can use larger and more efficient transport mechanisms) per unit of distance ($d$), and $c_I$ reflects the unit-equivalent cost of obtaining information about conditions in the market. These unit-equivalent costs are a function of distance from the household to the market ($\partial c_I/\partial d_j$ is likely to be positive) conditioned on access to cellular phone signals and possession of a cellular phone. We hypothesize that access to cellular phones and signals reduce the marginal impact of distance on cost of obtaining market information. If a cellular phone can be used to obtain information about a nearby market, it can also be used to obtain information about relatively distant, but similar, markets.

This simple model yields several important insights into the impacts of the variables in $x$ on market choice. First, larger-scale and wealthier farmers are more likely to choose more distant markets because the unit cost of transport per distance traveled falls with quantity transported. Second, households with better access to paved roads are more likely to market in distant markets for similar reasons. Third, access to cellular phones is likely to raise the probability of attending more distant markets by lowering costs of obtaining information from a distance.

### 2.1. Empirical methods: quantitative analysis

In any marketing period, the producer faces options that can be characterized differently. One interesting question is: Does cellular phone ownership affect decisions to sell potatoes in more distant urban markets? To empirically model this decision process, we could use a binary-dependent variable problem such as a probit equation. A second interesting question is: Does cellular phone ownership affect the general choice of markets among the following ($J$) alternatives: single markets ($J - 1$ of these), or multiple markets? We hypothesize that these decisions are functions of variables representing household characteristics, location, wealth, and access to cellular phones. In either case, we face the vexing problem of a right-hand side variable (cellular phone ownership) that is likely to be related to unobserved household attributes also affecting market choice.

To address the first question, consider Eq. (1) with two choices: sell in urban markets or sell in rural markets. Denote $U_i^*$ as the difference in utility for household $i$ associated with selling in urban markets minus that of selling in rural markets and $C_i^*$ as the utility difference between owning a cellular phone and not. Both variables are latent, and they lead to the two-equation model

$$U_i^* = \beta' X_i + \theta C_i + \varepsilon_i \tag{3.1}$$

$$C_i^* = \alpha' Z_i + \mu_i, \tag{3.2}$$

where $X$ and $Z$ are vectors of determinants of the outcome (with overlap) and $\beta$, $\alpha$, and $\theta$ are vectors of parameters and parameters to be estimated. We observe the outcomes $Y_i = 1[U^* > 0]$ and $C_i = 1[C^* > 0]$, that is whether the household markets in urban areas and owns a cellular phone. Endogeneity of cellular phone ownership to the market decision is due to unobserved (to the econometrician) factors associated

with both decisions. Under such circumstances, $E[\varepsilon|C] \neq 0 \leftrightarrow \text{cov}[\mu, \varepsilon] \neq 0$, and estimation without addressing this problem will lead to biased and inconsistent parameter estimates.

If we make the additional assumptions

$$(\mu, \varepsilon) \sim N\left[(0, 0), \left(\sigma_\mu^2, \rho\sigma_\mu, 1\right)\right], \tag{4}$$

and $Z$ is a valid set of instrumental variables uncorrelated with $(\mu, \varepsilon)$, then $P(Y = y, C = c) = P(Y = y \mid C = c) \times P(C = c)$, and the model is equivalent to a bivariate probit model, which can be estimated using FIML (Green, 2003).

The second question reflects the household choice of markets among $J$ alternatives (where we have $J$–1 single market options and the $J$th alternative is multiple markets). Returning to Eq. (1), the farmer chooses market $k$ when $p_k - c_k = \max_j[p_k - c_k]$ over the $J$ market choices. If the $\eta_j$s are independently and identically Gumbel distributed, the model specification is multinomial logit (the market choices are mutually exclusive) and the probability that household $i$ selects alternative $j$ is

$$p_{ij} = \frac{e^{\beta_j X_i + \theta_j C}}{\sum_{l=1}^{m} e^{\beta_l X_i + \theta_l C}} \; j = 1 \ldots . m. \tag{5}$$

To estimate this model we must still address the endogeneity of cellular phone ownership (i.e., estimation of Eq. (5) with the choice modeled as Eq. (3.2)). Instrumental variable (IV) techniques are frequently used to handle such endogeneity, but IV needs to be adjusted in the case of nonlinear models (Murphy and Topel, 1985). We apply two IV approaches to address this endogeneity bias: two-stage residual inclusion (2SRI) and two-stage predictor substitution (2SPS) (Terza et al., 2008). 2SPS extends the linear two-stage least squares (2SLS) estimator to nonlinear regressors. The endogenous variable (C) in the second-stage regression (the MNL) is predicted using a first-stage probit; the predictions ($\hat{C}$) are substituted into the MNL at the second stage.

The 2SRI estimator has an identical first stage, but in the second stage MNL regression, the endogenous variable is not replaced with its predicted value ($\hat{C}$). Instead, the first-stage residuals, together with the endogenous variable are included as regressors in second-stage estimation (Terza et al., 2008). More formally, for 2SPS, the MNL Eq. (5) is rewritten as

$$p_{ij} = \frac{e^{\beta_j X_i + \theta_j \hat{C}}}{\sum_{l=1}^{m} e^{\beta_l X_i + \theta_l \hat{C}}}, \tag{5a}$$

where $\hat{C}$ represents the prediction from Eq. (3.2) estimated as a probit. For 2SRI, Eq. (5) is estimated as

$$p_{ij} = \frac{e^{\beta_j X_i + \theta_j C + \delta_i \hat{\mu}_i}}{\sum_{l=1}^{m} e^{\beta_l X_i + \theta_l C + \delta_i \hat{\mu}_i}}, \tag{5b}$$

where $C_i$ is observed cellular phone ownership ( = 0,1) and $\hat{\mu}_i$represents the residual ($C_i - \hat{C}_i$) from equation 3.2. Since models (5a) and (5b) use probit estimates from the first-stage regression, the standard errors of the second-stage coefficients must be adjusted. We use the Murphy–Topel adjustment outlined in Hardin (2002) and Hole (2006).[2]

The main source of the data for this analysis is a household survey conducted in Tiraque immediately following the 2007 potato harvest. The survey was applied to 304 families in 18 communities, some with access to cellular phone signals at or within 200 m of their dwelling and others without access. The survey collected information on household and farm characteristics, assets, consumption, production and income. A unique feature of the data set was that households and fields were georeferenced and geographical information systems overlays of road networks allowed us to compute travel time to roads, major transportation nodes and markets, thus avoiding own-reporting biases documented in Escobal and Lazlo (2008). Variables are described and summary statistics are presented in table 1.

Identification of the effects of cellular phone ownership on marketing decisions requires suitable instruments. These instruments should affect market outcomes only through their impact on cellular phone ownership; they should be uncorrelated with the errors in both the first and second stages. We have three strong candidates (all binary variables): (i) household is located in area with access to a good cellular signal; (ii) household has migrants who reside outside of Bolivia; and (iii) household has access to electricity. As noted above, because of irregular topography, areas with weak or no cellular phone signal are scattered. Since cellular phones are relatively new to the area, endogenous sorting of households into favorable locations has not taken place, and observations in the area showed that access to a cellular signal was random and not related to household or productivity-related variables. We stratified our survey based on access to a usable cellular phone signal. Analysis showed that we were successful in this randomization.[3]

The justification for the second instrument is as follows: as noted below, many households reported first purchasing cellular phones to maintain contact with migrating family members. While the presence of a migrant elsewhere in Bolivia might plausibly be related to market choice, it is difficult to argue that the existence of external migrants would have the same correlation. This presence is external to the market choice decision. Access to electricity (the third instrument) facilitates use of

[2] This adjustment involves computing the two-step variance as $\hat{V}_2 + \hat{V}_2(\hat{C}\hat{V}_1\hat{C}' - \hat{R}\hat{V}_1\hat{C} - \hat{C}\hat{V}_1\hat{R}')\hat{V}_2$, where $\hat{V}_1$ and $\hat{V}_2$are the estimated covariances for the first and second-stage model, respectively, and $\hat{C}$ and $\hat{R}$are defined on p. 522 in Hole (2006).

[3] As a check of randomness we conducted tests of differences of our independent variables between households with access to cellular signals and those without good access. For most variables, the differences were not significantly different between the two groups of households. Exceptions were age of head and number of people over 15 years old. Households without access to cellular signals were headed by someone slightly older (50 years vs. 46 years) and had more over 15-year-old members (3.7 compared to 3.0) than those with access to cellular signals.

Table 1
Variables used in quantitative models

| Variables | Description | Unit | Mean | SD |
|---|---|---|---|---|
| Market | Farmer market channel choice | % attending Tiraque | 44.9 | |
| | | % attending Punata | 14.1 | |
| | | % attending Cochabamba | 5.6 | |
| | | % attending Santa Cruz | 4.3 | |
| | | % attending more than one | 31.2 | |
| Age | Age of the head of the household | Years | 47.1 | 14.8 |
| Age2 | Age square | Years | 2440.2 | 1512.1 |
| Gender | Gender of the head of the household | 1 = head of household is female (%) | 0.1 | 0.4 |
| Literacy | Literacy of the head of the household | 1 = head of the household is literate (%) | 0.8 | 0.4 |
| Hsize15 | Number of members older than 15 | Number | 3.2 | 1.7 |
| Hsize_15 | Number of members 15 or younger | Number | 2.4 | 2.0 |
| Qproduced | Potatoes produced in prior season | 1000 Kg | 6.9 | 7.0 |
| Nplots | Number of plots owned | Number | 5.2 | 2.4 |
| Tiraque* | Distance to Tiraque | Hours | 0.7 | 0.2 |
| Punata* | Distance Punata | Hours | 1.3 | 0.2 |
| Cbba* | Distance Cochabamba | Hours | 2.4 | 0.2 |
| StaCruz* | Distance Santa Cruz | Hours | 12.4 | 0.3 |
| Hpavedroad* | Distance from farm to nearest paved road | Hours | 0.5 | 0.9 |
| Cellphone | Ownership | 1 = household owns a cell phone (%) | 0.5 | 0.5 |
| Signal | Access to cell-phone signal | 1 = household has access from homestead to cellular signal (%) | 0.8 | 0.4 |
| Extmigrant | Household has migrants outside the country | 1 = household has members outside Bolivia (%) | 0.3 | 0.5 |
| Electricity | Access to electricity | 1 = household has electricity access (%) | 0.7 | 0.5 |

*Source:* Household survey 2007.
*Variable was computed using GIS techniques.

modern ICT, but is not expected to be related to market choice except through such facilitation. We use the same set of instruments in the bivariate probit and MNL estimation; we apply tests of the validity of these instruments under the assumption that the model is at least identified—that is, the first exclusion restriction is valid. These tests are described below.

### 2.2. Qualitative methods

In addition to the quantitative analysis, a rapid market appraisal (RMA) and individual case studies were used to interpret the findings and understand the relationship between cellular phone ownership, use of information networks to obtain information, and gender responsibilities in potato marketing. The RMA was based on methods developed by Holtzman (2003), and relied on semi-structured interviews conducted during February–July 2008 with key informants at different stages of the potato value chain. Four types of interviews, differentiated by actor, were used. A total of 25 key informants were interviewed, including farmers, wholesalers, retailers, and indirect actors (NGOs, local governments and extension agents). The RMA identifies functions at each point in the chain, price information, market constraints and opportunities, and the roles that cellular phones and gender play within the chain.

Case studies of six potato-producing households were conducted in April–July 2008; three households had access to a strong cellular phone signal and three did not (Table 2). This method included semi-structured interviews, direct observation and participatory tools (Yin, 2003). Interviews focused on the dynamics of marketing decisions, access to information, and gender roles in the marketing process. The RMA and case study interviews were retrospective; respondents were asked about current decision making and to reflect on how conditions had recently changed.

## 3. Results

### 3.1. The quantitative evidence: decisions about market choice

We use two estimation strategies to address the question of role of cellular phones in: (i) participation in urban markets, and (ii) overall market choice. Independent variables include size of the household (number of people 15 years old and above, and number under 15), and age, gender and literacy of the household head. Production variables—quantity produced and number of plots—were included to reflect possible economies of scale in transport and farmer wealth as wealthier farmers tend to have more land and, hence, plots under cultivation[4]. Travel time distance from the homestead to each market is measured using an ARC-GIS algorithm based on topography and the grade of the road; this variable is normalized by time to the Tiraque market. GIS-calculated time to the nearest paved road is also included.

[4] Bolivian farmers are averse to providing information about their land holding sizes and when the research team conducted random tests of areas reported compared to measured are, we discovered only weak correlation. The number of plots roughly reflects holding sizes and proxies wealth.

Table 2
Summary statistics of case study families

| Variable description | CS-1 | CS-2 | CS-3 | CS-4 | CS-5 | CS-6 |
|---|---|---|---|---|---|---|
| Families | Isidoro Zapata<br>Aida Moreira | Leandro Orellana<br>Betty Flores | Oscar Duran<br>Sonia Morales | Sabino Camacho<br>Catarina Muriel | Joaquin Vallejos<br>Rosenda Alvarado | Panfilo Alvarado<br>Maria Rodriguez |
| Community | Toralapa baja | Damy rancho | Cebada jich'ana | Sankayani alto | Kayarani | Koari alto |
| Market(s) proffered by farmers | Tiraque | Tiraque, Punata | Santa Cruz, Cbba | Tiraque | Tiraque, Punata. farm-gate | Tiraque, Punata, Santa Cruz |
| Total potato quantity produced (kg) | 1,950 | 2,312 | 7,000 | 8,700 | 1,500 | 5,232 |
| No. of family members | 6 | 5 | 6 | 7 | 5 | 11 |
| No. of plots owned | 3 | 2 | 3 | 3 | 3 | 8 |
| Farm size (has) | 0.25 | 0.22 | 1.50 | 1.05 | 0.30 | 4.41 |
| Distance to Tiraque (hours) | 0.18 | 0.70 | 0.65 | 1.04 | 0.85 | 0.96 |
| Distance to Punata (hours) | 0.93 | 1.32 | 1.29 | 1.62 | 1.52 | 1.59 |
| Distance to Cochabamba (hours) | 1.90 | 2.46 | 2.35 | 2.46 | 2.84 | 2.99 |
| Distance to Santa Cruz (hours) | 12.78 | 12.33 | 12.44 | 12.44 | 11.93 | 12.20 |
| Distance from the farm to nearest paved road (hours) | 0.03 | 0.04 | 0.05 | 0.10 | - | 0.22 |
| Age | 28 | 26 | 28 | 43 | 65 | 51 |
| Literacy | Yes | Yes | Yes | Yes | No | Yes |
| Access to loan | Yes | No | Yes | No | No | No |
| Cell phone ownership | Yes | Yes | No | Yes | Yes | No |
| Transport ownership | Yes | No | No | No | No | No |

*Source:* Case study interviews, April–July, 2008.

### *3.2. The probability of selling in an urban market: bivariate probit results*

The probability of attending an urban market with endogenous cellular phone ownership (Eqs. 3.1 and 3.2) is estimated as a bivariate probit as suggested by Green (2003). Instruments for identification of the cellular phone ownership effect are cellsignal, extmigrant and electricity; we tested the appropriateness of the model using a Hausmann-like test[5] and rejected the efficient (restricted) model ($P > 0.0054$). We tested our overidentifying restrictions (extmigrant and electricity) and failed to reject their exclusion from the second-stage regression using a likelihood ratio test ($P > 0.9646$). These tests suggest that the bivariate probit results in Table 3 with three instrumental variables are appropriate. Marginal effects of impacts of independent variables on the probability of choosing an urban market were decomposed using Green's (2003) methods.

Although many variables in the bivariate probit are not efficiently estimated, those that are have expected signs. For example, wealth, whether measured by quantity of potato produced or number of plots, is positively associated with ownership of cellular phones. Controlling for wealth, family demographics such as literacy and household size do not affect ownership. Our three instruments (signal, extmigrant, electricity) are positively and strongly related to cellular phone ownership, and, through this impact, have indirect positive impacts on the choice of an urban market.

Turning to the equation of interest, choice of marketing in urban markets depends primarily on household location factors and ownership of a cellular phone (and, indirectly, on other variables affecting cellular phone ownership). Longer distances to both urban markets (cbba and scruz) lower the probability that the household sells in urban markets. Access to cellular phone signals and electricity increase the probability of selecting an urban market by 9 and 6 percentage points, respectively.[6] Location in these favored areas increases access to information and lowers costs of attaining market information by allowing households to purchase cellular phones. This purchase helps lower the risks associated in marketing in urban areas.

Household ownership of a cellular phone, controlling for its endogeneity and other factors, increases the likelihood of marketing potatoes in urban areas by about 47 percentage points. The variable is strongly significant, and our tests, along with the significance of the rho statistic in Table 3, indicate that controlling for endogeneity is important. The significance of this variable allows us to examine indirect effects.

Although the wealth variables do not directly affect the choice of markets, wealthier producers are more likely to own cellular phones and, through this indirect effect, their total effect on the probability of selling in an urban market is positive but quantitatively rather small. This is further evidence that access to information limits the ability of highland producers to market

[5] Using the suest family of procedures in STATA and comparing the fully efficient univariate probit (cellphone not treated as endogenous) with the bivariate probit results.

[6] These results are seen in the bottom-half of Table 3.

Table 3
Recursive Bivariate Probit model of cell-phone ownership and attendance at urban market. Dependent variables = 1 if household attends urban market; = 1 if household owns cell-phone

| | Coef. | Std. Err. | $z$ | $P > z$ | Marginal effects | | |
|---|---|---|---|---|---|---|---|
| | | | | | Direct | Indirect | Total |
| Urbmarket | | | | | | | |
| Age | −0.012 | 0.011 | −1.08 | 0.28 | −0.004 | 0.000 | −0.004 |
| Age2 | −0.001 | 0.001 | −1.05 | 0.294 | 0.000 | 0.000 | 0.000 |
| Gender | −0.205 | 0.440 | −0.47 | 0.641 | −0.063 | −0.004 | −0.067 |
| Literacy | 0.055 | 0.436 | 0.13 | 0.9 | 0.017 | 0.008 | 0.025 |
| Hsize15 | −0.047 | 0.074 | −0.64 | 0.522 | −0.014 | 0.004 | −0.010 |
| Hsize_15 | −0.014 | 0.054 | −0.25 | 0.803 | −0.004 | 0.000 | −0.004 |
| Qproduced | 0.001 | 0.002 | −0.08 | 0.937 | 0.000 | 0.002 | 0.002 |
| Nplots | −0.005 | 0.049 | −0.11 | 0.912 | −0.002 | 0.006 | 0.004 |
| Punata | 0.030 | 0.952 | 0.03 | 0.975 | 0.009 | | 0.009 |
| Cbba | 3.469 | 0.992 | 3.5 | 0 | 1.056 | | 1.056 |
| Scruz | −0.470 | 0.123 | −3.83 | 0 | −0.143 | | −0.143 |
| Hpavedroad | −1.891 | 2.896 | −0.65 | 0.514 | −0.575 | | −0.575 |
| Cellphone | 1.665 | 0.359 | 4.63 | 0 | | | 0.473 |
| Intercept | −5.903 | 1.660 | −3.56 | 0 | | | |
| Cellphone | | | | | | | |
| Age | −0.003 | 0.007 | −0.46 | 0.647 | | | |
| Age2 | −0.001 | 0.000 | −1.34 | 0.181 | | | |
| Gender | −0.050 | 0.274 | −0.18 | 0.856 | | | |
| Literacy | 0.103 | 0.287 | 0.36 | 0.719 | | | |
| Hsize15 | 0.050 | 0.056 | 0.89 | 0.372 | | | |
| Hsize_15 | 0.005 | 0.045 | 0.12 | 0.908 | | | |
| Qproduced | 0.025 | 0.015 | 1.71 | 0.088 | | | |
| Nplots | 0.076 | 0.040 | 1.88 | 0.061 | | | |
| Signal | 1.168 | 0.215 | 5.43 | 0 | | 0.094 | 0.094 |
| Extmigrant | 0.560 | 0.195 | 2.86 | 0.004 | | 0.045 | 0.045 |
| Electricity | 0.733 | 0.174 | 4.21 | 0 | | 0.059 | 0.059 |
| Intercept | −2.280 | 0.488 | −4.67 | 0 | | | |
| /athrho | −0.900 | 0.447 | −2.02 | 0.044 | | | |
| rho | −0.717 | 0.217 | | | | | |

*Note:* Marginal effects represent the marginal impact of the independent variable on the probability of attending an urban market. They were computed as follows: Define $A = \alpha'Z$ (Eq. 3.2); $B0 = \beta'X$; $B1 = \beta'X+\gamma$ (Eq. 3.1); $A^*0 = (A - \rho B0)/(1 - \rho 2)^{1/2}$; $A^*1 = (A - \rho B1)/((1 - \rho 2)^{1/2}$; $B^*0 = (B0 - \rho A)/((1 - \rho 2)^{1/2}$; $B^*1 = (B1 - \rho A)/((1 - \rho 2)^{1/2}$. Then for any continuous variable $z$, $\partial E(Y|C)/\partial z = [\varphi(B1)\ \Phi(A^*1) + \varphi(B0)\ \Phi(-A^*0)]^*\ \beta_z + = [\varphi(A)\ \Phi(B^*1) + \varphi(-A)\ \Phi(B^*0)]^*\ \alpha_z$. The first part of the equation is the "direct" effect and the second is the "indirect" effect. The marginal effect of the endogenous binary variable ($C$) is $= \Phi(B1) - \Phi(B0)$. Marginal effects were evaluated at variable means.

their potatoes in urban markets; as noted above, increased production should lower the per-unit cost of transport and make it easier to market over long distances. Based on second stage results (qproduced and nplots were not significant), this transport cost reduction is less important than the indirect cellular phone ownership cum information access factors.

### *3.3. Determinants of market choice: MNL 2-stage estimates*

We broadened the investigation by estimating a multinomial logit model with five potential (and mutually exclusive) outcomes: marketing in any one of our four markets or marketing in multiple markets (option 5). We used similar regressors as in the bivariate probit. We began by testing the independence of irrelevant alternatives assumption of MNL using a Hausman test. We failed to reject the assumption that the coefficients differed consistently as we deleted different categories of the response variable. We tested the 2SPS and 2SRI models and rejected the former in favor of the latter; this rejection is consistent with the literature, which finds 2SPS to be inconsistent in nonlinear models (Terza et al., 2008). The high significance of the probit residuals in the 2SRI MNL regression reflects the endogeneity of cellular phone ownership. We present the 2SRI, with Murphy-Topel adjusted standard errors in Table 4; first-stage probit results are presented in Table 5. Since MNL results are notoriously difficult to interpret, we present marginal effects (columns MFX in the table)—calculated at variable means; these are interpreted as the marginal impact of a change in the independent variable on the probability of choosing each market (Punata, Cochabamba, Santa Cruz, and multiple).

Cellular phone ownership has a significant and positive impact on the probability of choosing every market, except Tiraque. The strongest effects of cellular phone ownership are on the probability of marketing in Cochabamba and in multiple markets (marginal effects of 20% in both cases). Cellular phone ownership also increases the probability of attending the most

Table 4
Results of the market choice model

| Variable | Coef. | Std. Err. | $z$ | $P > z$ | MFX | Coef. | Std. Err. | $z$ | $P > z$ | MFX |
|---|---|---|---|---|---|---|---|---|---|---|
| | Punata market | | | | | Santa Cruz | | | | |
| Age | 0.021 | 0.017 | 1.24 | 0.213 | 0.002 | −0.052 | 0.053 | −0.97 | 0.332 | −0.002 |
| Age2 | 0.001 | 0.001 | 1.04 | 0.3 | 0.000 | −0.001 | 0.003 | −0.26 | 0.791 | 0.000 |
| Gender | −0.824 | 0.776 | −1.06 | 0.288 | −0.047 | −12.086 | 618.076 | −0.02 | 0.984 | −0.439 |
| Literacy | 0.632 | 0.832 | 0.76 | 0.447 | 0.012 | 12.152 | 515.639 | 0.02 | 0.981 | 0.436 |
| Hsize15 | −0.201 | 0.149 | −1.35 | 0.178 | −0.023 | 0.086 | 0.269 | 0.32 | 0.748 | 0.004 |
| Qproduced | 0.000 | 0.000 | −1.83 | 0.068 | −0.012 | 0.000 | 0.000 | 0.24 | 0.808 | 0.001 |
| Nplots | −0.001 | 0.114 | −0.01 | 0.991 | −0.008 | 0.196 | 0.165 | 1.19 | 0.233 | 0.004 |
| Hpavedroad | −0.786 | 0.874 | −0.9 | 0.368 | −0.012 | −0.346 | 0.714 | −0.49 | 0.628 | 0.018 |
| Punata | 1.396 | 2.033 | 0.69 | 0.492 | 0.249 | −3.661 | 3.529 | −1.04 | 0.299 | −0.104 |
| Cbba | −2.940 | −1.413 | −2.08 | 0.037 | −0.044 | −7.216 | −3.154 | −2.29 | −0.022 | −0.153 |
| Scruz | −0.571 | 0.199 | −2.87 | 0.004 | −0.028 | −0.782 | 0.390 | −2 | 0.045 | −0.014 |
| Cellphone | 2.727 | 1.317 | 2.07 | 0.038 | 0.118 | 4.569 | 2.288 | 2 | 0.046 | 0.089 |
| Ecell | 2.373 | 1.336 | 1.78 | 0.076 | 0.110 | 2.006 | 2.232 | 0.9 | 0.369 | 0.005 |
| Intercept | −4.548 | 2.586 | −1.76 | 0.079 | | −23.617 | 515.658 | −0.05 | 0.963 | |
| | Cochabamba | | | | | Multiple Markets | | | | |
| Age | −0.003 | 0.034 | −0.09 | 0.932 | 0.000 | 0.008 | 0.015 | 0.54 | 0.592 | 0.002 |
| Age2 | −0.002 | 0.002 | −0.73 | 0.466 | 0.000 | 0.001 | 0.001 | 1.41 | 0.159 | 0.000 |
| Gender | −0.195 | 1.316 | −0.15 | 0.882 | 0.032 | 0.209 | 0.566 | 0.37 | 0.712 | 0.284 |
| Literacy | 0.071 | 1.376 | 0.05 | 0.959 | −0.042 | 0.168 | 0.655 | 0.26 | 0.797 | −0.205 |
| Hsize15 | −0.186 | 0.230 | −0.81 | 0.419 | −0.008 | 0.057 | 0.123 | 0.46 | 0.644 | 0.020 |
| Qproduced | 0.000 | 0.000 | −0.75 | 0.451 | −0.002 | 0.000 | 0.000 | 0.52 | 0.602 | 0.007 |
| Nplots | 0.074 | 0.186 | 0.4 | 0.692 | 0.000 | 0.148 | 0.084 | 1.77 | 0.077 | 0.023 |
| Hpavedroad | −4.877 | 2.634 | −1.85 | 0.064 | −0.202 | −0.708 | 0.402 | −1.76 | 0.078 | −0.011 |
| Punata | 0.253 | 3.967 | 0.06 | 0.949 | 0.046 | −2.073 | 1.604 | −1.29 | 0.196 | −0.384 |
| Cbba | −12.075 | −3.760 | −3.21 | 0.001 | −0.440 | −3.502 | −1.177 | −2.97 | 0.003 | −0.206 |
| Scruz | −1.691 | 0.465 | −3.64 | 0 | −0.062 | −0.420 | 0.157 | −2.67 | 0.008 | −0.013 |
| Cellphone | 6.331 | 2.047 | 3.09 | 0.002 | 0.203 | 2.680 | 1.046 | 2.56 | 0.01 | 0.206 |
| Ecell | 5.631 | 2.033 | 2.77 | 0.006 | 0.188 | 2.343 | 1.078 | 2.17 | 0.03 | 0.213 |
| Intercept | −17.924 | 5.854 | −3.06 | 0.002 | | −3.795 | 2.030 | −1.87 | 0.062 | |

*Note:* Standard errors corrected using Murphy–Topel correction. Ecell is the predicted error from the first-stage probit (table 5). Marginal effects are computed at variable means; these are interpreted as the marginal effect of an increase in the independent variable on probability of choosing each market outcome. Results from Tiraque market are suppressed for space reasons.

distant market—Santa Cruz—by about 9%. Urban markets offer generally higher prices than the rural markets (see below) but prices change frequently (particularly in Cochabamba, where participants note rapidly fluctuating prices); as noted below, ownership of a cellular phone reduces uncertainty associated with marketing in distant and multiple markets. Ownership of a cellular phone has a strong negative impact on marketing in the nearest and most widely attended market—the Tiraque potato market. The probability of marketing potatoes in Tiraque alone is nearly 62% lower for households owning a cellular telephone, all else held constant. Cellular phones enhance marketing flexibility and broaden market choices.

The only other variables consistently affecting the probability of choosing potato markets are related to household location. Increased distance from a paved road is associated with a large reduction in the likelihood of marketing in Cochabamba and a weaker negative effect on marketing in multiple markets. Households living farther from Cochabamba and Santa Cruz compared to Tiraque have lower probabilities of attending all markets, except the Tiraque market, where the effect is strongly positive (marginal effects of 0.843 and 0.117, respectively). Market choice probabilities are more sensitive to relative distance from Cochabamba, and this increased sensitivity is logical. Variations in distance to Cochabamba are more pronounced in the study area compared to relative variations in the distance to Santa Cruz. While distance helps determine selection of the latter market, it is relatively less important than other factors.

Our instrumental variables have indirect impacts on market choice based on their impact on cellular phone ownership; the first-stage probit results are shown in Table 5 (a positive marginal effect in this stage is associated with a higher value of the error term in the second-stage MNL regression). The marginal effects of the error term (ecell) are positive and significant in the second-stage (except for the Tiraque market, where the marginal effect of ecell is negative, –0.516, and strongly significant), indicating that indirect effects of these instruments on potato market choice are positive. Household wealth, as measured by potato production and number of plots, also has small indirect effects; the variables are not significant in the second-

Table 5
First-stage estimates of probability of owning a cell-phone

| Dependent variable: household owns cell-phone = 1 | | | | |
|---|---|---|---|---|
| Cellphone | Coef. | Std. Err. | $z$ | MFX |
| Age | −0.004 | 0.007 | −0.57 | −0.001 |
| Age2 | −0.001 | 0.000 | −1.35 | 0.000 |
| Gender | 0.001 | 0.278 | 0 | 0.000 |
| Literacy | 0.184 | 0.292 | 0.63 | 0.055 |
| Hsize15 | 0.042 | 0.058 | 0.71 | 0.012 |
| Qproduced | 0.027 | 0.015 | 1.82 | 0.008 |
| Nplots | 0.071 | 0.041 | 1.73 | 0.021 |
| Punata | −0.197 | 0.622 | −0.32 | −0.059 |
| Cbba | −0.706 | −0.620 | −1.14 | −0.210 |
| Scruz | −0.063 | 0.075 | −0.84 | −0.019 |
| Signal | 1.132 | 0.268 | 4.23 | 0.337 |
| Extmigrant | 0.612 | 0.204 | 3 | 0.182 |
| Electricity | 0.749 | 0.185 | 4.04 | 0.223 |
| Intercept | −3.359 | 0.941 | −3.57 | |

stage regression, but do have very small positive effects on the probability of owning a cellular phone.

Household-level attributes such as age, literacy and gender of the household head do not significantly influence market choice. This finding is explained in two ways: (i) first, the populations in the area are relatively homogeneous and minor differences in family structure do not affect major decisions such as choice of potato markets, and (ii) marketing potatoes is a process that involves traditions and relationships—only significant changes in external conditions (such as new information technology) affect these marketing strategies.

In summary, ownership of cellular phones, and household location with respect to markets and other variables all affect potato sales location decisions. Wealth effects and economies of scale in transport are positively associated with cellular phone ownership and thus have an indirect effect on marketing, but these effects are statistically and economically weak. Once cellular phone ownership is controlled for, we find no substantial direct effect of these variables. Cellular phones enhance market access even for poor producers in remote Bolivia; they represent a wealth-neutral technology.

### *3.5. Qualitative findings: role of women and information networks*

Cellular phone ownership has a measurable impact on potato market choice, but the mechanisms by which ownership affects decision making and women's roles in these decisions needs further investigation. Our RMA and case studies are used to more fully understand the potato marketing process, to deepen understanding of women's roles, and to identify how ICT is affecting long-standing information networks in the area.

Our case studies show that household management is largely the women's responsibility, but most decisions are taken jointly. The entire family participates in agricultural activities. Men prepare the soil, and women share responsibilities for planting, weeding and harvesting. Potato marketing decisions are made by men and women together. Before going to market, the household determines a base price based on production costs and market information received from various sources. Farmers have different degrees of access to information about prices and markets, and they clearly state that this information affects marketing choices.

Case study and RMA respondents stated that in the past men acquired initial market information through discussions with neighbors, potato transporters, and truckers. Some used land-line telephones to acquire information from friends and their social networks in distant markets. Introduction of cellular phones into the region has affected information-gathering. The principal means of gathering market information is now through cellular phones, but men continue to control the information flow. Many respondents in the RMA and all cell-phone owners in the case studies claimed that cellular phones were initially purchased to maintain contact with migrating relatives. Women were often the catalyst behind these purchases. Families consider the cellular phone to be a jointly owned asset, and ownership is not gendered. But, despite apparent gender equity in use of cellular phones, men continue to monopolize their use to obtain market information. They communicate with long-standing contacts and subsequently transmit market information to their wives, and families jointly make marketing decisions. The cellular phone has not fundamentally changed gender roles: market decisions continue to be jointly made, and men continue to control access to market information.

The success of cellular phones as a market data gathering tool relies on the strength of farmer social networks. The cellular phone connection creates stronger links between already-existing network nodes and, according to our interviewees, has not fundamentally affected the size of the network. For example, respondents who recently began to sell in Santa Cruz said male family members used their cellular phones to contact ex-neighbors and relatives near that market—their social network was strengthened by these contacts, but nodes themselves did not change. In the past, obtaining up-to-date market information from these sources would have been difficult. Respondents in the case studies made it clear that they continue to avail of the same sources of information; and these sources are based on long-standing networks which have not changed since the introduction of cellular service.

Farmers and market participants state that potato marketing information gathering has improved since the appearance of cellular phones. Before the introduction of cellular phone technology, farmers stated that they arrived at markets with incomplete price information. Weak information left them in a poor bargaining position, particularly in urban markets where day-to-day price fluctuations are more pronounced. Some would travel to the markets to gather price data before transporting their products, but transport delays created significant risks. Despite the nonperishable nature of the product, farmers state that once they arrive at a market with their potatoes they are unwilling to return without making a sale. While the quality of

the potato is not affected by storage and transportation, just like a perishable product it must be sold quickly once it reaches the market. Market information is critical to profitability of small-scale producers, and faster-moving information has affected decision-making and market dynamics.

Market participants noted a subtle shift in negotiation practices since the advent of cellular phone services; farmers now arrive with more complete information about conditions in specific markets and appear less surprised and less aggressive during negotiations. Women's roles as negotiators have not changed, but market participants note fewer conflicts in recent years. Despite better information, the negotiation process in Tiraque-area potato markets is heated and women play a major role.

Men and women travel together to the market, but once in the market, women take over. Women negotiate sale prices and consummate sales. The RMA showed clearly that the markets are dominated by women. The marketing network is simple; products are delivered to intermediaries who re-sell some in the same market, transport to other markets to sell to wholesalers, or sell to restaurants or retail establishments.

Upon arrival in the market, women sellers perform an initial reconnaissance to verify prices. Before every sale we observed, the seller and buyer entered into heated negotiations, lasting between 30 minutes and two hours. Factors affecting the negotiation process are the origin of the potato, quality and variety, and gender and age of the seller. According to all interviewees, wholesalers (80% of whom are women) take advantage of the old, the young and of men. These negotiations can get heated, and males and female alike say that women are better negotiators. Men in the RMA and in the household case studies state that they "allow" their wives to negotiate because women have better negotiation and bargaining skills, and because most wholesalers are women. Men consider it undignified to argue with women. Virtually all the potato transactions we observed in all of the markets were between female buyers and sellers.

Bolivian potato markets continue to be controlled by women; recent changes in market destinations appear to have had no qualitative impact on conduct within specific markets. The presence of cellular phones has had an impact on marketing decisions, but has not fundamentally altered the structure of potato information networks or gender roles in decision making and potato marketing.

## 4. Conclusions

This study explored the effects of access to information and gender relations in the potato market chain on marketing decisions. The quantitative analysis showed that cellular phones are having a strong impact on potato marketing in the Tiraque region of Bolivia. Controlling for their endogeneity in marketing decisions, cellular phones induce households to market to more distant urban markets, where prices are higher, but risks are also higher. Increased distance to urban markets is associated with less likelihood of attending the most lucrative markets, but cellular phones are having an impact on market destination.

The qualitative analysis provided nuanced understanding of intra-household decision making and potato marketing processes and helped us understand how the technology affects gender and information gathering networks. Women continue to assume important roles in the marketing process, and, while access to cellular phones has expanded market choices, the roles of women remain strong. Families owning cellular phones have better access to market information, which affects their decision of where and how much to sell. Cellular phones allow farmers to conduct transactions over the phone, reduce risk, and make potato marketing more efficient. Higher-return markets are farther from the watershed and farmers attend them only when they believe it is worth the transactions cost. Uncertainty about these parameters has been reduced by the cellular phone technologies. Even farmers living in areas with weak signals buy phones and take advantage of improved market information; access to the cellular phone, not the quality of the signal, is the main determinant of the decision to market in Santa Cruz.

Sources of market information for potato sellers continue to be friends, relatives, and market intermediaries. The advent of the cellular phone has not fundamentally altered the sources of information used, but has strengthened links to distant nodes in long-standing information networks and speeded the flow of information through them. Cellular phone technology has lowered the cost of gathering market price data. Having this information before determining the market allows farmers to make more informed decisions. Access to cellular phones is particularly influential in making a decision to sell in the market that is viewed by most as the "best" potato market—Santa Cruz. Participation in this market is lower for female-headed households and the qualitative information shows that men are much more frequent participants in Santa Cruz.

An additional gender-related impact of cellular phone technologies may be sustained influence of men in marketing decisions. Men are responsible for using the phones to obtain market-related information. Men play an important role as information intermediaries or brokers. Because of the speed with which information travels through ICT networks, male control of information may grow over time. Ultimately, however, the price received is mainly determined by female negotiating skills, especially outside of Santa Cruz. Potato marketing decisions are made jointly by men and women; decisions about where and when to market are made by men and women together. Once the product arrives at the market, the woman takes over.

To make farmers more competitive in the potato market, access to information still needs to be improved. One method of achieving this goal could be through expansion of cellular phone access. NGOs and others working in highland areas should recognize the critical role of efficient marketing and how cellular phones improve access to markets even for remote producers. Access could be enhanced by promoting markets for used phones and identifying cellular "hot spots" in isolated

areas. Furthermore, farmer groups could be organized to collect market information from their various markets and spread information through text messaging or automatic dialing.

## Acknowledgments

The authors thank two anonymous reviewers and Editor Gerald Shively for helpful suggestions. We are also thank Wen You, Bradford F. Mills, George W. Norton, and participants at seminars at Virginia Tech, Penn State University and PROINPA (Bolivia) for comments, advice, and discussions. Funding for this research was provided by the SANREM CRSP, and was made possible by the United States Agency for International Development and the generous support of the American people through USAID Cooperative Agreement No. EPP-A-00-04-00013-00.

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