Hartwich, F., M. Monge Pérez, L. Ampuero Ramos and J.L Soto, 2007
Knowledge management for agricultural innovation:
Lessons from networking efforts in the Bolivian Agricultural Technology System.
Knowledge Management for Development Journal 3(2): 21-37
www.km4dev.org/journal

Knowledge management for agricultural innovation: lessons from networking efforts in the Bolivian Agricultural Technology System

Frank Hartwich, Mario Monge Pérez, Luis Ampuero Ramos and José Luis Soto

Many small farmers in Bolivia continue to depend on semi-subsistence farming systems characterized by insufficient use of improved local and advanced knowledge and technology, and low levels of productivity. This is despite the continuous efforts of research, extension and development programmes to promote the generation and use of new knowledge in agricultural production and value added. An often considered reason for this dilemma is obstacles in the communication and management of knowledge. Different empirical studies have shown that knowledge, in fact, cannot be easily generated in research organizations, and passed down to the extension services and development projects which diffuse it among farmers. In response, new ways of managing knowledge have emerged across developing countries, focusing on new dynamics such as participation, collaboration and joint learning between farmers and other agents contributing to the development and diffusion of knowledge beyond the traditional farmer-extension link.

Over the last five years, within the institutional setting of the Bolivian Agricultural Technology System *Sistema Boliviano de Tecnología Agropecuaria* (SIBTA), the Bolivian Government – with support from various donor agencies – has experimented with a new approach to diffuse technological innovations among small farmers propagating the concept of markets for local knowledge. SIBTA is a governing and funding mechanism to promote applied research and technology transfer for agricultural development. In this new approach, regional foundations for technological development have been formed and made responsible for allocating funds to applied innovation projects responding to demands articulated by farmers' groups. The foundations contract knowledge suppliers, such as research organizations and private knowledge consultants, to transfer knowledge to the farmers. Implicitly, this scheme promotes a form of knowledge management that reaches beyond the farmer-extension link, involving a third institution – the regional foundations – as promoters, analysts, financers and coordinators of knowledge exchange. The scheme has proved successful in terms of financial management and identification of demands for technology although there has been some criticism of the ability of the system to reach all farmers and whether it has sufficient impact on improved livelihoods.

In this paper, we present results of an analysis of the innovation behaviour of farmers based on two case studies related to knowledge management. In the first case, the regional foundations of SIBTA promoted innovation through a network of technology providers, farmers and private sector agents. In the second case, farmers received technical assistance services from technology providers based on the linear model of

technology transfer. The analysis of these two cases aims to ascertain how knowledge management modalities affect innovation among small farmers. It seeks to determine empirically if knowledge management schemes that involve multiple agents from the public and private sector, as well as from civil society, enhances positively farmers' attitudes towards innovation. The findings are thought to be of interest not only to the stakeholders in agricultural innovation in Bolivia but also to policy and decision makers who promote agricultural innovation among smallholders in other countries around the world.

Theoretical concepts and approaches to knowledge management for agricultural innovation

Knowledge management is concerned with ways of exchanging knowledge among those who can develop it and those who can use it. The lack of exchange of knowledge among and between farmers, and those who produce of farm-relevant knowledge, has often been regarded as the key issue in pro-poor agricultural development. For that reason, many agricultural extension and development programmes, run by both governments and international donor agencies, have focused on diffusing knowledge to farmers who, in turn, were expected to gain from applying this knowledge in their production practices.

Knowledge can be understood as both information and skills that are acquired through individual experience and trial and error, within an organization or a learning community, or from outsiders adapting it to local contexts. Knowledge that rural and farming communities are typically interested in includes cultural management practices; new agricultural technologies; diagnostic information about plant and animal disease and soil related problems; market information on inputs and sales (prices, seller, buyers, retailers); market demand and quality of products required for these markets; and land records and government policies. The concerted efforts and practices used by organizations and individuals to identify, create, accumulate, re-use, apply and distribute knowledge are commonly labelled knowledge management.

A key distinction in knowledge management is often made between explicit knowledge (that can be codified and articulated in formal language) and tacit knowledge (personal knowledge embedded in experience) (Polanyi 1966). Traditional corporate and development theory generally focus on developing and diffusing explicit knowledge. Knowledge management programmes, based on this approach, attempt to manage the process of information exchange between groups of specialists, companies, and research and development (R&D) organizations. However, during the last decade, a growing body of literature has emphasized the development of tacit knowledge and translation between the two different knowledge forms. The argument here is that a good part of knowledge cannot be simply transferred but needs to be anticipated by processes of experience and learning by doing. Hence, to promote new knowledge among farmers, one would need to nurture open access to people's extensive tacit knowledge and to enable learning and knowledge flow. Additional wisdom is brought into this discussion by considering the mechanisms traditionally used for transferring local, indigenous or ancestral knowledge which is neither

generated nor communicated through the international and national science and technology institutions but communicated among farmers, linking newer generations with their ancestors (Howes and Chambers 1980, Warren 1989).

Most knowledge management programmes have been studied in the corporate sector. The underlying motivations of such programmes therefore relate to ideas of the knowledge economy, organizational efficiency, structural and cultural change, learning organizations, and financial profit (Hovland 2003). Consequently, recommendations focus on organizational practices such as information technology, communities of practice, expert systems, intranets and other networking tools and communication technologies as well as investment in R&D and the building of partnerships between research institutes and companies (Liebowitz 1999).

Knowledge management in developing country agriculture, however, has a distinct connotation. For example, small farmers do not need to look for cutting edge technology. Rather, they need to get access to the often abundantly available knowledge that can improve their livelihoods. Extension and development agencies try to assist farmers to access this type of knowledge but they are often biased to a certain trajectory of development, e.g. new plant varieties or processing technologies, where they have comparative advantages and can leverage funding. Poor farmers, however, would not feel comfortable to absorb one type of knowledge promoted by a certain technology provider if they have not cross-checked its usefulness with other farmers, community members and authorities, other development agents and even with product buyers. The issue here is that farmers try to reduce risk by contacting multiple sources of information in order to trust in a certain type of technology.

First and second generation knowledge management

First-generation knowledge management, both in the corporate sector as in agricultural development, has emphasized a top-down and technological perspective where the main goal was getting the right technological information to the right people at the right time. Röling and van de Fliert (1994) found that most investments in agricultural research and extension were based on the assumption that agricultural science generates technology which extension experts transfer to users, ignoring local knowledge creation and sharing, as well as the relevance of articulating demands by farmers and promoting their self-confidence and empowerment.

During the last decades this approach has been repeatedly put in question (Chambers et al. 1989, Russel and Ison 2000, Leeuwis 2004) and more balanced approaches have become common where the focus is not only on the supply side but also on satisfying the demand for the production of new knowledge. Inkpen (1996) and Sveiby and Simons (2002) have shown that for the corporate business sector, relevant knowledge is created collectively, in groups, through mechanisms of networking and communication. For the agricultural sector Röling (1996) and Sumberg et al. (2003) have argued that for knowledge to be absorbed by the community of users, it needs to get applied, reworked, adjusted and improved. Today's second-generation knowledge management emphasizes collaboration in the management of knowledge.

However, second-generation knowledge management is not to be achieved by simple means. Thompson and Scoones (1994) argue that knowledge management cannot be improved by simple measures, such as by transferring power from the outside to the inside, from researchers to farmers, but only through complex social processes that do not necessarily follow systemic patterns. According to these authors, knowledge creation requires knowledge management practices capable of involving multiple agents, consistent with recent approaches to innovation1 based on the ideas of auto-organization of entrepreneurs (Miles et al 1997), social R&D networks (Sorenson et al. 2006) and complex adaptive systems (Kauffman 1995). In a complex adaptive system, individuals and organizations act and survive by adapting and learning to organize themselves into communities, providing the necessary ground for the creation and improvement of knowledge. Agents in such a system are free to act and learn independently or collectively. In other words, their collective behaviour is complex, not managed from above but emergent from the structure of the network of interactions in which they are embedded. Creativity and innovation increase with the diversity of the members in the system, and the levels of learning and adaptation increase with the density of communication within the system.

Strategies and development programmes that are in line with second generation knowledge management and newer innovation systems theory focus on measures that create learning spaces among multiple agents, including for example:

1. Instilling clear goals/strategies for the innovation initiatives to take place;
2. Analyzing the knowledge available from available sources and identification of best practices
3. Providing access to the creation and communication of tacit knowledge
4. Setting up and promoting the maintenance of linkages among a wide range of actors that dispose of relevant knowledge related to the topic of concern;
5. Providing tools that allow for the search of knowledge;
6. Promoting creativity and discourse; and
7. Manifesting and capturing new knowledge being learned.

Methodology

This study seeks to analyze how knowledge management influences the behaviour of farmers towards innovation. Based on the above theoretical deliberations regarding the role of knowledge management in the innovation process, the following two hypotheses were formulated:

1. Multiple-agent knowledge management that involves public and private sector organizations and civil society enhances the adoption of innovations among farmers; and
2. The embeddedness of farmers in social networks determines the extent to which they adopt innovations.

The study involved two types of analyses. First, qualitative data were collected on the institutional setting in four projects that fostered innovation among smallholders. The cases were picked from a wide range of applied innovation projects in the Bolivian agricultural sector. Emphasis was given to regional distribution and poverty orientation. The two sectors chosen were quinoa, a high altitude pseudo-cereal cultivated by a majority of semi-subsistence farmers in the Altiplano, and peanuts, cultivated by a substantial number of small and subsistence farmers in the drier parts of the valleys and lowland Chaco. In each of these sectors, a project of advanced multi-agent knowledge management and a project of more traditional, linear knowledge management were identified analyzing the participation of different types of agents, funding arrangements, and the extent of joint learning and impact of the innovation.

Second, quantitative data were collected within these four projects with regard to the individual behaviour of farm households towards innovation. Some 30 farmers directly associated with the innovation projects were randomly chosen from project rosters. These farmers were interviewed with regard to the extent to which they adopted the innovations promoted under a certain knowledge management scheme. Data on a number of socio-demographic variables which could possibly lead farmers to adopt a specific innovation were also collected (see Table 1). Information at the farmers' level was complemented by interviews with other knowledge agents, including technical assistance agents, funding agents, local government officials, transportation service providers and middlemen, buyers, processors, exporters, agricultural input providers (seeds, fertilizers and pesticides), and private credit agents. Individuals interviewed from each of these sectors were not sampled as the aim was to interview all existing agents of the social network that directly or indirectly promotes technology and knowledge sharing in the fields of peanuts and quinoa production, processing and marketing.

Based on this information, a variable was estimated to depict the farmer's connectedness, assuming that better connected farmers would have higher levels of adoption. This involved the construction of an affiliation (or two-mode) network describing the relations between farmers (as 'innovators', or mode 1) and other knowledge and technology providers (as 'innovation promoters', or mode 2). From this network, a distinct measure was derived that indicates the farmers' 'embeddedness' in the network, that is, the ratio of actual to possible relations in the network, also known as degree centrality. This embeddedness can be interpreted either as a result of a farmer's networking efforts (active) or as a given structural constraint determined by the web of interactions among actors (passive). In either case, the connectedness variable provides insights on how interaction influences the uptake of innovations.

The quantitative data collected allowed running a multivariate regression analysis using a Tobit model that explains the average degree of adoption across the diverse components of each of the innovation packages considered, according to a set of independent variables. Tobits are censored normal regression models which are able to deal with the type of dependent variable generated in the study (ranging from 0 to 100% and censored to the left as the sample population consists of both adopters and

non-adopters); they have been frequently used in studies of adoption of agricultural innovations (c.f. Adesina and Baidu-Forson 1995, Pender and Kerr 1998, Feder and Savastano 2006, Moser and Barrett 2006).

Table 1: Variable categories and indicators

Indicator	Type of Data
Dependent variables: Average adoption rate across a set of x innovation elements of a promoted package (rate for every element valued on a percentage scale)	Continuous
Dummy for application of multi-agent knowledge management	Binomial
Distance to market (km)	Continuous
Perceived utility of innovation: Expected output increases (1 to 5 Likert scale, ranging from insignificant to very high)	Ordinal
Age of farmer (years)	Interval
Market orientation: Share of total output left for home consumption (%)	Continuous
Propensity to change and experimentation (1 to 5 Likert scale, ranging from 'completely dislikes it' to 'likes it a lot')	Ordinal
Farmer's education level (1 to 5 Likert scale, ranging from 'rudimentary' to 'very high')	Ordinal
Connectedness and networking farmer's degree centrality (rate of actual to possible ties in a network that shows the different types of innovation agents with whom the farmer interacts frequently to very frequently. Innovation agents include 'change agents' such as researchers or extension workers from projects and NGOs; 'Market agents' such as input sellers, product buyers and transporters; 'Other farmers' such as relatives, neighbours and farmers associations; and 'Other Actors' such as local governments).	Continuous

Cases of knowledge management in Bolivia

In the following section, we discuss each of the four agricultural innovation projects analyzed in the study with reference to the knowledge management scheme. The discussion follows a scheme which describes the agents involved in knowledge management, the funding arrangements, and learning dynamics.

Case 1: Introduction of new quinoa varieties and cultivation practices by PROINPA Foundation in Viacha region, department of La Paz

The private non-profit research organization Fundación PROINPA initiated this project in 2004 aiming to assist a producers' community adjacent to its experimental research site and support it in adopting PROINPA's new high yielding quinoa varieties and complementary cultivation techniques (Soto et al. 2006). Funds were provided by the Fundación Altiplano, the regional semi-public entity managing SIBTA's applied technological innovation funds.

According to SIBTA rules, the proposal for the project needed to be co-developed by the farmer's organization and the technology provider. In practice, it was developed

by PROINPA soliciting feedback from the farmers in a number of planning meetings. Assistance from the Fundación Altiplano in designing and developing the project was restricted to the application of general funding rules set by SIBTA. The 15% co-financing which, according to SIBTA rules, had to be provided not in-kind but in cash was brought in by the cooperative of the Jalsuri community, a substantial contribution which may not be matched by the benefits from involving in this partnership. Also participating in the project was the owner of a small processing plant, Cereales Andina Ltd, whose interest was to purchase good quality quinoa for processing. The company bought most of the harvest of the producers affiliated to the proj,ect in 2004 and part of their harvest in 2005. The inclusion of a buyer in the project and especially the intensive communication between buyer and farmers, provided an important element of learning with regard to market conditions and solutions to improve product quality.

Learning among the 140 participating farmers and PROINPA's researchers was mainly centred on the set of innovations that PROINPA sought to communicate to farmers under the service contract signed with the Fundación Altiplano. The innovation set resulted from PROINPA's previous action research with farmers and was not further adjusted in the project. In fact, farmers who experience a long standing relationship with PROINPA did not see the current project as a particularly new initiative but as a continuation of general technical assistance that they have received from PROINPA.

The project has been evaluated positively by its funding agencies, revealing high adoption levels that can partly be confirmed by our study (53% average adoption across the 30 farmers, with a standard deviation of 26%). Part of the adoption, however, has to be understood in the context of the subsidies that the project provided. PROINPA, in fact, handed out seeds free of charge and provided additional incentives in the form of fertilizers and pesticides.

Case 2: Introduction of new quinoa varieties and cultivation practices by the NGO CETHA-PAIS in Northern Altiplano region, Municipality Jesús y San Andrés de Machaca, Department of La Paz

The NGO Centro Educación Técnico Humanístico Agropecuario (CETHA), supported by the Catholic Church and by funding from international donations, runs an educational programme Apoyo a Iniciativas Socioeconómicas (PAIS) aiming at strengthening farmers' food production and improve their nutritional status (Colque et al. 2003). In this context, it maintains a model farm and a processing plant. Among others, this programme helped 157 farmers in two poor communities to adopt new quinoa varieties, control pests and diseases with synthetic pesticides, and apply organic manure. Pesticides and varieties were given for free and a number of training exercises and field days were held by the NGOs staff and external specialists in order to persuade farmers to adopt these new cultivation practices within their farming systems.

The two communities were characterized by ancestral village structures and strong social capital among farmers, with substantial authority exercised by indigenous leaders. Individual farmers would not adopt an innovation without consultation of the

community but wait until the community decides to adopt the technology. In this situation, with limited support from village leaders, it was difficult for CETHA-PAIS staff to promote the introduction of new cropping techniques in quinoa. Also, there were virtually no other agents with knowledge on quinoa present in the locality (e.g. buyers, extension projects, development programmes and others) who would support the arguments about the usefulness of the promoted innovation package. Finally, villagers collectively decided to adopt the new varieties and apply pest control and fertilization only to a minimal extent as these involved additional costs and labour. Hence, average adoption levels of the 30 farmers interviewed across all components of the innovation package were low (27%, StDev = 14).

Case 3: Improvement of productivity and competitiveness of peanut cultivation in Mairana Municipality by ANAPO

This project sought to improve income levels for peanut producers by introducing a new export peanut variety, Florman; optimized preparation of soils and seeding; fertilization; weed pest and disease control; better timing of harvesting; and post-harvest treatments. The project was funded by SIBTA through its regional funding agency, the Fundación Valles while complementary financing (15%) was provided by the local Government of the Municipality of Mairana. Provider of the technical assistance service became the National Soyabeans and Wheat Producer Association (ANAPO), an influential producers' association with an R&D and technical assistance department with particular interest in exploring the peanut market. The main partner of ANAPO was a local farmers association. A fixed price for the product was set before harvest and guaranteed by a buyer, Shirosawa S.R.L, who markets peanuts to Japan and other international markets.

The project provided for intensive knowledge management through the interaction of the diverse actors involved: the Fundación Valles planned the activities in the frame of a wider peanut development programme, leveraged funds, and assured the accumulation and exchange of knowledge across various regions and institutions. The producers' association shared practical knowledge on cultivation and post-harvest techniques, and provided feedback on the use and application of the promoted technologies. The buyer informed about the conditions and demands on international markets. Input providers (this role was taken by ANAPO and the buyer who provided subsidized inputs to the farmers) discussed best practices on input applications with farmers. The municipality assured that the project complied with local development strategies.

Key to the success of the project was that the technology provider not only provided technical assistance and organized capacity strengthening but also helped to maintain linkages between the various actors and strengthened the organizational capacity of the producer organization. About 250 small agricultural producers with their families benefited from the reduction of production costs by some 30% and from an increase in yields of 40%. This was achieved despite the fact that farmers, on average, applied only 50% (St.Dev. = 27) of the recommended elements. In addition to achieving the project's goals, other unexpected achievements were realized: new skills were acquired regarding the production and commercialization of peanuts; the farmers'

association experienced organizational development and strengthening; and collaborations with agents from other sectors were initiated.

Case 4: Improvement of productivity and competitiveness of the peanut value chain in Padilla Municipality by PROINPA Foundation

Knowledge on the cultivation of peanuts is rudimentary in the department of Chuquisaca and based on ancestral practices, resulting in low productivity levels (Hartwich et al. 2007). In this context, the non-profit research organization, Fundación PROINPA, initiated a project to promote the application of improved cultivation practices (contour lines, soil preparation, high density seeding, application of chemical herbicides, pest and disease control); the introduction of higher yielding varieties; and the propagation of new post-harvest measures (machine husking, seed preparation, production of peanut butter, commercialization on national markets and organizational strengthening of the producers association) to a group of 57 farmers (FDTA Valles 2005). Further diffusion of the technology in the vicinity was expected to reach some 1,300 families.

The project was funded by SIBTA's applied technical innovation fund through the Fundación Valles. The private partner was the producers association APAJIMPA and the Municipality of Padilla provided the required counterpart funding. Active management of knowledge was only achieved between the two main partners PROINPA (as the technology provider) and the farmers' association (as recipients of technical assistance). The Municipality and the Fundación Valles remained in the background as sponsors. Buyers or input sellers were not explicitly included in the project. Study reveals that adoption levels of the 30 farmers interviewed oscillate around a mean of 52%, which is slightly below the level of the official evaluation of the project conducted under SIBTA. Effects of the low intensity innovation promoted, however, are not expected to exceed 15% in household income.

Conclusions

In conclusion, the study found that the four projects promoting agricultural innovation involved different agents to different degrees, practiced very different styles of knowledge management, and led to different levels of adoption and overall project success. Three of the cases (1, 3, and 4) were funded by independent semi-public Foundations operating under SIBTA's institutional arrangement, though this did not imply a common approach to knowledge management. In some cases, the foundations did strictly stick to their funding role, while in other cases they were actively involved in planning the project in the context of existing market and technological opportunities, involving various private and public agents, improving communication, brokering the exchange of knowledge and contributing to organizational development. Project success was by far higher in the latter cases.

Projects that promote traditional technology transfer and do not tap into the capacities of a mix of actors (case 2 and 4) appear to be less successful as they struggle when considering the condition and evolution of buyers and consumer markets, and when increasing the confidence of farmers in the knowledge and technologies they promote.

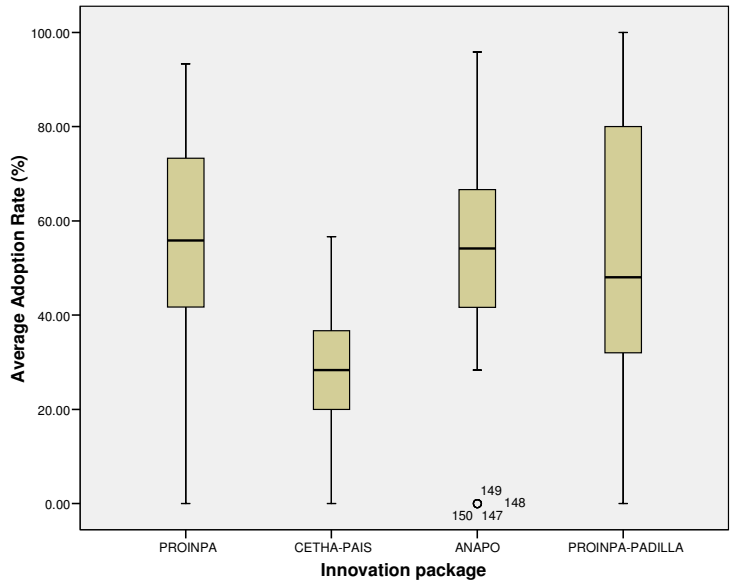
Empirical evidence of the influence of knowledge management on farmers' innovation behaviour

Results of our quantitative data reveal that farmers under the condition of multiple-agent knowledge management, on average, had higher adoption rates than farmers under the traditional knowledge management projects (see Figure 1). However, this may be anecdotal evidence from only four cases. Also, one should not compare average adoption levels without controlling for other region-specific and context-specific factors such as geographic location, socio-economic and agro-ecological conditions, and type of innovation promoted.

Table 2 shows the results of the model estimations of our analysis of adoption behaviour at the individual farmers' level in dependence of the variables introduced in section 4. The first column depicts the estimators of the two cases characterized as traditional knowledge management, while the second column depicts those of multiple-agent knowledge management; last column represents a model considering all four cases.

The variable distance to market was introduced as a proxy for region-specific effects; the spread of distance was homogeneous within the groups of 30 farmers affiliated to one innovation project, but heterogeneous between the four groups2. The results reveal that the distance to market is not significantly influencing the innovation behaviour of farmers. This finding suggests that the difference between innovation cases across regions does not necessarily need to explain differences in farmers' adoption of innovation; in our case it indicates that the degree of adoption of innovation elements used in this study is a robust indicator to compare adoption across local cases and different sectors.

Figure 1: Distribution of adoption rates of innovation packages among farmers



(Source: Study data. Numbers depict outliers)

Table 2: Results from the Multivariate Regression Analysis

Model Estimations	Traditional knowledge management cases (n = 60)	Multiple knowledge management cases (n = 60)	All cases (n=120)
Variable estimations			
Dummy for knowledge management			26.598 (.000**)
Distance to market	-0.117 (.104)	0.161 (.528)	0.161 (.630)
Output share left for home consumption	0.058 (.550)	-0.085 (.893)	-0.008 (.893)
Propensity for experimentation	0.130 (.551)	4.958 (.138)	4.958 (.014*)
Education level	11.020 (.000**)	10.216 (.000**)	10.216 (.000**)
Perception of utility: Expected output increases	0.036 (.000**)	0.040 (.000**)	0.040 (.000**)
Connectedness and networking Degree centrality	51.272 (.000**)	27.548 (006**)	27.549 (.007**)
Overall model parameters			
Intercept or Constant	21.327 (.000**)	16.983 (.000**)	16.983 (.000**)
Log likelihood function	-248.518	-229.900	-229.901
ANOVA based fit measure	0.370	0.592	0.592
DECOMP based fit measure	0.379	0.602	0.602

(Source: Study data)
Figures in brackets represent the t-statistics. Asterisks indicate significance at * 5%, and ** 1%.

The analysis revealed that the dummy variable for the type of knowledge management contributed significantly to the observed levels of adoption. Farmers that participated in innovation schemes characterized by multiple-agent knowledge management approaches had higher levels of adoption than those participating in traditional schemes. This corresponds to the postulation made in our first hypothesis.

Other variables that significantly influenced the adoption of innovations among farmers were the educational level, the farmers' perception of the utility of the innovation package introduced, and particularly their connectedness within the network. In fact, degree centrality – the measure for the farmer's connectedness and tendency towards networking – was the single most significant and positively correlated variable to adoption (with beta values of 54.1 and 27.5 respectively). This stresses the importance of farmers' interactions in their decisions to adopt innovations. This argument corresponds with the assumptions posed in hypotheses two.

The DECOMP fit measure for the Tobit model revealed a value of 0.38 (traditional knowledge management model) and 0.60 (multiple agent management model). The higher fit found for the second type of knowledge-management approaches may be due to the fact that the model specifications chosen here respond slightly better to situations in which farmers adopt innovation in the context of a multiple-agent

knowledge management. Also, it is a reflection of the higher dispersion of adoption levels found for the first type of knowledge management approaches, as evidenced in figure 1. In any case, the DECOMP-based fit levels of the two models, as well as the overall model with 120 cases (0.60), constitute very comfortable level of overall fit given the cross-sectional nature of the study and according to the standards found in the agricultural adoption literature, supporting thus our model specifications.

Conclusions

Innovation among smallholders in developing countries requires the existence and development of individual capabilities among farmers as well as the deployment of learning processes among a wide variety of actors, including knowledge and technology providers, farmers, financial institutions and other support from government, and other agents.

Farmers and their organizations typically have restricted contacts to a few knowledge and technology providers such as NGOs, development agencies, or government support programmes. Such agencies and programmes are usually monothematic, providing expertise and support only in one particular area (such as improved seeds, irrigation, land titling, credit, etc.), while not being able to provide knowledge in other aspects. However, farmers face multiple problems of which a particular knowledge provider can only address a few. Farmers are aware of the limited focus of knowledge and technology providers regarding the broad range of their problems and therefore take caution to quickly adopt the promoted knowledge. Rather, they cross-check and evaluate potential benefits and costs on the basis of opinions of other farmers and agents that dispose of complementary knowledge on the issue of concern. Once they get interested in the adoption of knowledge they may not simply adopt it but, together with the network of surrounding agents practice, process, improve the knowledge and adapt it to their needs and local conditions.

SIBTA

SIBTA with its fund for applied technical innovation projects has experimented with introducing a new knowledge management scheme based on the idea of markets for local knowledge. Implicitly, this scheme permitted networking among a range of agents extending the traditional linear models of knowledge transfer. Our analysis of four projects fostering technical innovation among smallholders in rural Bolivia – two of which applied modern multiple-agent approaches while the two others applied traditional approaches – revealed that promoters of agricultural innovation in Bolivia use very different strategies, often within the same organization. In some cases, SIBTA's scheme to promote technical innovation in agriculture has enabled the building of multiple-agent partnerships for innovation. However the scheme is limited to the diffusion of certain technology packages, not embracing opportunities of interactive learning and innovation development across various regions and agents with complementary capabilities. Sometimes SIBTA projects even emerge from initiatives of technology providers who link with farmers for the solely reason to leverage funds while the regional foundations and other agents did not contribute to the exchange of knowledge and joint learning. In any case, outside of SIBTA there

seem to be even less opportunities and initiatives to form platforms to connect innovating agents.

Farmers

Results of the analysis at the individual farmers' level show that the type of knowledge management technology providers apply to agricultural innovation projects clearly influences overall adoption rates. There is also evidence for the effects of the embeddedness of farmers in local innovation and learning networks on the adoption behaviour. The more central farmers are located in these networks, the higher is their level of adoption. In other words, if farmers, in addition to knowledge transfer agents contracted by SIBTA, maintain contacts also with other knowledge agents, their uptake of knowledge is over-proportionally high. The source of those network effects can be twofold: certain agents catalyze and enhance the uptake of knowledge; and joint learning occurs among various knowledge agents and users having positive effects on the usefulness of knowledge generated and diffused.

Multiple-agent learning, despite SIBTA's efforts to match farmers' demands with supply from technology providers, does not take place spontaneously. Apparently, collaboration in innovation development and knowledge sharing are often not part of the mental model of many rural development actors. In some cases, development programmes, such as SIBTA, do not only spur collaboration but also competition among rival technology providers who seek funding. In a context where the knowledge capacities are extremely scarce and collaboration is amenable to provide the critical mass necessary for joint learning, competition can become counterproductive. Those who aim at the funding and promotion of agricultural innovation, in rural contexts such as in Bolivia, may revise opportunities to follow strategies that take into account the complexity and the multiple sources of innovation processes. They should promote measures that allow for communication-intensive and collaborative technology development and transfer among a wide range of actors that dispose of relevant knowledge, setting up of knowledge exchange and learning platforms, and providing access to the creation and communication of tacit knowledge.

References

Adesina, A. A. and J. Baidu-Forson (1995) Farmers' Perceptions and Adoption of new Agricultural Technology: Evidence from Analysis in Burkina Faso and Guinea, West Africa. Agricultural Economics 13: 1-9.

Armbrecht, F. M. R.; R.B. Richard; C.C. Chappelow; G.F. Farris.; P.N. Friga; C.A. Hartz.; M.E. McIlvaine; S. R. Postle; and G.E. Whitwell (2001). Knowledge Management and R& D Processes. *Research Technology Management* 44(4), 28- 49

Chambers, R. A. Pacey and L. Thrupp eds (1989) Farmers First: Farmer Innovation and Agricultural Research. Intermediate Technology Publications: London

Colque G., W. Plata, R. Queso, E. Aquino, F. Alaro y G. Hilares (2003) Granja CETHA-Qurpa: Sistematización y lecciones aprendidas. Comisión Episcopal de Educación (CEE): La Paz, Bolivia

FDTA-Valles (2005) Proyecto Mejoramiento de la Productividad y competitividad de la Cadena Agroproductiva del maní en el Municipio de Padilla. Informes trimestrales. FDTA Valles: Cochabamba, Bolivia

Feder, G. and S. Savastano (2006) The Role of Opinion Leaders in the Diffusion of New Knowledge: The Case of Integrated Pest Management. *World Development* 34: 1287-1300.

Hartwich, F., T. Arispe and M. Monge (2007). Innovación en el Cultivo del Maní en Bolivia: Efectos de la Interacción Social y de las Capacidades de Absorción de los Pequeños Productores. *IFPRI Discussion Paper* No. 692 Sp. IFPRI: Washington D.C.

Hovland, I (2003) Knowledge Management and Organisational Learning: An International Development Perspective - An Annotated Bibliography. ODI Working Paper No. 224, Overseas Development Institute, London

Howes, M. and R. Chambers (1980) Indigenous technical knowledge: Analysis, implications and issues, in D. Brokensha, D. Warren and O. Werner (eds) Indigenous Inkpen, A.C. (1996) Creating Knowledge through Collaboration. *California Management Review* 39: 123-140

Kauffman, S. (1995) At Home in the Universe: The Search for the Laws of Self-Organization and Complexity. Oxford University Press: New York

Leeuwis, C. (2004) Communication for Rural Innovation: Rethinking Agricultural Extension. Third Edition. Blackwell: Iowa and Oxford

Levin, D. and R. Cross (2004) The strength of weak ties you can trust: The mediating role of trust in effective knowledge transfer. *Management Science* 50: 1477-1490.

Liebowitz J, ed. (1999) The Knowledge Management Handbook. CRC Press, Boca Raton

Miles, R. E., C. C. Snow, J. A. Mathews, G. Miles, and H. J. Coleman Jr. (1997) Organizing in the knowledge age: Anticipating the Cellular Form Academy of Management Executive 11(4)

Moser, C. M. and C.B. Barrett (2006). The Complex Dynamics of Smallholder Technology Adoption: The case of SRI in Madagascar. *Agricultural Economic*s 35: 373-388.

Pender, J. L. and Kerr, J. M. (1998). Determinants of Farmers' Indigenous Soil and Water Conservation Investments in semi-arid India. *Agricultural Economics* 19: 113-125.
Polanyi, M (1966) Tacit Dimension (1983 reprint) Doubleday: New York

Röling, N. (1996) Towards an Interactive Agricultural Science. *Journal of Agricultural Education and Extension* 2(4): 35 - 48

Röling, N. and E. van de Fliert (1994) Transforming extension for sustainable agriculture: The case of integrated pest management in rice in Indonesia. *Agriculture and Human Values* 11(2-3), 1572-8366

Russell, D.B. and R. L. Ison eds (2000) Agricultural Extension and Rural Development: Breaking Out of Traditions: A second-order system perspective. Cambridge University Press: Cambridge, U.K

Sorenson, O. J. W. Rivkin and L. Fleming (2006) Complexity, networks and knowledge flow. *Research Policy* 35(7): 994-1017

Soto J.L., F. Hartwich, M. Monge, and L. Ampuero (2006) Innovación en el Cultivo de Quinua en Bolivia: Efectos de la Interacción Social y de las Capacidades de Absorción de los Pequeños Productores. *ISNAR Division Discussion Paper* No. 11. IFPRI and PROINPA: Washington D.C.

Sumberg J.; C. Okali and D. Reece (2003) Agricultural research in the face of diversity, local knowledge and the participation imperative: theoretical considerations *Agricultural Systems* 76 (2): 739-753

Sweiby, K.-E. and R. Simons (2002) Collaborative climate and effectiveness of knowledge work – an empirical study. *Journal of Knowledge Management* 6(5): 420 - 433

Thompson, J. and I. Scoones (1994) Challenging the populist perspective: Rural people's knowledge, agricultural research, and extension practice. *Agriculture and Human Values* 11(2-3): 58-76

Warren, D.M. (1989) Linking scientific and indigenous agricultural systems. In J.L. Compton (ed) The transformation of international agricultural research and development. Lynne Rienner: Boulder.

Abstract
This paper presents results of an analysis of adoption of innovations among farmers affiliated to four agricultural innovation projects in Bolivia that promote different modalities of knowledge management. In two of the cases, regional foundations of the Bolivian Agricultural Technology System (SIBTA) fostered knowledge management and exchange involving multiple-agents and results show that these are relatively more successful than traditional technology transfer projects. Results of the analysis at the individual farmers' level demonstrate that the adoption of innovations is determined by the knowledge management modalities of the project to which they were affiliated to as well as by the degree of embeddedness of the farmer in local innovation and learning networks. This confirms current wisdom that farmers need intensive relations, not only to one type of extension or development agency but to many different agents, in order to be able to draw from a sufficient critical mass of

knowledge, gain confidence on the relevance of the knowledge, and learn jointly to apply and improve an innovation. Those who finance and promote agricultural innovation should consider that the creation and diffusion of innovation is a complex process which can be enhanced by fostering interactive learning among farmers and other agents that dispose of and develop farm relevant knowledge.

About the authors

Frank Hartwich is a research fellow at the International Food Policy Research Institute where he works on issues of innovation in pro-poor agricultural development. Before he worked with the International Service for National Agricultural Research in The Netherlands and the Natural Resources Institute in England in agricultural research and development issues in sub-Saharan Africa. His current research focuses on rural innovation networks, innovation systems theory and public-private partnerships, particularly in Latin America. He holds master degree titles in Agricultural Science from the University of Bonn, Germany, and in Management in Agro-business from ENSA Toulouse, France, and a PhD in Agricultural Economics from the University of Hohenheim, Germany.
Frank Hartwich, International Food Policy Research Institute (IFPRI), c/o IICA, Apdo. 55-2200 San José, Costa Rica. E-mail: f.hartwich@cgiar.org.

Mario Monge is a research analyst at the International Food Policy Research Institute. He specialized field of analysis is the application of Social Network Analysis to processes of innovation among resource poor farmers. Before he directed operations of an agricultural development project on the Nicoya Peninsula in Costa Rica (PRODAPEN) funded by the International Fund for Agricultural Development (IFAD). Prior to this he worked for the Tropical Agricultural Research and Higher Education Centre (CATIE) as part of the Centre's technical cooperation in Central America. His current research focuses on rural innovation networks and processes of adoption/diffusion of innovations in Bolivia and Nicaragua. Mario holds a M.Sc. degree in International Agricultural Development from the University of California at Davis.
Mario Monge International Food Policy Research Institute (IFPRI), c/o IICA, Apdo. 55-2200 San José, Costa Rica. E-mail: m.monge@cgiar.org

Luis Ampuero works as a consultant on institutional development issues and agricultural innovation in Bolivia. He provides professional assistance to several private research and development organizations in the Andean region and Mexico. He also serves as President of the Fundación Casa de la Agricultura, a non profit organization promoting rural development initiatives for low income farmers. Previously, he worked for the Interamerican Institute for Cooperation in Agriculture (IICA), in Costa Rica and Peru. He holds a M.Sc. and a Ph.D. in Agricultural Economics from Iowa State University, and a M.Sc degree in Business Administration from the National University of Costa Rica.
Luis Ampuero, P.O. Box 826, Cochabamba, Bolivia. E-mail: laampuero@yaho.com

José Luis Soto is a socio-economist and gender specialist in the field of Andean Grains of the Foundation for the Promotion of Research and Andean Products (PROINPA) in Bolivia. His research focuses on the diffusion of innovation among smallholders and the assessment of the impact of technology adoption. He holds a

Master (M.Sc.) in Rural Development from the National University of the Altiplano in Puno, Peru.
José Luis Soto, Fundación para la Promoción e Investigación de Productos Andinos (PROINPA), Apdo. 1078, La Paz, Bolivia. E-mail: jl.soto@proinpa.org

[1] Innovation can be understood as a social process by which knowledge is created, adapted, diffused within a network of specialists and users and successfully applied in social and economic practices.
[2] PROINPA-Jalsuri: Mean = 7.6 km, StDev = 9.15, CETHA PAIS: Mean 74.8 km, StDev = 45.6, ANAPO-Mairana: Mean = 12.9km, StDev = 7.6, PROINPA – Padilla: Mean 16.7 km, StDev = 23,7km