

**Adoption of Modern Agricultural Technologies
by Lowland Amerindians in Bolivia:
The Role of Households, Villages, Ethnicity, and Markets**

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Abstract

A survey of 102 Mojeño and 62 Yuracaré Amerindian households of the department of Beni in the Bolivian rain forest was done to measure the effects of household and village attributes, ethnicity, and markets on the adoption of chemical herbicides and pesticides for farming. We hypothesized that: i) village attributes would matter more among households with weak links to the market, ii) that the determinants of adoption among Amerindian households integrated to the market would resemble the determinants of adoption among smallholders who already form part of well-established markets, and iii) that ethnic membership would not matter because, as a null hypothesis, we assume all cultures are equally adept at processing information about technological innovations. The results of a probit model with Huber robust standard errors confirmed only the first hypothesis. Village variables overhadowed household variables among households with weak links to the market. Conventional determinants of adoption such as education, wealth, and income did not drive adoption among Amerindians well integrated to the market, as they do among smallholders. Lastly, membership in the Mojeño ethnic group seems to deter adoption owing, perhaps, to their participation in messianic movements.

Key words: Bolivia, education, rain forest, adoption, chemicals, Mojeño, Yuracaré, ethnicity, technological innovation.

**Adoption of Modern Agricultural Technologies
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Introduction. Researchers have studied the adoption of new farm technologies because new technologies raise the income of smallholders (Ruttan 1977; Barham *et al.* 1995), produce broad and equitable benefits to society (Lipton and Longhurst 1989; De Franco and Godoy 1993), and may lower pressure on renewable natural resources (Bedoya 1995: 225-227; Southgate and Clark 1993; Southgate and Whitaker 1992; Southgate 1991; Moran 1993; Ledec and Goodland 1988; Hecht 1993; Almeida and Campari 1994). So far researchers have chiefly studied adoption by smallholders in developing nations or by farmers in industrial nations rather than by tribal or by other rural populations with few links to the market, such as lowland Amerindians (Feder, Just, and Zilberman 1985).

The study of adoption of new farm technologies among lowland Amerindians merits attention for at least two reasons. First, lowland Amerindians in the early stages of integration to the market probably behave differently than smallholders who form part of well established market economies. When faced with the same economic incentives Amerindians may respond differently than smallholders. A study of the determinants of adoption in populations undergoing acculturation could help measure the changing weight of human capital, village institutions, ethnicity, and markets in the decision to adopt new technologies and so contribute to the debate about economic and non-economic determinants of behavior as indigenous people modernize. Second, the topic deserves attention because lowland Amerindians are becoming the chief stewards of their forests (Poffenberger 1990). In the lowland humid forests of Latin America, village councils and households (more so than outsiders) are deciding more and more how land, minerals, and timber should be used (Conklin and Graham 1995; Greenbaum 1989; Dodds 1993; CEDI 1990, 1993; Vidal 1989; Turner 1995). Understanding how villages, markets, and culture help or hinder households to adopt innovations in agriculture could inform policy-makers about how best to improve farm productivity and lower pressure on the forest.

The neglect of villages and ethnicity in studies of adoption of farm technologies. Quantitative studies on the adoption of farm technologies have sidestepped the role of ethnicity and villages. Since Griliche's (1956) landmark study, researchers of adoption who use historical information have focused on the role of economic variables (principally prices) in the diffusion of new technologies. Researchers who use cross sectional information have studied attributes of the person (eg, education) or of the household (eg, wealth, social status). Scholars have recently

started using panel information to study the role of village neighbors in learning about and adopting new farm technologies (Munshi 1995; Foster and Rosenzweig 1994). We draw on the spirit of these three lines of thinking and stress the demand side of adoption.

The paucity of information on ethnicity and villages in quantitative studies of diffusion stems from several causes. First, the analytic machinery of microeconomics is largely silent on how villages or ethnicity may hinder or help adoption, though it has much to say about how attributes of the person or of the household shape adoption. Since village variables often correlate with household and with personal attributes, researchers routinely acknowledge the importance of including village variables to control for endogenous variation in explanatory variables and to avoid producing bias estimates of parameters, but this sensitivity seems largely confined to village studies of health rather than to village studies of agricultural adoption (Alderman and Garcia 1994: 503; Duraisamy 1992; Tansel 1993; Rosenzweig and Wolpin 1988; Strauss 1990). In the best of cases villages seem to enter the analysis of adoption as dummy variables, ethnicity as a residual. Second, researchers may have left out village attributes and ethnicity because the variables were not too amenable to intervention by policy. Third, researchers may have been sensitive to village attributes and to ethnicity while in the field but may have dropped them from the analysis or from the publish results because the variables were difficult to define (Klitgaard 1992) or were insignificant in the results. Lastly, ethnicity and village attributes may have been unimportant among smallholders in developing nations and farmers in industrial nations, the subjects of standard research. In more traditional settings where village dynamics still hold sway, such as one finds with many tribal populations or with foragers who are becoming farmers, a household-based approach that leaves out village attributes and culture may only tell part of the story.

Adoption with socioeconomic heterogeneity: hypotheses. The study of adoption of new farm technologies among people who are not yet fully part of market economies must acknowledge diversity in culture, villages, and households. As Amerindian households become part of market economies, attributes of the household, of the village, and of the ethnic group may raise or lower the costs of getting information about new technologies or in getting the new technology and, in so doing, help or hinder adoption. For example, traditional redistributive mechanisms in the village may lower incentives to adopt if households perceive that the benefits of adoption will spill over to those who do not take risks. By interacting with attributes of people and of households, village and ethnic attributes can narrow or broaden the attractiveness of adopting new farm technologies. But the

weight of households, villages, and ethnicity in adoption will vary over the continuum of integration to the market. Below we advance three hypotheses about what we expect to find with adoption as we move along an idealized autarky-to-market continuum.

Hypothesis one: village attributes matter more when there is little integration to the market. In the early stages of integration to the market, village attributes will overshadow household attributes in the decision to adopt. Bands and traditional villages with their norms of delayed reciprocity (Sahlins 1972) should allow households to overcome shortcomings in their personal endowments and help them to adopt or to do things which they may otherwise find difficult to do. For instance, illiteracy, a conventional deterrent to adoption, may not hinder adoption in traditional villages provided people have schooled brethren who can help them to decode the new technology out of reciprocal kin obligations. The presence of only one privately-owned sprayer for chemicals in a village could predict adoption well if the owner of the sprayer is mortgaged to the have-nots by bonds of blood and affinal reciprocity. In the more advanced stages of integration to the market, as households become more separated from one another and as village institutions and networks of reciprocity weaken or break down (García Barrios and García Barrios 1990), households have to fend more on their own; we would then expect household and personal attributes to overshadow village attributes in adoption.

Hypothesis two: the determinants of adoption among Amerindians integrated to the market should resemble the determinants of adoption among smallholders. In the advanced stages of integration to the market we would expect lowland Amerindians to behave like smallholders. Conventional personal and household determinants, such as education, credit, income, and wealth should encourage adoption in the advanced stages of integration.

Hypothesis three: ethnicity does not matter in adoption. After controlling for personal and for household attributes, village fixed effects, and integration to the market, ethnic membership should not matter because, as a null hypothesis, we assume that all lowland Amerindian cultures are equally adept at receiving and processing information about technological innovations.

To test these hypotheses we did field work among lowland Amerindians in the rain forest of the department of Beni, Bolivia. Below we discuss the methods, model, variables, and the results of the study.

Methods. We did field research among the Yuracaré in the national park Isiboro-Sécure (mostly in river Sécure) and the Mojeños, both in the department of Beni. We chose these Amerindian groups because they contain large variance in explanatory variables, particularly in their degree of integration to the market. Shortage of time and money prevented us from studying more isolated but smaller lowland groups (eg, Chácobo, Pacahuara, Ese Ejja).

We studied the adoption of chemical herbicides and of pesticides because we found these technologies easier to identify and, therefore, they contain lower measurement errors than other technologies. We did not study the adoption of two other innovations -- improved plant varieties and mechanical dibbles -- because we had difficulty placing plant varieties into a modern or into a traditional category and because the use of mechanical dibbles reflects selected intervention by outside organizations. We found mechanical dibbles in villages where outsiders had introduced them on purpose to help villagers cope with the aftermath of the floods of 1992-1993.

Field work took place during ten weeks, from July to September, 1995. During that time we interviewed 102 Mojeño and 62 Yuracaré households in 13 villages. The indigenous government of each ethnic group helped us to pick three rain forest villages in their group along a continuum of integration to the market. For each village chosen, they helped us to select a replicate with the same degree of integration to the market. Thus, each ethnic group contained a total of at least six research sites straddling different amounts of involvement in the market. To avoid missing the tail of the acculturation distribution -- for instance, households that had moved to towns -- and so biasing the sample toward households with few links to the market, we also interviewed households that lived and worked in nearby towns but that kept a toehold in village life.

In each village we interviewed the village headmen and heads of households. From the headmen we collected statistics on village variables, such as wages, encroachers, number of stores, number of villagers studying outside, and presence of public institutions and non-government organizations.

From (mainly) male heads of households we collected information about each household. Before interviewing households the village headman called a meeting to explain our study to villagers. Interviewing only those who attended the meeting would have skewed the sample toward the more civic-minded villagers, toward the bilingual speakers, toward the ones with more free time, or toward non-migrants. To avoid the slant, we also interviewed as many households as we could, including households headed by women, households which did not attend the

meeting, or households which did not speak Spanish. We used bilingual speakers from the village to interview people who only spoke an Indian language. We interviewed between 31% and 86% of the households in each village.

The Mojeño and the Yuracaré compared. Though the Yuracaré of the river Sécore and the Mojeños display many socio-economic similarities, they also differ in history and in culture, which may help to explain some of the results discussed later.

The villages we studied lie along several parallel rivers, which drain the Eva-Eva Mosetene basin before discharging their waters into the river Mamoré. Except for a few villages which abut or include savanna, most of the villages studied lie in primary rain forest. Many settlements of the Mojeño face encroachment from loggers and from cattle ranchers (Thiele *et al.* 1995). Although both groups forage, they rely on swidden farming along river banks for the bulk of their subsistence and use wooden dibbles and metal tools to prepare their land (Alvarado 1996). The chief cash crops include rice, cassava, and fruits. Some villagers also sell firewood, logs, and thatch. During the past five years, but especially since the floods of 1992-1993, ranchers, loggers, missionaries, and non-government organizations have brought chemicals, chainsaws, mechanical dibbles, and new varieties of rice, maize, and pasture grasses (Lehm 1994). Mojeño and Yuracaré innovators are experimenting with the cultivation of beans, wheat, vegetables, and soybeans. Both groups buy or barter with outsiders for kerosene, clothing, salt, school supplies, medicines, lard, and metal tools. Besides selling crops, the Mojeño and the Yuracaré earn cash from wage labor during the dry season (May to November) in logging camps, in cattle ranches, and in towns.

But paralleling these similarities lie differences in history, economy, politics, and culture. The Mojeños number 17,180 people and the Yuracaré 1,186 to 2,079 people (Molina 1994; Muñoz 1995). The Mojeños have had centuries of contact with Catholic missions and with cattle ranchers (EPRM 1989: 82-83; Jones 1980, 1991, 1995). A longer history of contact explains in part why Mojeño villages have a denser population and more stores, more government offices, and more out-migrants. At present the Mojeños are largely bilingual and benefit from the agricultural extension, adult education, and credit offered by non-government organizations and also benefit from the proximity to the market of the town of San Ignacio de Moxos. In contrast to the history of the Yuracaré, the history of the Mojeños is peppered with messianic movements going back to the nineteenth century (Riester 1976; Lehm 1991). Three of the more isolated Mojeño villages we surveyed, Carmen del Aperecito, Mercedes del Cavitu, and San Salvador spawned out of a recent messianic

movement in search of a better way of life in a promised land stocked with cattle but without outsiders (Lehm 1991).

In contrast to the Mojeños, the Yuracaré have had fewer contacts with missionaries or with cattle ranchers in part, perhaps, because they have been more skillfull at avoiding them (Ribera 1983; Miller 1917; Paz Patiño 1991). When Mather (1922) canoed through the river Sécore about 75 years ago he found no Yuracaré (or any other) settlements along the river, which suggests that the presence of the Yuracaré in this refuge area may reflect encroachment by highlanders and by cattle ranchers (Ribera 1983). In recent years the Yuracaré have halted the advance of loggers, ranchers, and highlanders owing to their political leadership. Like the Mojeños, the Yuracaré of the river Sécore are mostly bilingual and (their more accessible villages at least) benefit from agricultural extension, adult education, and credit offered by non-government organizations. But unlike the territory of the Mojeños, access to the territory of the Yuracaré lies intentionally off limits to most of the rest of the world. The indigenous government of the national park Isiboro-Sécore has vetoed demands by the council of tillagers of remote Yuracaré villages to build feeder roads to logging camps or to the city of Cochabamba for fear of luring encroachers.

In Table 1 we compare information from the survey about Mojeño and Yuracaré households and villages. Mojeño households have lived significantly fewer years in their villages and have fewer adult women, but they have more wealth (proxied by the ownership of a radio), more agricultural and total income, more education, and have received more credit from outsiders than the Yuracaré. Mojeño villages are younger and larger and lie closer to towns and cities than Yuracaré villages. Mojeño villages also contain more chain saws, sprayers for chemicals, vehicles, outboard motors, and ham radios than Yuracaré villages. Although the Mojeños seem more modern than the Yuracaré, the two groups contain the same percentage of adopters (about 14%).

-- INSERT TABLE 1 ABOUT HERE --

The model. To test the hypotheses about the changing weight of household, village, and ethnic determinants on adoption as households become part of market economies we used a probit and a logit model; since the results of the analysis did not vary by the type of model used we only report the results of the probit model. As Feder and his associates point out (Feder et al. 1985), researchers should measure the decision to adopt and the intensity of adoption. We rely on a model with a discrete binary dependent variable -- the adoption of chemicals (herbicides or pesticides) -- because we had difficulty collecting reliable information on the quantity or on the value of chemicals used by households.

The probit model predicts the probability (P_i) that the i th household will adopt chemicals. The dependent variable, Y , is an indicator which takes the value of one if the household adopts chemicals, and it takes the value of zero if the household does not adopt chemicals. We express the model as:

$$[1]. \quad P_i = \Pr(Y_i=1) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\beta_0 + \sum_{k=1}^K \beta_k X_{ik}} e^{-t^2/2} dt$$

P_i is the probability (measured by the standardized normal cumulative distribution function) that the i th household will adopt chemicals given explanatory variables X_{ik} . β_0 and β_k are the coefficients we need to estimate and t is a standardized normal variable with a mean of zero and a variance of one.

We used the Cook-Weisberg test for heteroscedasticity and rejected the assumption of constant variance at less than the one percent level. To correct for heteroscedasticity we used the probit model with Huber robust standard errors.

The variables: definition. Table 2 contains a definition and a summary of the variables used in the model. We left out from the analysis information which, though relevant, seemed to contain large errors in measurement (eg, estimates of people's age or of residence duration in the village).

-- INSERT TABLE 2 ABOUT HERE --

Dependent variable: chemicals. We defined chemicals as a discrete, binary dummy variable which took the value of one if households adopted chemical pesticides or herbicides in 1994 and which took the value of zero if households did not adopt the inputs. To make easier the interpretation of results we equate the name of dummy variables with the value of one. For instance, chemicals=1 if a household used chemicals.

Explanatory variables. We group explanatory variables into three types: household, village, and ethnic.

Household. We included the following household variables: the number of adults or people over the age of ten, the maximum education of the male head of the household, and illness of the household head in 1994. Illness entered as a dummy variable, shock, if the household head had been unable to work in 1994 owing to illness. To measure wealth we asked about the ownership of a radio and cattle; we entered both variables as dummies. To measure income we asked about earnings outside the farm (ofarminc) and estimated total imputed agricultural income (impaginc) by multiplying the quantity of beans and of rice (the

two chief crops) harvested times the regional sales price for each of the crops. Our estimate of farm income underestimates true farm income because we did not have time to collect information on income from animals, foraging, or from other crops besides beans and rice. We did not find a suitable instrument to control for endogeneity when using income as an explanatory variable.

Village. For Mojeños we measured the distance by road from the village to the town of San Ignacio de Moxos; for Yuracaré we measured the distance by the river from the village to the city of Trinidad. Although we collected information on the travel time to reach villages we did not use the information in the analysis because travel time varies by season, by type of transport, and by whether or not travel is upriver or downriver. We computed the ratio of villagers to teachers, health workers, and villagers studying outside the village to measure the number of potential brokers villagers had at their disposal to get information about the outside world. The variable broker must be read with care because it measures the potential load of villagers for each broker, not the number of brokers per villager.

Ethnic. Ethnicity entered as a dummy, Mojeño. We did not split Mojeños into subgroups (eg, Ignaciano, Trinitario) because subgroups differ mainly in language rather than in agricultural practices.

Since rice is the chief cash crop in the area we used it to split the pooled sample into households that were and that were not integrated into the market.

Rationale for the choice of explanatory variables. Since boys and girls over the age of ten help to weed, we hypothesized that the number of people over the age of ten in a household would reduce the need to use chemicals. Research in Asia (Phillips 1994; Jamison and Lau 1982) shows that education beyond a threshold of about four years speeds the adoption of improved plant varieties, though the threshold seems higher in Latin America or for other technologies (Yifu Lin 1991; Hiebert 1974; Putler and Zilberman 1988; Batte et al. 1990; Bravo-Ureta and Evenson 1994). Illness of the head of the household has an ambiguous role on the adoption of chemicals. Illness could induce households to use chemicals to catch up but illness could also reduce the amount of cash to buy chemicals. Wealth, proxied by the ownership of cattle or of a radio, should make it easier to adopt because it makes households less averse to risk (Cancian 1979) and makes it easier for them to get credit. Proximity to urban centers should enhance adoption because it lowers the costs of inputs and raises the price of outputs, making adoption more profitable (Mann 1989; Brush et al. 1992). Information about new

technologies, obtained from village brokers or from the radio, should increase the probabilities of adoption (Feder et al. 1985:260-261; Feder et al. 1987; Munshi 1995: 33-34; Just et al. 1980; Feder and O'Mara 1981). Off-farm income and imputed agricultural income should make it easier for households to buy or to barter new technologies.

Descriptive information on the sample. The information in Table 2 suggests that the average household in the sample contains about three adults. Male heads of household have 2.4 years of schooling. In 1994 54% of the household heads never missed a day of work from illness. Half of the households owned radios, but only 12% owned cattle. Households earned 470 Bolivianos (Bol) from off-farm income; the value of the typical farm output reached Bs 533 (in 1995 one US dollar equaled 4.87 Bolivianos). Thirty nine percent of the households sold rice. The typical village was 128 kilometers from the nearest town. The ratio of villagers to teachers, health workers, and villagers studying outside was about 50 to one. All the variables contain large variance.

Table 3 contains a summary of the same variables split by adopters and by non-adopters within and across ethnic groups. Among Mojeños, adopters and non-adopters resemble each other in all of the explanatory variables of interest except in shocks, income, and in the likelihood of selling rice. Mojeño adopters have statistically significantly higher shocks and income (both off-farm and farm) and are more likely to sell rice than non-adopters. Among Yuracaré, adopting households are wealthier (proxied by the ownership of a radio or cattle) and are more likely to live closer to town and to sell rice than non-adopters; all the differences are statistically significant. As we shall see, the significance of many of these differences disappear or gain strength once we control for other variables.

-- INSERT TABLE 3 ABOUT HERE --

Results of probit model. In Tables 4-6 we present the results of the probit. Table 4 contains the results of the pooled sample with and without village variables. Tables 5 and 6 contain results split by ethnic group (Table 5) and by whether or not households sold rice (Table 6). We use Table 4 to test the importance of ethnicity (hypothesis three) and community variables (hypothesis one), Table 5 to compare the determinants of adoption between ethnic groups (hypothesis three), and Table 6 to discuss the effect of market integration on adoption (hypothesis two). To make easier the reading of results we report coefficients, robust standard errors, and the probability of adoption when explanatory variables take on their mean value. For instance, in Table 4 the probability of adopting chemicals in a model with community variables increase by 7.7% if the

household owns a radio. In discussing results we focus on variables significant at the 10% level and below.

-- INSERT TABLES 4-6 ABOUT HERE --

The determinants of adoption in the pooled sample. The results from the pooled sample suggests that shocks, the number of villagers per broker, and the ownership of a radio seem to induce or to help households to adopt, but distance to the market town and being a Mojeño seem to deter adoption.

Among household variables, radios, shocks, and ethnicity matter. The ownership of a radio and illness were positively associated with adoption. Radios proxy for wealth but they also have an independent, more direct effect on adoption because they allow households to get information about new technologies from local radio stations, which often transmit information about the use of chemicals. The positive link between the illness of the head of the household (shock) and adoption suggests that people may be using chemicals to meet shortfalls in the availability of labor in their household. Lastly, being a Mojeño deters adoption for reasons discussed later.

Each of the two village variables mattered on its own. Distance to market town curbs adoption; the farther away the village, the lower the probabilities of adoption. The number of villagers per broker was significant at the 1% level. The result is surprising; we would have expected that a higher ratio of villagers to brokers would have slowed adoption because of the greater load per broker.

We used a likelihood ratio test to see whether the model with both village variables, distance and brokers, explained the information better than the restricted model without village variables. The results of the likelihood ratio test shown in Table 4 suggests that the model with village variables provides a significantly better fit than the model without village variables at the 3.98% level of significance.

The determinants of adoption by ethnic group. The results of Table 5 suggest that several household and village variables shape adoption among Mojeños, but few variables seem to explain adoption among the Yuracaré.

Among Mojeños, shocks, imputed farm income, and the ratio of villagers to brokers all bear a statistically significant, positive relation to adoption, but distance deters adoption at a statistically significant level. Among the Yuracaré only cattle seems to help with adoption.

The determinants of adoption across different degrees of integration to the market. To examine the determinants of adoption within different levels of integration to the market we split the sample in two by whether or not they had sold rice.

Among households integrated to the market, shocks encourage adoption, but the number of adults in the household, village-to-city distance, and being a Mojeño all seemed to hinder adoption. Among more autarkic households, the number of adults in the household, the ratio of villagers to brokers, and the amount of off-farm income eased adoption, but distance to market town and being a Mojeño curbed adoption.

Discussion. We now turn to the three hypotheses outlined at the beginning of this article.

Hypothesis one: village attributes matter more when there is little integration to the market. The results shown in Table 6 lend partial support to this hypothesis. In the sub-sample of households with weaker links to the market both village attributes -- distance to market town and the ratio of villagers to brokers -- are statistically significant determinants of adoption. In the sub-sample of the population that sells rice, only village-to-town distance is significant. Village brokers seem to play a less negative or more positive role in adoption in modern communities; as households become part of market economies, villagers may have to rely more and more on vertical ties to get information about new technologies or to buy the new technologies. In more autarkic settings, villagers may have to rely more on horizontal ties and less on vertical brokers to gain access to the new technology.

Hypothesis two: the determinants of adoption among Amerindians integrated to the market should resemble the determinants of adoption among smallholders. The results shown in Table 6 do not confirm the hypothesis. We expected Amerindians integrated to the market to behave like smallholders who already form part of well established markets. Among Amerindian households taking part in the market for crops we expected conventional household variables -- human capital, income, wealth, and the like -- to play a prominent role in adoption. None of these types of variables were significant. Instead we found that demographic variables (eg, number of adults, shocks) and village-level variables mattered most.

Hypothesis three: ethnicity does not matter in adoption. Contrary to our expectations, the results shown in Table 4 and 6 suggest that being a Mojeño discourages adoption in the pooled sample and within different levels of integration to the market. The negative association between being a Mojeño and adoption is

surprising because Mojeños have had many centuries of contact with ranchers, farmers, and Jesuit and Franciscan missionaries.

We advance two explanations for the unexpected result. First, unlike other lowland groups in Bolivia, the Mojeños have had a long experience with messianic movements. During these episodes entire villages have given up all trappings of the modern world and migrated en masse farther into the forest in search of a promised land. Mojeño households have a statistically shorter residence duration in their villages than Yuracaré households (Table 1), which may reflect circumscription, vestigial participation in messianic movements, or both. The movement of Mojeños in search of a better way of life, game, and land, and the shedding of modern possessions (at least for some of them) may help to explain in part why ethnic membership matters. Second, the quality of extension services among Mojeños may differ from that of the Yuracaré; extension agents among the Mojeños may be more active in discouraging the use of chemicals in farming in favor of more natural forms of weed and pest control. We did not have the time to explore these issues.

Conclusions. The study contains several tentative lessons for scholars and for policy-makers.

Some attributes of the villages matter and are amenable to policy intervention. The model with disaggregated village attributes explains the information better than the model without village attributes. Although our information only allowed us to test two village attributes -- distance to market town and schooled brokers -- we suspect there may be other features of the village amenable to policy intervention, such as the maximum number of grades taught in the village school or the presence of sewers, latrines, and the like all of which, individually or jointly, could speed adoption through their effect on human capital. Future studies of adoption in Bolivia, and certainly among lowland Amerindians, should try to capture aspects of the village which are both subject to intervention by policy and likely to speed the adoption of judicious technologies. The ways by which village attributes hurt or hinder adoption still need more thought.

Policies to speed the adoption of new technologies must take culture into account. Culture seems to matter, though, as with villages, the paths by which culture affects adoption remain unclear. Policies to encourage adoption across ethnic groups will probably differ. For instance, among the Yuracaré some adoption seems to be driven by brokers and by herd size perhaps because cattle allows households to overcome credit constraints or to buy new technologies. It follows that improvements in the extension services offered to Yuracaré or in the herd size of the Yuracaré could enhance the adoption of innovations in farming.

But among Mojeños, these policies would curb rather than enhance adoption. Instead, among Mojeños the best ways to encourage adoption would seem to lie in policies to improve the value of farm output and transport.

The need for a theory of adoption. To guide future research on adoption researchers need to develop a coherent theory of adoption and of the acquisition of new knowledge. The theory and its empirical application must take culture, communities, and economics seriously and must not rest on ad hoc insights. As Marx taught long ago, in relatively autarkic communities people hunt, fish, forage, farm, and labor in many types of activities simultaneously; unlike modern or peasant economies, the net effect of a conventional economic variable on any one activity gets filtered by its effect on other activities. For example, formal education, an unadventurous predictor of adoption in peasant economies, consistently curbed adoption in the pooled sample, within ethnic groups, and within different strata of integration to the market. Research among the Tawahka Amerindians of Honduras echoes these findings (Godoy et al. 1996). Perhaps the strong incentive produced by formal education in indigenous rain forest economies to work outside the farm or to leave the forest induces households to neglect agriculture and to adopt less. Weaving human capital, economics, culture, and communities into a coherent theory of adoption remains a challenge.

Table 1
 Comparison of Mojeño and Yuracaré households and villages

<u>Household variables</u>	<u>no</u>	<u>Mojeño</u>		<u>Yuracaré</u>	
		<u>avg</u>	<u>sd</u>	<u>avg</u>	<u>sd</u>
Number	164	102		62	
% chemical adopters	161	14	.35	13	.34
Demography:					
Years in village	156	10	9.6	17	14***
Family size	164	5.8	2.5	5.7	2.6
Adult women	164	1.3	.80	1.6	1.0**
Adult men	164	1.7	1.1	1.8	1.0
Human capital:					
Education of male head	158	3.0	2.3	1.3	1.8***
Education of female head	156	2.2	2.1	1.1	1.7***
Days lost to illness by head	159	29	70	26	71
Income (Bol):					
Imputed from farm/a/	161	730	759	220	305***

Table 1
Comparison of Mojeño and Yuracaré households and villages

<u>Household variables</u>	<u>no</u>	<u>Mojeño</u>		<u>Yuracaré</u>	
		<u>avg</u>	<u>sd</u>	<u>avg</u>	<u>sd</u>
Income (Bol):					
Outside farm	153	428	1137	536	969
Total income	150	1170	1475	759	933**
Wealth:					
Heads cattle '94	164	.84	4.3	.54	1.6
Heads cattle '95	164	.73	3.6	.38	1.1
Radio (%)	164	56	49	38	49**
Integration to market:					
% of rice sold	123	22	26	17	24
% of maize sold	92	18	32	13	24
Credit from outside village (Bol)	162	108	421	32	134

Table 1
Comparison of Mojeño and Yuracaré households and villages

Village variables	Ethnic group	
	Mojeño	Yuracaré
Number	6	7
<u>Average value/village:</u>		
Age	17	20
Population	198	96
Distance (km) to city	86	192
Maximum grade taught in school	5	3
Technologies/village		
Chainsaws	1.8	0
Sprayer for chemicals	1.1	.42
Communication/village		
Vehicles	.16	0
Outboard motor	1.5	.85
Ham radio	1	.14
Villagers/broker	50	43

/a/ Rice and maize output in arrobas times local price, Bol 10/arroba for rice and Bs.5/arroba for maize. In 1985 one US dollar equaled 4.87 Bolivianos (Bol).
T tests for equality of means. Significance: *, **, and *** at \leq 10%, \leq 5%, or \leq 1%.

Table 2
Definition and summary of variables

<u>Variable</u>	<u>Definition</u>	<u>no</u>	<u>avg</u>	<u>sd</u>
<u>Dependent:</u>	Chemicals (D)/a/, pesticide or fertilizer	161	.14	.35
<u>Explanatory:</u>				
Adults	Household members more than 10 years old	164	3.2	1.6
Edmale	Maximum education of male household head	158	2.4	2.2
Shock (D)	Household head too ill to work	164	.46	.50
Radio (D)	Ownership of radio	164	.50	.50
Ofarminc	<u>Bolivianos</u> from work outside the farm 1994	153	470	1072
Impaginc	<u>Bolivianos</u> ; imputed maize and rice income	161	533	671
Cattle94 (D)	Household owned cattle in 1994	164	.12	.32
Vildist	Distance of village in km from nearest town	159	128	93
Brokers	Ratio of villagers to teachers, health workers and villagers studying outside	158	48	33
Mojeño (D)	Dummy for ethnic group	164	.62	.48

/a/ (D) = dummy. Name of dummy variable equals one.

Table 3
Average value of explanatory variables for adopting and non-adopting households

Variable	Ethnic group:		By ethnic group and adoption:					
	Mojeño	Yuracaré	Mojeño		Yuracaré		Pooled	
			adopt	non-adopt	adopt	non-adopt	adopt	non-adopt
Number	102	62	16	86	10	52	26	138
Chemicals	.14	.13	.14		.13		.14	
Adults	3.1	3.4	3.3	3.1	3.9	3.4	3.5	3.2
Edmale	3.0	1.3***	3.3	2.9	1.1	1.3	2.6	2.3
Shock	.51	.38*	.86	.45***	.3	.4	.65	.43**
Radio	.56	.33**	.68	.54	.7	.3**	.69	.46**
Cattle94	.11	.12	.12	.11	.5	.07***	.23	.10**
Ofarminc	428	536	925	347*	194	604	607	446
Impaginc	730	220	1024	673*	262	212	731	495*
Vildist	86.0	192.0***	59	91	146	201*	97	133*
Brokers	50	43	44	51	32	46	39	49

T tests for equality of means are for adopters and for non adopters in a group and for differences between ethnic groups. Significance: *, **, and *** at $\leq 10\%$, $\leq 5\%$, or $\leq 1\%$.

Table 4
 Probit for determinants of adoption of chemicals:pooled sample

Variable	Village variables:					
	with			without		
	coef	se/a/	df/dx	coef	se/a/	df/dx
Adults	.06	.08	.00	.07	.08	.01
Edmale	-.07	.08	-.00	-.05	.08	-.00
Shock	.85	.30	.12***	.78	.28	.13***
Radio	.55	.34	.07*	.62	.33	.11**
Ofarminc	.00	.00	.00	.00	.00	.00
Impaginc	.00	.00	.00	.00	.00	.00
Cattle94	.56	.37	.10	.74	.34	.17**
Vildist	-.01	.00	-.00***	na	na	na
Mojeño	-1.51	.46	-.27***	-.22	.30	-.03
Broker	.01	.00	.00***	na	na	na
_cons	-.91	.73		-2.2	.56	
Number		142			142	
Pseudo R ²		21			15	

Likelihood ratio test for constrained and unconstrained models:
 chi2(2)=6.45. Prob>chi2 = 3.98%. Significance: *, **, and ***
 at ≤ 10%, ≤5%, or ≤1%.

/a/ Huber robust standard errors.

Table 5
 Probit for determinants of adoption of chemicals by ethnic group

Variable	Ethnic group:					
	Mojeño			Yuracaré		
	coef	se/a/	df/dx	coef	se/a/	df/dx
Adults	.11	.11	.01	-.21	.22	-.01
Edmale	-.04	.11	-.00	-.17	.16	-.01
Shock	1.11	.45	.10***	.54	.57	.05
Radio	.41	.42	.03	.86	.71	.09
Ofarminc	.00	.00	.00	-.00	.00	-.00
Impaginc	.00	.00	.00	.00	.00	.00
Cattle94	-.16	.54	-.01	1.55	.69	.31**
Vildist	-.02	.01	-.00***	-.00	.00	-.00
Broker	.04	.01	.00***	-.00	.00	-.00
_cons	-2.98	.88		-.52	1.29	
Number		88			54	
Pseudo R ²		26			35	

Significance: *, **, and *** at $\leq 10\%$, $\leq 5\%$, or $\leq 1\%$.

/a/ Huber robust standard errors.

Table 6
 Probit determinants of adoption of chemicals by
 degree of integration to the market

Variable	Sale of rice:					
	yes			no		
	coef	se/a/	df/dx	coef	se/a/	df/dx
Adults	-.66	.30	-.06**	.27	.12	.00**
Edmale	-.06	.16	-.00	-.13	.17	-.00
Shock	1.44	.67	.17**	-.01	.44	-.00
Radio	.25	.56	.02	.90	.57	.02
Ofarminc	-.00	.00	-.00	.00	.00	.00*
Impaginc	.00	.00	.00	.00	.00	.00
Cattle94	.55	.65	.07	-.68	.76	-.00
Vildist	-.02	.00	-.00***	-.01	.00	-.00***
Mojeño	-6.38	1.95	-.99***	-1.55	.59	-.04***
Broker	.00	.00	.00	.03	.01	.00***
_cons	7.74	2.93		-2.39	1.10	
Number		58			84	
Pseudo R ²		49			37	

Significance: *, **, and *** at $\leq 10\%$, $\leq 5\%$, or $\leq 1\%$.
 /a/ Huber robust standard errors.

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